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# EFFECT OF DIETARY SUPPLEMENTATION WITH BETAINE, THYME OIL AND THEIR MIXTURES ON PRODUCTIVE PERFORMANCE OF GROWING RABBITS

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**ABSTRACT:** The present experiment was carried out to evaluate the effect of dietary supplementation with betaine (BET) and thyme oil (THY) and their mixtures (MIX) on nutrients digestibility, caecum characteristics, growth performance, carcass traits, and economic efficiency of growing rabbits. A total number of 72 growing New Zealand white (NZW) male rabbits, 5-week-old and with average weight  $616 \pm 7.82$  g were divided into 9 experimental groups. The control group was fed a basal diet without supplementation (T1), whereas the other groups were fed the same basal diet supplemented with 1500 mg BET (T2), 750 mg BET (T3), 1000 mg THY (T4), 500 mg THY (T5), 1500 mg BET + 1000 mg THY (T6), 1500 mg BET+500 mg THY (T7), 750 mg BET + 1000 mg THY (T8), 750 mg BET + 500 mg THY (T9). The experimental period extended for 8 weeks. The results indicated that feed dry matter digestibility and digestible energy were significantly ( $P < 0.05$ ) improved with rabbit fed T2, T3, T4, T6, and T9 diets. In contrast, a significant ( $P < 0.001$ ) decrease in total volatile fatty acids and ammonia-N concentration of cecum content was recorded with rabbits fed T4, T5, T7, T8 and T9 diets compared with (T1) those fed the control diet. Feed intake, hematological parameters, and carcass traits were not significant ( $P < 0.05$ ) affected by dietary supplementation. Daily weight gain was significantly ( $P < 0.001$ ) increased in rabbit fed the supplemented diets except those fed T8 diet. Feed conversion ratio and economic efficiency recorded the best results with rabbits fed T2, T4 and T6 diets. Dietary supplementation with 1500 mg betaine or 1000 mg thyme oil/kg diet or mixture of theme with the same levels are recommended to improve the feed utilization and growth performance parameters and health status of NZW rabbits.

**Key words:** Rabbits, thyme oil, betaine, growth performance, digestibility, carcasses, economic efficiency.

## INTRODUCTION

Feed additives are used widely in animal feeding to improve the growth and feed efficiency as well as animal health (Abd El-Hack *et al.*, 2015).

Recently, phytochemical additives are commonly used in animal feeds and are generally regarded as safe. Thyme (*Thymus vulgaris* L.) is an aromatic evergreen herb. It has recently been getting a great interest because of its medicinal properties. Essential oil of thyme has antimicrobial, anti-inflammatory, and antioxidant

properties and has been reported to promote growth performance (Rašković *et al.*, 2015).

Thyme oil (THY) is used as a feed supplement in farm animal nutrition because of its contents, such as thymol which have a positive impact on growth, feed utilization and economic profits. The enhancement in animal performance can be attributed to enhance appetite, absorption, metabolism of nutrients and its ability to modulate the gut microbiota (Abd El-Hack *et al.*, 2016). Placha *et al.* (2013) demonstrated that dietary thyme oil supplementation at 0.5 g/kg diet improved antioxidant status and intestinal health of rabbits as well as increased

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meat quality and shelf-life by preventing lipid oxidation.

Betaine (BET), N, N, N-trimethylglycine, is an important source of methyl groups which can spare methionine and choline. Betaine is synthesized from choline using choline oxidase and it can provide methyl groups to homocysteine to form methionine. Physiologically, betaine has osmoprotective properties, which is important in the renal, nervous, cardiovascular and immune systems. It used in farm animal feeds for several benefits as carcass fat reduction, sparing choline and aiding cell osmoregulation (Kidd *et al.*, 1997).

This study was carried out to investigate the effect of different levels of thyme oil and betaine alone or in a combination in the diet on nutrients digestibility, some blood constituents, growth performance, carcass components and economical efficiency of growing rabbits.

## MATERIALS AND METHODS

The present work was carried out at the Rabbit Research Farm and Laboratories of the Animal Production Department, Faculty of Agriculture, Zagazig University, Egypt.

A total number of 72 growing (NZW) male rabbits with average body weight of  $616 \pm 7.82$  g, were used. Rabbits were randomly assigned to 9 groups (8 animals in each); the 1<sup>st</sup> group (T1) fed diet without any additives (control), whereas the other groups were fed diets contained 1500 mg BET (T2), 750 mg BET (T3), 1000 mg THY (T4), 500 mg THY (G5), 1500 mg BET + 1000 mg THY (T6), 1500 mg BET + 500 mg THY (T7), 750 mg BET + 1000 mg THY (T8), 750 mg BET + 500 mg THY (T9).

BET is a commercial product (Betafin<sup>®</sup> S4) produced of Danisco Animal Nutrition- Finland were provided by Multivita Company for Animal Nutrition, Sixth October City, Egypt. THY is a commercial product (Nutural Zataar Oil) was obtained from El Hawag Factory, Badr City, Egypt.

All animals were individually house-caged (stainless steel cages). The dimensions of cage was 40×30×25 cm. All rabbits were continually provided with fresh water, and were maintained

under the same managerial, hygienic and environmental conditions all over the experimental period (8 weeks). The rabbits were acclimatized for a period of one week before the beginning of the trial. Rabbits were fed *ad-libitum* during the experimental period.

The experimental pelleted diets were formulated to cover the recommended nutrient requirements of growing rabbits according to (NRC, 1977). The formulation and chemical analysis of the basal-diets fed to rabbits are shown in Table 1. Each feed additive was pre-mixed with one kg of diet.

Feed intake was recorded weekly. Weight of rabbits was done in the morning before having access to feed and water. Body weight gain was calculated by subtracting the live body weight at the beginning of the study period from the live body weight at the end of this period. Feed conversion ratio (feed intake/ body weight gain) was calculated.

At the last week of trial, 3 rabbits from each group were randomly choosing for the digestibility trial. Feces of each rabbit was daily collected, weighed before offering the morning meal at 9 a.m. The daily feces of each rabbit were stored at -20°C. The six days mixed fecal samples were kept for routine analyses. Fecal samples were dried in oven at 60°C for 48 hr., then ground. Composite samples for each animal was taken for chemical analyses. Feeds and feces samples were analyzed for dry matter, organic matter, crude protein, crude fiber and ether extract according to (AOAC, 2000).

Apparent digestibility coefficient (ADC) was calculated as follows:

$$\text{ADC} = \frac{[(\text{total nutrients intake} - \text{total nutrients in feces}) / \text{total nutrients intake}] \times 100}{100}$$

Nutritive values in terms of total digestible nutrients (TDN %) and the digestible crude protein (DCP %) were calculated according to classic formula (Cheeke *et al.*, 1982) as follows:

$$\text{TDN (\%)} = \text{DCP (\%)} + \text{DCF (\%)} + \text{DNFE (\%)} + (\text{DEE (\%)} \times 2.25)$$

Where:

DCP = Digestible crude protein, DCF = Digestible crude fiber, DNFE = Digestible nitrogen free extract, DEE = Digestible ether extract.

**Table 1. Formulation and chemical analysis of the basal-diet**

<b>Ingredient (%)</b>	<b>(%)</b>
Alfalfa hay	33
Barley	25
Wheat bran	25
Soybean meal	15
Sodium chloride	0.5
Limestone	1.2
Minerals and vitamins mixture*	0.3
Total	100
<b>Chemical analysis (% on DM basis)</b>	
Organic matter	85.5
Crude protein	18.52
Crude fiber	15.15
Ether extract	4.39
Nitrogen free extract	47.44
DE (K Cal/Kg diet)*	<b>2579</b>

\* Each 3 kg of minerals and vitamins mixture contains: manganese 60 g, zinc 50 g, iron 30 g, copper 4 g, iodine 0.3 g, selenium 0.1 g and cobalt 0.1 g, vitamin A 12000000 IU, vitamin D3 2000000 IU, vitamin E 10000 mg, vitamin K3 1000 mg, vitamin B1 1000 mg, vitamin B2 5000 mg, vitamin B6 1500 mg, vitamin B12 10 mg, Biotin 50 mg, folic acid 1000 mg, pantothenic acid 10000 mg, Niacin 30000 mg and Choline chloride 600000 mg.

\* Digestible energy (DE) was calculated according to **Schieman *et al.* (1972)**.

The digestible energy (DE) values (kcal/ kg diet) of the experimental diets were calculated according to **Schieman *et al.* (1972)** as follows:

$$DE = 5.28 \text{ DCP (g)} + 9.51 \text{ DEE(g)} + 4.2 (\text{DCF} + \text{DNFE}) (\text{g}).$$

At the end of the experimental period three rabbits from each group were randomly taken for slaughter after being fasted for 12 hours. After complete bleeding, the carcass and some non-carcass components were weighed. The carcasses were prepared by removing the skin, feet, paws, genital organs, urinary bladder and digestive tract. According to **Blasco *et al.* (1993)**, hot carcass weight (the main body, head, kidneys, liver, heart, lungs and other total edible parts) were determined. The carcasses were weighed and the weights of the liver, spleen, kidneys, heart and lungs were recorded and

expressed as g/kg of slaughter weight (SW). Dressing percentage = (carcass weight)  $\times$  100/ live body weight.

Blood samples with EDTA were collected from 3 rabbits at slaughter time to estimate some hematological blood parameters. Total red blood cells (RBCs), hematocrite, hemoglobin (Hb), total white blood cells (WBCs) and lymphocytes were carried out according to the method of **Grindem (2011)** using a Hema Screen 18 Automated Hematology Analyzer (Hospitex Diagnostics, Sesto Fiorentino, Italy).

Caecum and illume digesta was obtained by gentle finger stripping for measuring ammonia-N, total volatile fatty acids (TVFA's), dry matter (DM) and pH values. The pH values were immediately determined. The pH values were determined by using the consort pH meter model

P107 with combined electrode. Residual of digesta was divided into two portions kept deep freeze at -20°C until further analyses. Ammonia-N (NH<sub>3</sub>-N) concentration was estimated by distillation method according to AOAC (2000). Total volatile fatty acids concentration was determined by steam distillation as mentioned by Warner (1964).

Economic evaluation was calculated according to the following equation:

$$\text{Economical efficiency} = \text{Net revenue} / \text{Total feed cost}$$

Where:

Feed cost/Kg weight gain = feed conversion ratio x cost of one kg diet. Other overhead costs were assumed constant.

The data of treatments were statistically analyzed with a one way ANOVA test in a completely randomized design as the following model:  $Y_{ij} = \mu + T_i + e_{ij}$

Where:

$\mu$  = the overall mean,  $T_i$  = the fixed effect of treatment,  $e_{ij}$  = residual error.

The significant differences among means were compared using Duncan's New Multiple-Range test (1955).

## RESULTS AND DISCUSSION

### Effect of Feed Additives on Feed Intake

The daily feed intake (DFI) of rabbits fed the experimental diets are presented in Table 2. Overall the experimental period (0-8<sup>th</sup> week), the DFI was significantly ( $P < 0.05$ ) affected by the dietary treatments. However, during the first two weeks of the experiment, the DFI was significantly increased ( $P < 0.05$ ) in response to all tested feed additives compared to the control group. Also, during 4<sup>th</sup>-6<sup>th</sup> week of the experiment, both BET 750 and BET 1500 supplemented groups showed a slightly increase in DFI compared to the control. In contrast, THY 500 and BET 1500 + THY 1000 showed a significant decline in DFI.

Similar results were found by Abd El-Moniem *et al.* (2016) who reported that growing rabbits fed diets supplemented with 1000 mg BET/kg showed insignificant

differences in DFI. Also, Pirompud *et al.* (2005) revealed that no significant differences in DFI were recorded in the birds fed BET supplemented diets. Moreover, Tollba *et al.* (2007) reported that BET supplementation to laying hen diets had no significant effect on DFI. Also, El-Husseiny *et al.* (2007) reported that insignificant differences were recorded in DFI due to BET supplementation. In the same line, Gerencser *et al.* (2014) reported that addition of 3% thyme to rabbit diets had no effect on DFI. Also, Bassiony *et al.* (2015) found that DFI of rabbits received 100 and 200 mg cinnamaldehyde and THY/Kg diet insignificantly reduced. Hernandez *et al.* (2004) found that the addition of 5,000 ppm *Labiatae* extract from thyme, sage and rosemary to broilers diets had no effect on the DFI.

The reduction of DFI in response to high levels of BET and THY dietary supplementation was also previously recorded. For instance, Mahmoud *et al.* (2016) reported that growing rabbits fed diets supplemented with 0.25% water thyme extract showed a significant decrease in DFI. Also, Han *et al.* (2009) found that DFI for finishing pigs fed 2% BET diet was lower than the other treatment groups. This reduction could be related to the strong organoleptic effect associated with the high concentration.

### Effect of Feed Additives on Nutrients Digestibility

The results of digestion coefficient of nutrients and nutritive values are shown in Table 2. The digestibility coefficients of dry matter (DM) and nitrogen free extract (NFE) was significantly ( $P < 0.05$ ) increased in the BET 1500 and THY 1000 supplemented groups. Also, DM digestibility coefficient was significantly increased by rabbits fed T6 and T9 diets (BET 1500+ THY 1000 and BET 750 + THY 500). The nutritive values including TDN and DCP were not significantly affected by any of the tested feed additives. However, the value of digestible energy (DE) was significantly ( $P < 0.05$ ) increased in response to all tested feed additives those fed except T5 (THY 500), T7 (BET 1500 + THY 500) and T8 diets (BET 750+ THY 1000) compared to control groups.

**Table 2. Feed intake, digestibility and nutritive values of the experimental diets as affected by tested additives**

Feed treatment (Feed additive)	Feed intake (g/day)	Digestibility coefficient (%)					Nutritive values (%)			
		DM	E.E	CP	CF	NFE	OM	DCP	TDN	DE
<b>T1 (Control)</b>	138±1.60 <sup>abc</sup>	59.23±0.52 <sup>b</sup>	75.23±3.13	74.63±0.54	31.77±1.02	66.89±1.58 <sup>b</sup>	63.26±0.56	13.82±0.10	57.80±0.52	2462±20.03 <sup>b</sup>
<b>T2 (BET1500)</b>	146±1.21 <sup>a</sup>	63.06±0.72 <sup>a</sup>	75.68±1.14	74.74±0.50	37.78±2.51	71.32±0.45 <sup>a</sup>	66.34±0.75	13.84±0.09	60.87±0.63	2612±28.29 <sup>a</sup>
<b>T3 (BET750)</b>	143±3.53 <sup>ab</sup>	63.54±1.54 <sup>a</sup>	76.46±1.73	75.80±0.89	39.06±3.65	70.06±1.28 <sup>ab</sup>	66.79±1.46	14.04±0.17	60.74±1.43	2631±60.04 <sup>a</sup>
<b>T4 (THY1000)</b>	140±2.19 <sup>abc</sup>	62.90±1.58 <sup>a</sup>	74.50±2.25	75.13±2.48	40.16±1.72	71.99±0.47 <sup>a</sup>	66.70±1.34	13.91±0.46	61.51±0.95	2606±62.29 <sup>a</sup>
<b>T5 (THY500)</b>	135±2.14 <sup>bc</sup>	61.88±1.01 <sup>ab</sup>	73.26±1.72	76.23±1.01	33.40±1.71	69.95±1.09 <sup>ab</sup>	65.08±0.97	14.12±0.18	59.60±0.87	2566±39.72 <sup>ab</sup>
<b>T6 (BET1500+THY1000)</b>	135±4.04 <sup>bc</sup>	65.40±0.97 <sup>a</sup>	73.83±1.31	78.23±1.64	40.67±3.24	70.03±0.18 <sup>ab</sup>	66.53±0.77	14.49±0.30	61.17±0.75	2704±37.95 <sup>a</sup>
<b>T7 (BET1500+THY 500)</b>	135±3.31 <sup>bc</sup>	61.92±0.80 <sup>ab</sup>	69.95±0.48	73.18±1.60	36.87±3.09	68.46±2.15 <sup>ab</sup>	63.70±2.16	13.55±0.30	58.52±1.71	2568±31.42 <sup>ab</sup>
<b>T8 (BET750+ THY 1000)</b>	133±3.68 <sup>c</sup>	62.51±1.04 <sup>ab</sup>	72.21±2.66	78.64±1.39	34.78±3.22	66.49±0.90 <sup>b</sup>	63.71±1.00	14.56±0.26	58.51±0.70	2590±40.88 <sup>ab</sup>
<b>T9 (BET750+ THY 500)</b>	141±2.95 <sup>abc</sup>	64.45±1.08 <sup>a</sup>	77.23±1.87	79.20±1.59	41.19±3.30	67.03±1.15 <sup>b</sup>	65.61±1.23	14.67±0.30	60.34±1.15	2667±42.14 <sup>a</sup>
<b>Sig.</b>	*	*	NS	NS	NS	*	NS	N.S	N.S	*

Means in the same column bearing different letters differ significantly (P<0.05)

NS = Not significant, \*P<0.05

Abd El-Moniem *et al.* (2016) showed that nutrients digestibility and nutritive values has been improved with rabbits fed diets supplemented with 1000 mg BET/kg diet. Improvement of nutrients digestibility following BET supplementation may be due to increasing the intestinal integrity (Kettunen *et al.*, 2001a) and surface area (Klasing *et al.*, 2002), water retention capacity of intestinal mucosal cells (Kettunen *et al.*, 2001b) and osmotic support of intestinal cells, since the processes of nutrient absorption are dependent on an intact gut epithelium, and the osmotic characteristic of BET may contribute to an improved nutrient digestibility (Eklund *et al.*, 2006). Furthermore, the improvement in nutrients digestibility could be attributed to the improvements in absorption capacity of the intestinal epithelium and enhanced fermentation activity of intestinal microflora (Ratriyanto *et al.*, 2009). Also, essential oil bioactive like THY have been previously reported to improve digestibility of nutrients (Osman *et al.*, 2005). Bassiony *et al.* (2015) reported that digestibility of CP, CF and EE significantly improved by addition of THY and cinnamaldehyde to diets at level of 100 and 200 mg/kg diet. Ibrahim *et al.* (2000) reported that addition of thyme to rabbit diet improved protein digestion. Langhout (2000) and Williams and Losa (2001) reported that essential oils of thyme have a stimulating effect on the animal digestive system, due to the increase of digestive enzymes and improve of nutrients utilization through the enhanced liver function (Safa and Al-Beitawi, 2009). The herb derivatives may have its effect through an increase in production of lactic acid bacteria, thus increasing the population of beneficial bacteria and reducing the presence of gram negative bacteria (Savage *et al.*, 1996). The positive stimulating effects of essential oil bioactives like THY on the digestive system could be responsible for their enhancing effects on digestion (Lee *et al.*, 2003; Cabuk *et al.*, 2003 and 2006; Ramakrishna *et al.*, 2003; Hernandez *et al.*, 2004). In contrast, Ali *et al.* (2008) found insignificant differences between treatments in nutrients due to using different levels of curcuma, lemon and citric acid.

Notably, among the tested additives diets treated with BET only evoked a significant ( $P < 0.05$ ) improvement in nutritive values

compared to the control diet. It was suggested that such favorable effect of BET could be linked to its potency in stabilizing cell membranes through interaction with membrane phospholipids and reduction in fecal water content and accordingly increase the digestibility of several nutrients (Klasing *et al.*, 2002). Additionally, BET has been shown to enhance intestinal immunity and improve gut health and function (Metzler-Zebeli *et al.*, 2009).

### Effect of Fed Additives on Some Cecum Contents

The cecal contents of DM and pH has not significantly ( $P < 0.05$ ) altered in response to any tested feed additives compared to the control group. But, the total concentration of volatile fatty acid (VFA) and  $\text{NH}_3\text{-N}$  were significantly ( $P < 0.05$ ) decreased in the caecum of rabbits fed THY500, THY1000 and all mixtures containing THY relative to the control group (Table 3). Similarly, Bassiony *et al.* (2015) reported that total VFA and  $\text{NH}_3\text{-N}$  concentration significantly ( $P < 0.05$ ) decreased in caecum content as affected by THY supplementation. Nevas *et al.* (2004) and Nezhadali *et al.* (2014) reported that thyme has high ability for inhibition of many strains of bacteria. Mahmoud *et al.* (2016) mentioned that the total VFA,  $\text{NH}_3\text{-N}$ , and pH values of caecum content were significantly ( $P < 0.05$ ) decreased in rabbits drank all levels of water thyme extract in comparison with control. The changes in the fermentation pattern of VFA and ammonia-N reflect significant changes of the caecum microorganisms and indicate that groups which receiving THY seem to show a lower VFA and ammonia-N in the caecum as compared with control animals. It might indicate either bacterial overgrowth, increased metabolic bacterial activity, or a lower absorptive capacity of the gut wall of the control status (Krieg *et al.*, 2009).

### Effect of Feed Additives on Some Hematological Parameters

Results in Table 4 show that hematological parameters [white blood cells (WBCs) count, lymphocyte, red blood cells (RBCs) count, hemoglobin (Hb), haematocrit and platelets] and glucose values were not significantly changed ( $P < 0.05$ ) by all tested feed additives at all the experimental periods. Comparable findings were

**Table 3. Effect of dietary supplementation with betaine (BET) and thyme oil (THY) on some caecum content parameters**

Feed treatment (Feed additive)	DM (%)	pH	TVFAs meq/100ml	Ammonia mg/100ml
T1 (Control)	26.32±0.54	5.90±0.04	54.04±0.40 <sup>a</sup>	19.55±0.32 <sup>a</sup>
T2 (BET1500)	19.66±1.48	5.75±0.06	53.23±0.16 <sup>a</sup>	18.52±0.19 <sup>ab</sup>
T3 (BET750)	23.21±2.79	5.70±0.15	52.86±0.34 <sup>a</sup>	18.64±0.54 <sup>ab</sup>
T4 (THY1000)	24.57±2.91	5.52±0.15	48.16±0.24 <sup>c</sup>	15.83±0.06 <sup>d</sup>
T5 (THY500)	25.04±2.11	5.50±0.23	48.98±0.15 <sup>c</sup>	16.30±0.33 <sup>d</sup>
T6 (BET1500+THY1000 )	21.65±1.07	5.88±0.01	52.52±0.30 <sup>ab</sup>	17.53±0.44 <sup>bc</sup>
T7 (BET1500+THY 500)	22.64±1.51	5.73±0.12	51.09±0.68 <sup>b</sup>	16.62±0.25 <sup>cd</sup>
T8 (BET750+ THY 1000)	22.13±2.76	5.66±0.14	51.29±0.61 <sup>b</sup>	17.66±0.26 <sup>bc</sup>
T9 (BET750+ THY 500)	24.06±0.62	5.87±0.07	51.19±0.85 <sup>b</sup>	18.21±0.44 <sup>b</sup>
Sig.	NS	NS	***	***

Means in the same column bearing different letters differ significantly (P<0.05)

NS = Not significant, \*\*\* P<0.001

**Table 4. Hematological parameters of New Zealand White rabbits as affected by feeding diets supplemented with different levels of betaine and thyme oil**

Feed treatment (Feed additive)	WBC <sub>s</sub> ( $\frac{9}{10^9/L}$ )	Lymphocyte ( $\frac{9}{10^9/L}$ )	RBC <sub>s</sub> ( $\frac{12}{10^9/L}$ )	Hemoglobin (g/dL)	Haematocrit (%)	Platelets ( $\frac{9}{10^9/L}$ )	Glucose (mg/dl)
T1 (Control)	8.31±1.25	3.22±0.60	4.96±0.14	11.63±0.22	35.07±0.68	328.33±88.66	97.33±5.04
T2 (BET1500)	9.55±1.08	3.87±0.70	5.07±0.25	12.53±0.86	36.75±2.47	320.67±69.33	106.67±16.33
T3 (BET750)	14.16±2.66	4.94±0.91	4.12±0.89	11.87±0.39	29.56±7.00	267.67±10.40	112.00±8.72
T4 (THY1000)	10.21±0.68	3.65±0.21	5.20±0.27	12.37±0.32	36.57±1.29	290.33±78.78	109.67±6.49
T5 (THY500)	10.91±2.47	4.30±0.20	5.30±0.14	12.97±0.48	38.14±1.54	280.33±22.67	119.67±7.69
T6 (BET1500+THY1000 )	12.42±1.37	3.38±0.73	5.26±0.29	12.80±0.61	37.29±2.15	227.67±43.52	111.67±6.94
T7 (BET1500+THY 500)	11.29±2.78	4.65±1.89	4.76±0.34	12.13±0.75	35.25±2.45	346.00±16.82	104.33±4.98
T8 (BET750+ THY 1000)	8.70±2.28	2.91±0.41	4.90±0.21	11.73±0.67	34.98±1.54	329.33±90.24	113.00±11.02
T9 (BET750+ THY 500)	9.62±1.51	2.97±0.39	4.99±0.26	12.50±0.70	36.59±1.94	356.33±55.35	104.67±8.97
Sig.	NS	NS	NS	NS	NS	NS	NS

NS = Not significant

previously reported by **Abd El-Moniem *et al.* (2016)** who showed that the mean values of RBCs, Hb, MCV, MCHC and platelets count were not significantly differ in BET supplemented rabbits. **Mahmoud *et al.* (2016)** illustrated that all tested levels (0.25, 0.50 and 0.75%) of water thyme extract did not significantly affect rabbit's hematological indicators.

**Bassiony *et al.* (2015)** reported that WBCs, RBCs, Hb, and lymphocytes significantly improved by cinnamaldehyde and THY addition. This discrepancy in hematological response in the different studies could be associated with duration of the feeding trial, type of diet and animal species.

### Effect of Feed Additives on Growth Performance

As shown in Table 5, both live body weight (LBW) and daily weight gain (DWG) were significantly ( $P < 0.001$ ) increased with all tested feed additives at all the experimental periods except BET750 +THY1000 supplemented group compared to the control group. The highest LBW was recorded in BET1500 then THY1000 and finally their mixtures. Also, the effect of the experimental treatments on feed conversion ratio (FCR) of growing rabbits is presented in Table 5. Overall, FCR was significantly ( $P < 0.01$ ) improved in BET1500, THY1000, and their mixtures supplemented groups compared to the control group.

Similar growth enhancing effect of BET has been previously reported in pigs (**Campbell *et al.*, 1995; Sul *et al.*, 2009**), ducks (**Wang *et al.*, 2004; Awad *et al.*, 2014**), geese (**Su *et al.*, 2009**), growing rabbits (**Hassan *et al.*, 2012; Abd El-Moniem *et al.*, 2016**) and poultry (**Zulkifi *et al.*, 2004; Attia *et al.*, 2005; Dunshea *et al.*, 2007**). The growth performance improvement due to BET supplementation might be attributed to several factors including donation of methyl groups (**Kidd *et al.*, 1997**), improved digestibility of specific nutrients (**Eklund *et al.*, 2006**), improved protein and fatty acids synthesis in the liver (**Rima, 2013**), and increasing growth hormone and insulin-like growth factor-I (**Huang *et al.*, 2006**), enhancing intestinal immunity (**Klasing *et al.*, 2002**) and improving gut health and function (**Kettunen *et al.*, 2001c; Metzler-Zebeli *et al.*, 2009**). Moreover, BET has been shown to stabilize cell

membranes through interaction with membrane phospholipids and to reduce fecal water content and increase the digestibility of several nutrients (**Kidd *et al.*, 1997; Klasing *et al.*, 2002**). These properties could reduce intestinal membrane damage, dehydration, diarrhea and mal-digestion and/or absorption which improves gut health and consequently enhances the ability of the animals to withstand coccidial infection (**Kettunen *et al.*, 2001c**). Comparable growth promoting effect has been previously reported with THY in chicken (**Hertrampf, 2001; Bölükbaşı *et al.*, 2006; Zidan *et al.*, 2016**) and growing rabbits (**Behboudi *et al.*, 2016; Shabaan, 2017**). The improvement in body weight gain may be due to its contents of bioactive compounds which have antimicrobial and antioxidant activity which improve each of feed conversion (**Gerencser *et al.*, 2014**), digestibility of nutrients (**Ibrahim *et al.*, 2000**) and some blood hematology (**Bassiony *et al.*, 2015**). Volatile oils from thyme were assessed as inhibitors of microbial growth (**Toghyani *et al.*, 2010**).

### Effect of Feed Additives on Some Carcass Traits

Dressing percentage, organs (liver, lungs, heart, spleen, kidney and caecum) weight as g/kg slaughter weight and caecum length were not significantly affected by dietary treatments (Table 6). Similar results were previously reported with BET (**Bassiony *et al.*, 2015; El-Sheikh *et al.*, 2017**) or THY (**Mahmoud *et al.*, 2016; Shabaan, 2017**) supplementation.

### Effect of Feed Additives on Economical Efficiency

Table 7 show that the feed cost/Kg weight gain decreased with elevated dietary additives which may be due to the improvement of weight gain and feed conversion ratio with the increase of the addition levels.

Interestingly, despite the growth promoting potential of BET and THY, individually or in combination, but it was surprising that no significant difference was recorded between the effects of their individual or concomitant dietary supplementation on the growth of rabbits. Mechanisms underlying the no additive or synergistic interactions between both compounds



**Table 5. Growth performance of New Zealand White rabbits fed diets supplemented with different levels of betaine and thyme oil**

Feed treatment (Feed additive)	Initial body weight (g)	Final body weight (g)	Daily weight gain (g/day)	Feed conversion ratio	Dead rabbits No.
T1 (Control)	612± 31.75	2301±21.71 <sup>d</sup>	30.17±0.29 <sup>e</sup>	4.79±0.05 <sup>ab</sup>	1
T2 (BET1500)	604±28.02	2607±20.33 <sup>a</sup>	35.76±0.54 <sup>a</sup>	4.26±0.07 <sup>cd</sup>	0
T3 (BET750)	619± 20.45	2483±36.61 <sup>bc</sup>	33.28±0.50 <sup>cd</sup>	4.46±0.08 <sup>bcd</sup>	0
T4 (THY1000)	627± 19.43	2564±26.11 <sup>ab</sup>	34.60±0.28 <sup>abc</sup>	4.35±0.07 <sup>cd</sup>	0
T5 (THY500)	617±23.50	2406±22.10 <sup>c</sup>	31.96±0.50 <sup>d</sup>	4.66±0.10 <sup>abc</sup>	0
T6 (BET1500+THY1000)	618±25.98	2574±28.72 <sup>ab</sup>	34.92±0.31 <sup>ab</sup>	4.14±0.12 <sup>d</sup>	0
T7 (BET1500+THY 500)	616±23.57	2399±34.39 <sup>c</sup>	31.84±0.48 <sup>d</sup>	4.33±0.09 <sup>cd</sup>	0
T8 (BET750+ THY 1000)	609±23.44	2281±24.26 <sup>d</sup>	29.86±0.46 <sup>e</sup>	4.97±0.27 <sup>a</sup>	0
T9 (BET750+ THY 500)	622±22.48	2526±55.32 <sup>ab</sup>	34.01±0.79 <sup>bc</sup>	4.68±0.18 <sup>abc</sup>	0
Sig.	NS	***	***	**	--

Means in the same column bearing different letters differ significantly (P<0.05)

NS = Not significant, \*\*P<0.01 and \*\*\* P<0.001

**Table 6. Dressing percentage and some internal organs weights of growing New Zealand White rabbits supplemented with different levels of betaine and thyme oil**

Feed treatment (Feed additive)	Dressing (%)	Liver (g/kg SW)	Lunges (g/kg SW)	Heart (g/kg SW)	Spleen (g/kg SW)	Kidney (g/kg SW)	Ceacum (g/kg SW)	Ceacum length (cm)
T1 (Control)	55.68±0.84	35.36±2.04	7.06±0.69	4.10±0.34	0.81±0.04	10.40±0.97	6.05±0.83	12.30±0.15
T2 (BET1500)	55.18±0.81	38.79±0.87	6.67±1.11	3.07±0.43	0.65±0.25	10.22±0.95	4.74±0.77	12.83±0.28
T3 (BET750)	56.33±1.04	34.16±3.05	6.75±0.51	3.48±0.29	0.86±0.20	9.02±0.66	5.24±0.18	13.63±0.89
T4 (THY1000)	57.85±0.68	36.50±2.50	7.80±0.87	3.39±0.45	0.73±0.26	8.55±0.85	6.11±1.21	12.07±0.23
T5 (THY500)	56.02±0.78	36.92±0.86	8.19±1.01	3.57±0.34	1.18±0.08	8.74±1.61	4.98±0.30	13.00±0.61
T6 (BET1500+THY1000)	56.52±0.62	38.31±1.45	8.56±0.12	3.04±0.22	0.71±0.18	11.40±1.33	4.64±0.51	12.03±1.28
T7 (BET1500+THY 500)	53.73±0.80	42.25±1.98	7.81±0.44	2.78±0.02	0.79±0.07	8.17±0.62	5.22±0.34	12.10±0.82
T8 (BET750+ THY 1000)	57.11±1.25	31.32±3.68	7.41±0.65	2.97±0.49	0.94±0.33	10.60±0.61	5.13±0.35	13.07±0.47
T9 (BET750+ THY 500)	57.75±0.88	34.64±1.58	7.88±0.46	3.92±0.12	0.81±0.12	8.61±0.98	6.02±0.49	13.07±0.32
Sig.	NS	NS	NS	NS	NS	NS	NS	NS

NS = Not significant

**Table 7. Input-output analysis and economic feed efficiency of the experimental tested diets**

Feed treatment (Feed additive)	Body weight gain (kg)	Total revenue/ rabbit (LE)*	Feed conversion (Kg feed/ Kg gain)	Price/Kg feed (LE)	Feed cost/Kg gain	Total feed cost (LE)	Net revenue (LE)	Economic efficiency (EE)**	Relative return (%)
T1 (control)	1.689	50.67	4.79	3.5	16.77	28.32	22.35	78.92	100
T2 (BET1500)	2.003	60.09	4.26	3.65	15.55	31.15	28.94	92.90	117.7
T3 (BET750)	1.864	55.92	4.46	3.575	15.94	29.71	26.21	88.22	111.8
T4 (THY1000)	1.937	58.11	4.35	3.6	15.66	30.33	27.78	91.59	116.1
T5 (THY500)	1.789	53.67	4.66	3.55	16.54	29.59	24.08	81.38	103.1
T6 (BET1500+THY1000)	1.956	58.68	4.14	3.75	15.53	30.38	28.30	93.15	118.1
T7 (BET1500+THY 500)	1.783	53.49	4.33	3.7	16.02	28.56	24.93	87.29	110.6
T8(BET750+THY 1000)	1.672	50.16	4.97	3.675	18.26	30.53	19.63	64.30	81.5
T9 (BET750+ THY 500)	1.904	57.12	4.68	3.625	16.97	32.31	24.81	76.78	97.3

\* Rabbit live weight. Kg /The price was calculated according to the local market price which was 30 L.E

\*\* Total feed cost/ economical efficiency =Net revenue

Price of one kg of diet was 3.50 LE. Price of selling of one kg live body weight of rabbits was 30 LE, the cost of one kg of BET 100 LE, and the cost of 50 ml of THY 5 LE.

are unknown. Though, the involvement of other mechanisms responsible for these interactions cannot be ruled out, as the fact that the co-exposure to both compounds might affect their bioavailability; but, this has not been evaluated. The knowledge of potential interactions and their underlying mechanisms may be of interest to formulate the most applicable mixtures of bioactives in the formulation of rabbit diets.

### Conclusion

Based on the results presented above, it could be concluded that supplemental dietary BET and/or THY could efficiently enhance nutrients digestibility and growth performance of growing rabbits. However, no additive or synergistic results found with the combination of both compounds merit to be taken into account when considering potential mixtures of bioactive as feed additives in rabbit's rations. Thus, from both health and an economic point of view, several benefits might be gained by adding these additives individually to the diet of commercial rabbits.

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## تأثير إضافة البتاين وزيت الزعتر ومخاليط كل منهما على الأداء الإنتاجي في الأرانب النامية

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أجريت تجربة لمدة 8 أسابيع لتقييم تأثير استخدام البتاين وزيت الزعتر أو مخاليط كل منهما كإضافات غذائية على نمو الأرانب وهضم العناصر الغذائية وخصائص الأعور وصفات الذبيحة والكفاءة الاقتصادية للأرانب النامية، تم تقسيم عدد 72 من ذكور الأرانب النيوزيلندية البيضاء عمر 5 أسابيع (متوسط الوزن  $616 \pm 7.82$  جم) إلى 9 مجموعات، تم تغذية مجموعة الكنترول (T1) على العليقة الأساسية (بدون إضافات)، في حين تم تغذية باقى المجموعات الأخرى على علائق تحتوي لكل كيلو جرام على 1500 مجم بتاين (T2)، 750 مجم بتاين (T3)، 1000 مجم زيت الزعتر (T4)، 500 مجم زيت الزعتر (T5)، 1500 مجم بتاين + 1000 مجم زيت زعتر (T6)، 1500 مجم بتاين + 500 مجم زيت الزعتر (T7)، 750 مجم بتاين + 1000 مجم زيت الزعتر (T8)، 500 مجم بتاين (T9)، أوضحت النتائج أن هضم المادة الجافة والطاقة المهضومة قد تحسن بشكل معنوى فى مجموعات T2، T3، T4، T6، T9، على النقيض حدث انخفاض معنوى في مجموع الأحماض الدهنية الطيارة وتركيز الأمونيا فى محتوى الأعور فى المجموعات T4، T5، T7، T8، T9 مقارنة مع مجموعة الكنترول، لم تتأثر صفات الذبيحة، قياسات الدم، والغذاء المأكول معنوياً بكل الإضافات الغذائية التي تم اختبارها، مقارنة مع مجموعة الكنترول، حدث زيادة معنوية فى وزن الجسم ومعدل النمو اليومي نتيجة استخدام الإضافات الغذائية فى كل المجموعات باستثناء مجموعة T8، حيث حققت المجموعات T2 و T4 و T6 أفضل تحويل للغذاء وأفضل كفاءة اقتصادية، وقد خلصت الدراسة إلى أن الإضافات الغذائية بالبتاين بتركيز 1500 ملجم أو زيت الزعتر بتركيز 1000 ملجم لكل كيلو جرام علف أو مخاليط كل منهما بنفس المستويات وذلك لتحسين معاملات الهضم والقيمة الغذائية للغذاء ومعدلات أداء النمو والحالة الصحية للأرانب النيوزيلندية البيضاء.

المحكمون:

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