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Effect of Dietary Additives on Growth Performance, Carcass Traits and Some Blood Constituents of Rabbits

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Abstract

Sixty 7-week-old New Zealand White rabbits were randomly distributed into 5 equal experimental groups. The experimental rabbits were fed the tested diets till 14 weeks of age during summer season. The basal diet without feed additives (control; T1) and the other experimental diets were supplemented with enzymes at 0.5 g/kg (T2), organic acids at 1.0 g/kg (T3), β-pro at 0.2 g/kg (T4) or their combination (T5). The criteria of response were body weight, weight gain, feed consumption, feed conversion ratio, some blood constituents, carcass traits and economic efficiency. The obtained results can be summarized as follows: Positive effects of feed additives were observed on live body weight, daily weight gain and feed conversion of growing rabbits. There were no significant effects on blood parameters or carcass traits due to feed additives. It can be concluded that dietary β-pro (enzymes+probiotics) or a combination of enzymes, organic acids and β-pro at the tested levels can be used to improve the rabbit performance, with no adverse effects on carcass characteristics or blood parameters.

Keywords: enzymes, organic acids, probiotics, rabbits

1. Introduction

Maximizing nutrient utilization is essential to the profitability and sustainability of rabbit production. Feeding costs are about 60-70% of rabbit production costs. Enzymes, probiotics and organic acids can be used as viable alternatives to antibiotic growth promoters for rabbits (Falcao-e-Cunha et al., 2007). Dietary enzyme supplementation can improve the nutritive value of cereal grains and their by-products. As a consequence, exogenous enzymes incorporation into rabbit diets has been reported to improve nutrient utilization (Bedford, 2000; Falcao-e-Cunha et al., 2007). In most monogastric animal diets, organic acids are frequently used instead of antibiotics as growth promoters. Dietary supplementation of organic acids can improve growth, feed conversion and nutrient utilization in rabbits (Dibner & Buttin, 2002; Falcao-e-Cunha et al., 2007). In addition, Davidson (2001), and Diebold and Eidelsburger (2006) suggested that organic acids have antimicrobial activity and control the intestinal microbial growth. The antimicrobial properties of organic acids vary for different organic acids (Chaveerach et al., 2002). Lactic acid can effectively reduce gastric pH and the proliferation of coliforms bacteria (Øverland et al., 2007). Formic and propionic acids have considerable activities against the pathogenic bacteria, fungi and yeast (Bosi et al., 2005; Creus et al., 2007; Øverland et al., 2007). Post-weaning piglets fed organic acids-supplemented diets exhibited lower contents of pathogenic bacteria and less incidence of diarrhea and mortality rate (Papatsiros et al., 2011).

Nowadays probiotics are used as growth promoters on a large scale to avoid the presence of residues of antibiotics in animal products used in human consumption. Probiotics have been reported to positively affect growth performance and health of rabbits (Ezema & Eze, 2010; Bhatt et al., 2017). Kritas et al. (2008) demonstrated that probiotic addition reduced proliferation of *Escherichia coli* in rabbits. El-Kholy et al. (2012) reviewed that added dietary probiotic bacteria isolated from mothers' feces significantly improved cell-mediated immunity in growing rabbits. During weaning, rabbits are more susceptible to diarrhea and intestinal disorders due to the transition from feeding on mother's milk to hard food. Different stressors such as dietary, environmental and behavioral factors affect feed consumption, intestinal tract development and adaptation to the weaning diet. The most critical period is 10-15 days post-weaning where rabbits are more sensitive to intestinal infections (Gallois et al., 2008; Bivolarski & Vachkova, 2014). Probiotics can improve the intestinal balance of the host animal. They have been reported to influence the weight of intestinal tract and caecal fermentation in rabbits (Kermauner & Štruklec, 1999). Probiotics may also contribute to improve the health status and gut function of weaning rabbits (Trocino et al., 2005; Kritas et al., 2008). Low contents of Lactobacilli are found in the rabbit caecum (Cheeke, 1987). The Lactobacilli are routinely used as a probiotic for sick rabbits because they are able to colonize at the rabbit's gastric pH. The combined microflora in rabbit caecum breaks down cellulose, zylan, pectin, ammonia, urea and proteins from the small intestine (De Blas & Gidenne, 1998). Falcao-e-Cunha et al. (2007) reviewed that probiotics has a positive effect on growth performance and mortality in rabbits. Therefore, this study was undertaken to evaluate the effect of dietary supplementation with enzymes, organic acids, β-pro and their combination on performance and carcass traits of growing rabbits.

2. Materials and Methods

The present study was carried out at Faculty of Agriculture, Mansoura University, Egypt, during June and July, 2015. Sixty growing 7-week-old New Zealand White (NZW) rabbits were divided into 5 equal groups of three replications each. All groups had approximately equal means of live body weight at the beginning of study. The experimental rabbits were fed till 14 weeks of age on five experimental diets during the experimental period. The average temperature and relative humidity during June and July were 30.1 ^{o}C and 89.6%, 32.3 ^{o}C and 93%, respectively. The basal diet is presented in Table 1. The first treatment without feed additives (control; T1) and the other experimental treatments contained enzyme mixture at 0.5 g/kg (T2), organic acids mixture (Fordex) at 1.0 g/kg (T3), β-pro at 0.2 g/kg (T4) and combination of enzymes, organic acids and β-pro at the previously mentioned levels (T5). Feed additives were added instead of the same amount of corn in the basal diet.

Each kg of enzyme mixture contained: xylanase 4,000,000 units; cellulase 400,000 units; beta-glucanase 200,000 units; pectinase 240,000 units; amylase 1,500,000 units; protease 750,000 units; lipase 50,000 units; phytase 50,000 units; glactosidase 400,000 units and mannanase 200,000 units. Each kg of organic acids (Fordex) contained propionic acid (99.5%) 192.50 g; formic acid (99.5%) 92.35 g; ammonium propionate (99%) 9.30 g; ammonium formate (99%) 55.70 g; ascorbic acid (98%) 80 g; silicon dioxide 50 g and calcium carbonate up to 1 kg. The β-pro product contained betaine-HCl 100 g/kg; *Lactobacillus planterum* 100 g/kg; *Enterococccus faecium* 50 g/kg; *Bifidobacterium bifidum* 2 g/kg; *Aspergillus oryzae* fermentation extracts 50 g/kg; xylanase 12,500 units/kg; hemicellulase 2,750 units/kg; beta-glucanase 2,250 units/kg; *bacillus subtilus* fermentation extracts 50 g/kg; alpha-amylase 25,000 units/kg; cellulase 4,500 units/kg and protease 12500 units/kg.

The animals were reared in cages; each cage has dimensions of 45 × 45 × 35 cm and supplied by a feeder and a stainless steel nipple for drinking. Fresh water and pelleted diets were freely offered during the experimental period from 7 to 14 weeks of age. No heating was applied in the rearing house. The experimental rabbits were kept under the same managerial and hygienic conditions. During the experimental period, growth performance were measured as live body weight, feed consumption and feed conversion ratio (g feed/g gain) on a weekly basis. Protein efficiency ratio (PER) was calculated as crude protein eaten (g)/weight gain (g). Efficiency of energy utilization (EEU) was calculated as the digestible energy intake (kcal)/weight gain (g). Performance index (PI) was calculated as live body weight (kg) × 100 divided by feed conversion according to North (1981). The feed cost per kg gain expressed as EGP was calculated as the feed conversion value × price of one kg diet.

Economic efficiency of feeding (EEF) was calculated as follows: EEF = [(Sale price per kg gain – Feed cost per kg gain)/Feed cost per kg gain] × 100. The sale price of one kg weight gain was 25 EGP.

Four blood samples were taken from each experimental group of rabbits at slaughtering in heparinized test tubes. The blood samples were centrifuged for separating blood plasma. The plasma concentrations of glucose, total protein, albumin, triglycerides, cholesterol and high density lipoprotein were determined using commercial kits according to Trinder (1969), Henry (1964), Doumas et al. (1971), Tietz (1995), Allain et al. (1974), and Sawle et al. (2002), respectively. Globulin concentration of blood plasma was calculated by the following equation: globulin = total protein – albumin. Activities of ALT and AST were also determined colorimetrically by commercial kits according to Reitman and Frankel (1957). The obtained data were statistically analyzed using a software program (Statgraphics, Version 5.0 STSC Rockville, 1991). Differences were considered significant at $P \leq 0.05$.

Table 1. Composition and chemical analyses of the basal diet

Ingredients %	Basal diet
Yellow corn	15.3
Soybean meal (44% CP)	19.0
Wheat bran	10.0
Alfalfa hay meal	39.2
Barley	12.0
Dicalcium phosphate	0.7
Limestone	1.0
Common salt	0.5
Vit. & Min. Premix*	0.3
Molasses	2.0
Total	100
Calculated analysis (air-dry basis: NRC, 1977)	
DE kcal/kg	2501
CP %	18.65
EE %	2.42
CF %	13.97
Ca %	1.17
P %	0.56
Lysine %	0.93
Methionine %	0.25
Methionine + Cysteine	0.59
Cost of 1kg diet; L.E.	2.45

Note. * Each 3 kg Vit. & Min. Premix contains: Vit.A, 12,000,000IU; Vit.D_3, 2,500,000IU; Vit.E, 10g; Vit.K, 2.5g; Vit.B_2, 5 g; Vit.B_6, 1.5 g; Vit.B_{12}, 10 mg; Biotin, 50 mg; Folic acid, 1.0 g; Nicotinic acid, 30 mg; Pantothenic acid, 10 g; Antioxidant, 10 g; Mn, 60 g; Cu, 10 g; Zn, 55 g; Fe, 35 g; I, 1.0 g; Co, 250 mg and Se, 150 mg.

3. Results and Discussion

3.1 Live Body Weight

The live body weights of rabbits from 7 to 14 weeks of age are presented in Table 2. The experimental treatments had no significant effect on live body weight during the experimental period from seven to twelve weeks of age; however in thirteen and fourteen weeks of age there were significant effects among the experimental treatments. The treatment five (the combination of feed additives; enzymes, organic acids and beta-pro) recorded the highest significant value of live body weight compared with the other experimental treatments, however the control rabbits had the lowest significant value of live body weight among experimental treatments in the thirteen and fourteen weeks of age. The experimental treatments T2, T4 and T5 were not significantly different in live body weight at the end of the experimental period.

The present results agree with the findings of EL-Sagheer and Hassanein (2014), who showed that using 1 or 2 g Vetazyme/kg diet (enzymes+probiotic) improved significantly body weight of rabbits than those fed the un-supplemented diet from 30 to 72 days of age. They also observed that rabbits fed diets containing Vetazyme at 1 g/kg diet achieved higher body weight and gained more than that fed the diet containing 2 g/kg. Attia et al. (2012) observed improvements in caecal fermentation pattern and nutrient metabolism due to feeding enzyme-supplemented diets which were coincided with higher live body weight in rabbits. Gidenne et al. (2002) reported that the increased live body weight and weight gain of rabbits fed enzymes may be due to the positive effect of enzymes on microflora growth in the intestinal tract as well as the increase in volatile fatty acids production and organic matter digestibility. On the other hand, Eiben et al. (2004) observed no beneficial effect on growth performance of rabbits due to dietary enzyme supplementation. Also, García-Palomares et al. (2006) stated that the addition of proteases (1 g/kg) to New Zealand × Californian rabbits in the diet containing 16% crude protein had no effect on growth performance traits (body weight and weight gain) in the experimental period (35 to 63 days old). Kliševičiūtė et al. (2016) indicated that inclusion of butyrate and mixture of organic acid salt in the rabbit feeds increased the body weight and growth rate of rabbits. Lam Phuoc and Jamikorn

(2017) reported that the dietary supplementation with *L. acidophilus* and *B. subtilisplus* improved body weight of rabbits than the control rabbits. Pogány Simonová et al. (2015) found that daily gain of rabbits fed the diet supplemented with *Enterococcus faecium* CCM7420 strain was higher than their control counterparts.

Table 2. Effects of dietary supplementation with enzymes, organic acids, β-pro and their combination on weekly body weight (g) of NZW rabbits

Treatments	Age in weeks							
	7	8	9	10	11	12	13	14
T1	810	1007	1252	1448	1576	1709	1869^{c}	2017^{c}
T2	817	1008	1219	1456	1627	1840	1998^{abc}	2212^{ab}
T3	812	1038	1268	1454	1629	1818	1984^{bc}	2205^{b}
T4	830	1023	1249	1479	1683	1877	2059^{ab}	2263^{ab}
T5	808	1002	1238	1477	1717	1912	2148^{a}	2338^{a}
Standard error of the means	40	39	37	38	40	52	51	40
Significance level	NS	NS	NS	NS	NS	NS	*	**

Note. Mean values with the same letter(s) are not significantly different.

3.2 Daily Body Weight Gain

Data from Table 3 show that there were no significant differences among the experimental groups of rabbits in daily body weight gain during the age intervals of 7-8, 8-9, 11-12, and 13-14 weeks of age. There were significant differences among the experimental rabbits during the periods of 9-10, 10-11, 12-13 and 7-14 weeks of age. During the period of 9-10 weeks of age T5 achieved the highest daily body weight gain, followed by T2 and then T4 without significant differences among them; however, the lowest means of body weight gain were recorded for T3 and T1 (control). It was observed that treatment five (fed the combined feed additives) achieved the highest mean of body weight gain among the experimental treatments during the periods of 10-11 and 12-13 weeks of age. During 10-11 weeks of age T5 achieved the highest mean of body weight gain, followed by T4 (fed β-pro), T3 (fed organic acids) and then T2 (fed enzymes) without significant differences among them, while the lowest mean of body weight gain was found for the control group (fed basal diet). During the 12-13 weeks of age, T5 achieved the highest mean of body weight gain while other treatments were not significantly different. During the total period of study (7-14 weeks of age), T5 recorded the highest value of daily weight gain, followed by T4 without significant differences between them, however there were no significant differences among T4, T3 and T2, but T1 (control) achieved the lowest value of daily weight gain. The obtained results agree with those of El-Sagheer and Hassanein (2014), who found that enzyme mixture at 1 g/kg diet positively affected growth performance of rabbit. Eiben et al. (2002) and Makled et al. (2005) found that feeding diets supplemented with enzyme preparations caused an improvement in growth rate of rabbits. Also, Kamal et al. (2008) demonstrated that supplementation of growing rabbit diets with either 0.5% malic, fumaric or citric acids from 4-12 weeks of age significantly increased weight gain of rabbits. In this concern, Yamani et al. (1992) found that a pelleted diet supplemented with probiotic improved body weight and weight gain in New Zealand White Rabbits during the growing period. Amber et al. (2004) reported that dietary supplementing *Lactobacildlus aciophilus* (Probiotic) for growing rabbits had a positive effect on average daily gain (+9.6%) comparing with the control group. Also, Ewuola et al. (2011) showed that the final live weight, and daily weight gain of rabbits fed prebiotic and symbiotic enriched diets were significantly higher than those fed the probiotic or the control diets. Kritas et al. (2008) also reported that supplemental probiotics resulted in higher body weight gains in rabbits. Recently, Bhatt et al. (2017) reported that Chinchilla rabbits fed diets containing probiotic (*Lactobacillus acidophilus* at 10^{7} CFU/g concentrate) achieved better body weight gain during the growing period.

On the other hand, Mourao et al. (2004) found no effect on growth rate of rabbits fed probiotic supplemented diet. Ribeiro et al. (2012), using coated sodium butyrate (23-63 days of age) and Romero et al. (2012), using a blend of esterified caproic and caprylic acids (28-56 days of age) found that dietary supplementation with organic acids did not affect growth rate of fattening rabbits. In harmony with the current results, other investigators observed that added dietary organic acids had a positive effect on body weight gain of rabbits, for examples Kamal et al. (2008) using single or combined addition of citric, fumaric and malic acids from 4 to 12 weeks of age; Debi et al. (2010) using citric acid from 30 to 86 days of age and Romero et al. (2011) using a blend of microencapsulated formic and citric acids from 28 to 77 days of age.

Table 3. Effects of dietary supplementation with enzymes, organic acids, β-pro and their combination on daily body weight gain (g) of NZW rabbits

Treatments	Age intervals (wk)							
	7-8	8-9	9-10	10-11	11-12	12-13	13-14	7-14
T1	28.21	35.00	28.04^{b}	18.27^{c}	18.99	22.80^{b}	21.19	24.64^{c}
T2	27.20	30.18	33.94^{a}	24.39^{b}	30.42	22.56^{b}	30.54	28.64^{b}
T3	32.38	32.86	26.55^{b}	24.94^{b}	26.96	23.81^{b}	31.49	28.43^{b}
T4	27.56	32.32	32.86^{a}	29.11^{b}	27.68	26.01^{b}	29.11	29.23^{ab}
T5	27.74	33.69	34.05^{a}	34.35^{a}	27.86	33.69^{a}	27.14	31.22^{a}
Standard error of the means	1.79	1.00	0.87	1.55	2.98	2.40	2.65	0.77
Significance level	NS	NS	**	**	NS	*	NS	**

Note. Mean values with the same letter(s) are not significantly different.

3.3 Feed Intake

Table 4 shows the data of daily feed intake of rabbits fed the experimental diets with different feed additives. The experimental treatments had a significant effect on feed intake during the 8th and 9th weeks of age, however after the 9th week of age this effect was disappeared until the end of the study (14 weeks of age). During the 8th week of age, the T3 recorded the highest feed intake, while the other experimental treatments were not significantly different in feed intake values. During the 9th week of age, rabbits in the control group (T1) recorded the highest mean of feed intake without differences among T1, T3 or T4; however, T2 had the lowest mean of feed intake. Also, there were no significant differences among T3, T4 or T5 in feed intake.

The present results of feed intake agree with Eiben et al. (2004), who reported that cellulose supplementation in diets of growing rabbits from 23 to 77 days of age did not affect feed intake. In contrast, Eiben et al. (2002) observed a reduction in feed intake of rabbits during the growth period due to adding enzymes. Kamal et al. (2008) clarified that supplementation of growing rabbit diets with either 0.5% malic, fumaric or citric acids from 4-12 weeks of age decreased feed consumption significantly in those groups than the control group. On the other hand, Cesari et al. (2008), using a blend of formic and lactic acids in rabbit diets (30-84 days of age), found that dietary inclusion of organic acids had no effect on daily feed intake or growth rate of the fattening rabbits. Fathi et al. (2017) found that dietary supplementation with probiotic (400 g/ton) achieved a significant increase in feed intake compared with control group. Ezema and Eze (2010) and Bhatt et al. (2017) reported that probiotics had a positive effect on feed intake of growing rabbits. Oso et al. (2013) found that rabbits fed probiotic-supplemented diets had significantly higher feed intake compared with their control counterparts.

Table 4. Effects of dietary supplementation with enzymes, organic acids, β-pro and their combination on daily feed intake (g) of NZW rabbits

Treatments	Age intervals (wk)							
	7-8	8-9	9-10	10-11	11-12	12-13	13-14	7-14
1	65.48^{b}	92.14^{a}	99.17	100.36	102.50	124.58	161.25	106.50
2	63. 21^{b}	85.48^{c}	95.71	96.07	103.81	122.86	151.19	102.62
3	69.70^{a}	91.67^{ab}	89.58	94.76	98.21	113.15	159.52	102.37
4	64.70^{b}	90.12^{ab}	92.79	102.50	104.29	116.49	186.90	108.26
5	65.30^{b}	88.93^{b}	100.42	100.24	104.46	116.90	170.24	106.64
Standard error of the means	1.04	0.97	4.29	2.26	3.04	4.74	11.22	2.51
Significance level	*	**	NS	NS	NS	NS	NS	NS

Note. Mean values with the same letter(s) are not significantly different.

3.4 Feed Conversion Ratio

Table 5 shows the effect of feed additives on feed conversion of NZW rabbits. The experimental treatments did not affect feed conversion during the periods of 7-8, 8-9, 12-13 and 13-14 weeks of age. However, feed conversion was affected significantly during the periods of 9-10, 10-11, 11-12 and the total period of study (7-14 weeks of age). Regarding the whole period of study all treated treatments (T2, T3, T4 and T5) achieved significantly better values of feed conversion compared with the control group (T1). The obtained results (Table 5) showed that the current feed additives (enzymes, organic acids and probiotics) led to improved feed conversion. The improvement in feed conversion may be due to better nutrient digestion and absorption as well as reduction of gastro intestinal pH, which led to a reduction of pathogenic microbes and thus improved the efficiency of feed utilization by rabbits. Lam Phuoc and Jamikorn (2017) found that feed conversion ratio was better in the rabbits received *L. acidophilus* alone or a complex of *B. subtilis* and *L. acidophilus* as compared to their control. These improvements in feed conversion of rabbits could be due to the greater nutrient digestibility and nitrogen retention in the *L. acidophilus alone* and *B. subtilis* supplemented rabbit diets. Ezema and Eze (2010) and Bhatt et al. (2017) indicted that dietary supplementation with probiotics had positive effect on feed conversion ratio of rabbits. Oso et al. (2013) suggested that the improvement in feed efficiency of rabbits in response to feeding probiotic-supplemented diets could be explained by increasing the beneficial microflora in the gut and improving nutrient digestion and absorption.

Regarding feed conversion, the present results are in good agreement with the findings of Eiben et al. (2004), who reported that supplementation of diet for early-weaned rabbits with a cellulase positively affected the feed conversion between 23 and 77 days of age. This agrees with the finding of Cachaldora et al. (2004), who reported that enzyme supplementation has beneficial effects on feed efficiency of fattening rabbits. Kamal et al. (2008) demonstrated an improved feed conversion of rabbits in groups which received malic, fumaric and citric acids. In growing rabbits, Amber et al. (2004) found that dietary supplementation with *Lactobacillus acidophilus* (Probiotic) had a positive effect on feed conversion while no effect was observed on mortality rate. They stated that the improvements were due to probiotic modification in caecal microflora. Kritas et al. (2008) also reported higher gains and better feed conversion ratio in rabbits supplemented with probiotics than their control counterparts. Also, Bhatt et al. (2017) reported that rabbits given diets supplemented with probiotics (*Lactobacillus acidophilus*) had superior feed conversion ratio to the control group. On the other hand, Yamani et al. (1992) found that feeding a pelleted diet supplemented with probiotic for New Zealand White rabbits during the growing period did not improve feed conversion of rabbits.

Table 5. Effects of dietary supplementation with enzymes, organic acids, β-pro and their combination on feed conversion ratio of NZW rabbits

Treatments	Age intervals (wk)							
	7-8	8-9	9-10	10-11	11-12	12-13	13-14	7-14
1	3.28	2.63	3.54^{c}	5.55^{c}	5.81^{b}	5.86	7.95	4.34^{b}
2	3.15	2.83	2.82^{a}	3.95^{b}	3.42^{a}	5.49	4.97	3.61^{a}
3	2.84	2.81	3.37^{bc}	3.82^{b}	3.68^{a}	4.77	5.18	3.60^{a}
4	3.27	2.79	2.83^{a}	3.55^{ab}	3.79^{a}	4.55	6.46	3.71^{a}
5	3.31	2.64	2.95^{ab}	2.93^{a}	3.89^{a}	3.47	6.52	3.42^{a}
Standard error of the means	0.22	0.095	0.142	0.20	0.48	0.54	0.83	0.10
Significance level	NS	NS	*	**	*	NS	NS	**

Note. Mean values with the same letter(s) are not significantly different.

3.5 Protein and Energy Utilization, Performance Index and Economic Efficiency of Feeding

Table 6 shows the effect of the experimental treatments on protein efficiency ratio (PER), efficiency of energy utilization (EEU), performance index (PI) and economic efficiency of feeding (EEF) of NZW rabbits. The analysis of variance showed that there were significant differences among the experimental treatments in PER, EEU, PI and EEF.

The control group (T1) recorded the highest significant values of PER and EEU comparing with the other experimental treatments. This means that the rabbits in the treated groups (T2, T3, T4 and T5) utilized protein and digestible energy more efficiently than rabbits in the control group. The improvement in PER and EEU may be due to the effect of feed additives used here. Regarding the performance index (PI), T5 which fed diet containing the combination of feed additives achieved the highest significant value of PI, followed by T2, T3 and T4 without significant differences among them; however, T1 had the lowest significant value of PI. Regarding the EEF, the control group (T1) recorded the lowest significant value of EEF comparing with the other experimental treatments (T2, T3, T4 and T5) without significant differences among them. The improvement in EEF was probably related to lower feed cost and improved feed conversion along with the higher body weight gain.

The obtained results partially agree with the findings of Uddin et al. (2014), who found that citric acid supplementation in rabbits diet improved growth performance of rabbits as compared to control. The observed improvement in performance of growing rabbits may be due to improving digestion and absorption of nutrients as well as reduction of intestinal pH which led to a reduction of pathogenic microbes from gastrointestinal tract. El-Sagheer and Hassanein (2014) found that dietary enzyme supplementation at 1 g/kg diet had a beneficial effect on growth performance of growing rabbits. Amber et al. (2004) showed that performance index and the net revenue were significantly increased by the probiotic diets, as compared to control diet. Onu and Oboke (2010) also indicated that enzyme or probiotics supplementation of maize processing waste-based diet enhanced the PER. However, Rabie et al. (2011) found that PER, EEU and PI of rabbits were not affected by dietary supplementation with probiotics during the period from 6 to 12 weeks of age. El-Deek et al. (2013) reported that performance index of male New Zealand White rabbits at 14 weeks of age was significantly improved by dietary supplementation with 0.2% probiotics. Lam Phuoc and Jamikorn (2017) found that growth performance and feed efficiency of weaning rabbits were positively affected by dietary probiotic. Chandra et al. (2014) attributed the improvement in growth performance in response to feeding the probiotic-supplemented diets to improved nutrient digestibility and absorption in the ileum. Pogány Simonová et al. (2015) reported that the administration of *Enterococcus faecium* CCM7420 strain to the rabbits altered their growth performance; these changes may influence the gut function and improve the nutrient uptake.

El-Adawy et al. (2000) recorded the highest economic efficiency value with the addition of 0.1 or 0.2% probiotic or 0.05, 0.1 or 0.2% antibiotic. Abdel-Azeem et al. (2009) observed the best net return, percentage of economic efficiency; relative economic efficiency and performance index due to supplementing probiotic on rabbit diets. El-Katcha et al. (2011) recorded that dietary supplementation of probiotic at 0.1 or 0.15 g/kg diet improve economic efficiency by about 64.9% and 49.7% in two different groups. Ogunsipe (2014) found that lowest cost of feed /weight gain for rabbits was recorded when rabbits were fed enzyme supplemented-based diet.

Table 6. Effects of dietary supplementation with enzyme, organic acid, β-pro and their combination on protein and energy utilization, performance index and economic efficiency of feeding

Treat	PER	EEU	PI	EEF %
1	0.81[a]	10.85[a]	46.69[c]	135.9[b]
2	0.67[b]	9.02[b]	61.35[b]	171.9[a]
3	0.67[b]	9.00[b]	61.25[b]	166.6[a]
4	0.69[b]	9.27[b]	61.08[b]	171.2[a]
5	0.64[b]	8.54[b]	68.44[a]	166.2[a]
Standard error of the means	0.02	0.25	1.46	6.70
Significance level	**	**	**	*

Note. Mean values with the same letter(s) are not significantly different. PER = protein efficiency ratio, EEU = Efficiency of energy utilization, PI = Performance index and EEF = Economic efficiency of feeding.

3.6 Blood Parameters

Table 7 shows the effect of the experimental treatments on some blood parameters (total protein, albumin, globulin, triglycerides, high density lipoprotein, cholesterol and glucose and the activity of AST and ALT enzymes) for 14 week old NZW rabbits. The obtained results showed that the experimental treatments did not have a significant effect on studied blood parameters. The values of studied parameters were in the physiological range of rabbits.

In harmony with the current results, Veselin et al. (2003) found no effect of feeding diets supplemented with enzyme preparation on blood concentrations of total protein, albumin or globulin of rabbits. Selim et al. (2004)

observed no change in plasma glucose concentration when rabbits were fed diet supplemented with commercial enzymes. Also, El-Tantawy et al. (2001) found that dietary Kemzyme supplementation did not alter blood plasma level of total lipids in rabbits. The present results agree also with the findings of Dorra et al. (2013), who reported that blood parameters of rabbits were not affected by dietary organic acids. Radwan and Abdel-Khalek (2007) found that dietary organic acids (0.5% acetic or lactic acids) did not affect blood plasma parameters (total protein, albumin, globulin and total lipids) of rabbits. On the other hand, Abd El-Latif et al. (2008) found that rabbits given drinking water with enzymes achieved high concentrations of serum total protein, albumin, globulin and glucose. They also stated that the elevation of these blood parameters may be due to the positive effect of enzymes on liver function and the digestibility of crude fiber and organic matter. Also, Makled et al. (2005) suggested that the increase in plasma total protein concentration by feeding the Optizyme-supplemented diets is due to an increase in crude protein digestibility which was associated with an improvement in growth performance of rabbits. In addition, Kamal et al. (2008) fed male New Zealand White rabbits on diets supplemented with organic acids (citric, fumaric and malic acids, singly or in combination) and found significant reductions in serum levels of cholesterol, total lipid and low density lipoprotein cholesterol.

Table 7. Effects of dietary supplementation with enzymes, organic acids, β-pro and their combination on blood parameters of NZW rabbits

Treatments	Total protein (g/dl)	Albumin (g/dl)	Globulin (g/dl)	Triglycerides (mg/dl)	Cholesterol (mg/dl)	Glucose (mg/dl)	HDL (mg/dl)	AST (U/l)	ALT (U/l)
1	5.77	3.06	2.71	61.62	78.5	113.1	24.93	52.10	12.65
2	5.70	3.06	2.64	62.73	78.9	117.4	27.47	54.33	12.82
3	6.09	3.13	2.96	62.21	80	115.5	28.20	58.36	13.65
4	6.03	3.12	2.91	67.03	83.8	117.4	29.53	55.89	13.51
5	5.75	3.02	2.74	67.54	85.8	113.3	26.68	53.75	13.00
Standard error of the means	0.19	0.14	0.17	3.22	4.1	4.2	1.13	2.61	0.77
Significance level	NS	NS	NS	NS	NS	NS	NS	NS	NS

3.7 Carcass Traits

Table 8 shows the effect of the experimental treatments on carcass traits of NZW rabbits at 14 weeks of age. The analysis of variance showed that there were no significant differences among the experimental treatments in carcass parameters.

Regarding the carcass traits, our results are in line with the findings of El-Sagheer and Hassanein (2014), who reported no significant effects on carcass criteria of rabbits due to strains or Vetazyme supplementation in diet except liver percentage. Dorra et al. (2013) reported that added dietary organic acids did not significantly affect carcass traits of the experimental rabbits. Also, Carraro et al. (2005), using sodium butyrate at 0.5, 1.0 or 2.0 g/kg, Radwan and Abdel-Khalek (2007), using 0.5% acetic or lactic acids, and Amaefule et al. (2011) using 0.5% of acetic, citric or formic acids, reported that carcass traits of rabbits were not affected by dietary supplementation with organic acids. In agreement with the present results, Viliene et al. (2017) found that dietary supplementation with organic acids, butyric acid, calcium formate or its salts did not significantly influence the carcass yield or the proportions of the various carcass parts. Fathi et al. (2017) reported that dietary supplementation with probiotic led to significantly highter dressing percentage compared with those given the other dietary treatments. Chrastinová et al. (2010) demonstrated that probiotics increased protein and fat contents in rabbit's carcass meat. Also, Simonová et al. (2010) found that meat of rabbits fed diets supplemented with probiotic had the highest fat content compared with the control group.

Table 8. Effects of dietary supplementation with enzymes, organic acids, β-pro and their combination on relative weights (%) of carcass traits of NZW rabbits

Treatments	Live weight (g)	Feet+fur %	Carcass %	Lungs %	Kidneys %	Heart %	Liver %	Total edible parts %
1	2021	17.9	60.2	0.61	0.66	0.25	3.1	64.21
2	1994	19.3	58.8	0.86	0.69	0.24	3.2	62.97
3	1989	18.2	59.7	0.88	0.64	0.27	2.9	63.56
4	1944	17.6	60.7	0.80	0.76	0.37	3.4	65.22
5	1975	18.6	58.7	0.66	0.72	0.33	3.1	62.86
Standard error of the means	87.7	0.5	2.1	0.09	0.05	0.04	0.26	2.29
Significance level	NS	NS	NS	NS	NS	NS	NS	NS

4. Conclusion

It can be concluded that dietary β-pro (enzymes+probiotics) or a combination of enzymes, organic acids and β-pro can safely be used for growing rabbits to improve their performance, with no adverse effects on carcass characteristics or blood parameters.

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