NUTRUTIONAL EFFECT OF BROCCOLI BY-PRODUCT AS FEED ADDITIVES ON PRODUCTIVE PERFORMANCE OF NEW ZEALAND RABBITS

Yasmin M.M. Mahmoud[1] and A.M. Kholif[2]

[1]Animal Production Research Institute, ARC, Ministry of Agriculture, Dokki, Giza, Egypt.

[2]Dairy Science Department, National Research Centre, Dokki, Giza, Egypt.

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SUMMARY

This study was conducted to estimate the effect of broccoli by-product (BB) as one of the promising feed additives on nutrients digestibility, growth performance of New Zealand White (NZW) rabbits, carcass characteristics as well as some blood parameters, caecal activities and economic efficiency were studied also. A total of 48 weaned rabbits at 6 weeks of age, with average body weight 747.92 g were used in this work. Rabbits were individually housed and fed the experimental dietary treatments using a complete randomized block design, where they were randomly assigned into three homogeneous groups (16 each). Three experimental dietary treatments were designed by using the basal ration with the addition broccoli by-product at 0.0, 1.0 % and 3.0 % levels of (CFM) for control (G1) and the two tested rations (G2) and (G3), respectively for 8 weeks as an experimental periods. The basal diet was formulated to fulfill the necessary requirements of growing rabbits. Results revealed that digestibility of most nutrients and feeding values were significant ($P<0.05$) higher for both tested rations (G2 and G3) than those of the control one (G1). In the meantime, insignificant difference was observed in digestion coefficient of (CF) among the experimental rations. Ration G3 showed significantly ($P<0.05$) the highest values of live body weight, total weight gain and feed intake followed by ration G2 versus the lowest values that recorded with control one (G1). Also, feed conversion and performance index were improved by the tested rations in comparison with those of control one, but the differences were not significant. Regarding carcass characteristic, group G2 and G3 showed significantly ($P<0.05$) higher weights and percentages of empty carcass (with head), giblets and dressing than those of the control one (G1). Similar trend was observed with the measurements of edible giblets (liver, heart and kidney) among the experimental treatments. Better economic efficiency was markedly improved due the addition of broccoli by-products as an additive source especial at the high level (G3). Blood biochemical constituents and caecal activities as pH, TVFAs and ammonia-nitrogen were also investigated. It can be concluded that up to 3.0 % BB can be fed to growing rabbits with no negative impact on digestibility coefficient, physiological functions, productive performance, carcass characteristics, cecum activity or economic efficiency.

Keywords: *Rabbits, broccoli by-products, digestibility coefficient, growth performance, blood biochemical, carcass traits, caecum activity and economic efficiency.*

INTRODUCTION

Nowadays, the income of livestock production enterprises is jeopardized by feed scarcity and increased prices as a result of the negative impact of global climate change on agricultural production,

Several endeavors have been devoted to using the green natural materials and / or medicinal plants as feed additives to improve the efficiency of feed utilization and productive performance as well as to environmental health (Bakshi *et al*., 2016; Shurson, 2020; Aboul-Fotouh *et al*., 1999). Earlier, recovery and bioconversion of vegetable residues to high value compounds has been receiving a great attention (Mahro and Timm 2007). Broccoli by-product has been used as non-traditional feed ingredients in the form of dried material (Ahuja *et al*., 2011). According to the Food and Agriculture Organization of the United Nations (FAO, 2020), around (25,984,758 tons) of broccoli were harvested globally in the year (2017). According to Jian *et al.* (2017), up to 20 million tons of broccoli and cauliflower crops are grown worldwide each year, with 15 million tons of by-products disposed of in the field. Campas-Baypoli *et al.* (2009) mentioned that broccoli is a kind of vegetables that belongs to family *Cruciferae* and genus *Brassica*. They cleared that up to 70% of the total weight of the broccoli plant is discarded and generating high quantities of stalks, florets and leaves as crop residues and a small percentage is used without any kind of treatments in animal feed, and reduce human-animal competition, as well as pollution (Schader *et al*., 2015). Broccoli by-products are flavorful and nutritious foods that are high fiber, protein and ash contents as well as fatty acids such as linoleic acid, palmitic acid and linolenic acid, and also contain amino acids such as aspartate, tyrosine, proline, glutamate and valine (Meneses *et al*., 2020). Furthermore, BB contains glucosinolates and polyphenolic components, as well as other bioactive components which have been known for their health-promoting properties such as peroxidases, flavonoids and carotenoids that favorable functional as antiallergic, anti-cancer and anti-obesity (Thomas *et al*., 2018; Pedroza *et al*, 2018). Additionally, BB are considering as a source of calcium, sodium, thiamin, niacin, pantothenic acid, iron, and selenium and good source of riboflavin, vitamin A, Vitamin C, vitamin B6, mangnese, folate, potassium, phosphorus and magnesium (USDA 2008 and 2011). However, little information has been published about the use of broccoli crop in the food industry field. Nutritionally, Ibrahim *et al*. (2011) recorded that rabbits fed diets contained 3% broccoli by-product in replacing to alfalfa hay in their diet led to significant (P<0.05) increased the final body weight and daily gain compared to those of control diet. On broiler chicken study, Mustafa and Baurhoo (2018) showed that digestibilities of (DM, OM and CP) were decreased (linear effect, P<0.05) with increasing the level of dried broccoli floret in the diets. Therefore, the nutrient and bioactive compound profiles of BB have been deserve more investigation, particularly as a feed additive in animal feeds. The present study was designed to estimate the effect of BB as a nontraditional feed additive on digestibility and feeding value of diet, some physiological properties of blood, growth performance, carcass traits, and biochemical traits of cecal activity in rabbits.

MATERIALS AND METHODS

The current work was carried out at Sakha Animal Production Research Station, that belonging to Animal production Research Institute (APRI), Agriculture Research Center (ARC), Giza, Egypt. Laboratory works were carried out at (APRI), Dokki, Giza, Egypt.

Experimental diets:

A suitable quantity of broccoli by-products (BB) (leaves, and false stems) were collected immediately after harvest (moisture content, about 90%), then chopped into 2-3 cm pieces and sun-dried for 2 weeks, powdered, and stored until added into the ingredients of the experimental dietary treatments. The Association of Official Analytical Chemists technique (AOAC, 2007) was used to determine the proximate composition of BB and the experimental diets for crude protein (CP), ether extract (EE), crude fiber (CF) and ash.

Feed ingredients of the experimental diets as well as their chemical composition are shown in the Table (1). Iso-caloric (2500 kcal DE/kg diet) and iso-nitrogenous (~17 percent CP) diets were used in the feeding experiment. Diets were prepared in pellet form that included adequate levels of nutrients to fulfill the necessary requirements for growing rabbits according to the Agriculture Ministry Decree (1996).

Animal housing, experimental design, and management:

Forty eight weaned New Zealand White rabbits (747.92 g body weight, 6 weeks old) were placed individually in galvanized wire batteries and assigned randomly to one of three dietary treatment groups (16 rabbits /each). Three experimental dietary treatments were designed by using the basal ration with the addition broccoli by-product at 0.0, 1.0 and 3.0 % levels of CFM for control (G1) and the two tested rations (G2) and (G3), respectively for 8 weeks as an experimental periods **(Table 1)**. Experimental rabbits were fed *ad libitum* and had unlimited access to fresh water through automatic drinkers equipped with nipples for each battery. Rabbits were monitored on a daily basis and kept in the same habitat and hygienic circumstances, as well as receiving the necessary vaccines. Every morning, when urine and feces were dumped on the ground from the cages, all cleaning and distinction practices were done properly. All rabbits were individually weighed at the start of the experiment, and subsequently weekly period until the 14 weeks of age (the end of the experiment), before being fed a meal in the morning. Throughout the feeding phase of the experiment, the feed intake was recorded weekly. Also, live body weight, body weight gain, feed consumption, feed conversion and performance index% (PI) were estimated and recorded at the end of the feeding trial.

PI = final live body weight kg/feed conversion × 100 as measured by North (1981).

Table (1): Ingredients and calculated chemical composition of the experimental diets (as fed).

Item	Experimental diet
Ingredient (%):	
Clover hay (12%CP)	30.00
Barley	17.00
Yellow corn	10.00
Soybean meal (44%CP)	17.00
Wheat bran	20.00
Molasses	3.50
DL-Methionine	0.10
Vitamins & minerals mixture[1]	0.50
Salt	0.50
Limestone	1.05
Di-Calcium phosphate	0.35
Total	100
Calculated chemical analysis[2]:	
Dry matter (DM), %	87.10
Crude protein (CP), %	17.08
Ether extract (EE), %	2.41
Nitrogen free extract (NFE), %	48.27
Ash, %	5.82
Digestible energy (DE) [3], kcal/kg	2513
Crude fiber (CF), %	13.52
NDF,%	37.81
ADF,%	21.76
Calcium, %	1. 01
Total phosphorus, %	0.52
Methionine, %	0.36
Lysine, %	0.82
DE:CP	147.11

1- Supplied per Kg. of diet: 12000 IU Vit. A; 2200 IU D3; 10mg Vit.E; 2.0 mg Vit.K3; 1.0 mg Vit.B1; 4.0 mg Vit.B2; 1.5 mg Vit.B6; 0.0010mg Vit.B12; 6.7 mg Vit. Pantothenic acid;6.67 mg Vit. B5; 1.07mg Biotin; 1.67 mg Folic acid; 400 mg Choline chloride; 22.3 mg Zn;10 mg Mn; 25 mg Fe; 1.67 mg Cu; 0.25mg I; 0.033 mg Se and 133.4 mg Mg.l.

2- According to MOA (2001).

3- Calculated according to Cheeke (1987): DE (Kcal/g) = 4.36 – 0.0491 (%NDF). %NDF = 28.924 + 0.657 (%CF). %ADF = 9.432 + 0.912 (%CF).

Digestibility trials:

Three rabbits from each treatment group were selected randomly and individually placed in metabolic cages throughout the last week of the experimental period (8 weeks) and received the same feeding regime and dietary treatments of the feeding trial. The individual feed intake was recorded and the daily total amount of feces for each rabbit was weighed every morning for the 7-days collection period. The faeces were sprayed with 2% boric acid as a trap to prevent ammonia-nitrogen from releasing then frozen at -20 ^{o}C until the collecting phase was completed and then composite samples for each animal were prepared for analysis. Each rabbit's feces were carefully mixed and dried at 60 degrees Celsius for 72 hours before representative samples were made and maintained until analysis. The sample of diets, BB and feces were grounded to pass through (1mm screen) and its chemical composition was determined according to AOAC (2007). Digestion coefficients of nutrients and feeding values were calculated according to Abou-Raya (1967).

Blood parameters:

Blood samples were extracted from three rabbits in heparinized sterile tubes for each animal immediately after slaughtering, and plasma was prepared by centrifugation at 3000 rpm for 20 minutes and stored at -20

0c until analysis. The total protein was determined using the Biuret method according to Henry *et al.* (1974), and total albumin was determined using the Doumas *et al.* (1971) method. The globulin concentration was estimated as the difference between the total protein and albumin. Creatinine was measured using the method suggested by Henry *et al*. (1974), while plasma glucose was measured using the method of Coles (1986). The activities of plasma aspartate aminotransferase (AST) and alanine aminotransferase (ALT) were measured using Reitman and Frankel (1957). Total cholesterol was measured using the Allian *et al.* (1974) using bio Merieux test kits. Uric acid was quantified according to Tietz (1986). All biochemical blood constituents were determined using a spectrophotometer (Spectronic 21 DUSA) and commercial diagnostic kits (Combination, Pasteur Lap.).

Carcass traits:

On the last day of the experimental feeding phase, three rabbits from each treatment group were randomly chosen and starved for 12 hours before slaughtering. Rabbits were slaughtered after their weights were recorded prior to slaughter. The empty carcass, (together with the head), heart, kidney, and liver, were weighed after complete skinning and bleeding to ascertain the carcass features. The empty carcass, giblets, dressings (total edible parts), and weights of the non-edible sections were conducted according to Cheeke (1987).

Cecum activity:

Cecal contents were sampled individually from three animals from each group at the end of the experimental period after fasting for 12 hours. Samples of cecum fluid were obtained after slaughtering rabbits and then filtered through four fold gauze and divided into three subsamples. The first part was immediately used for the determination of pH using a Bechman pH meter and the second part was used to estimate the concentration of ammonia nitrogen by applying the micro-diffusion method according to Conway (1958), while the third one was maintained by the addition of 1 ml N/10 HCL and 2 ml of phosphoric acid per 2 ml of juice of cecal contents to determine the total concentration of volatile fatty acids according to, Eadie *et al*. (1967).

Economic efficiency:

Economical efficiencies were calculated as: the ratio between incomes price of the weight gain and the cost of feed intake over 6-14 weeks of age.

Statistical analysis:

The obtained data were statistically analyzed using one-way analysis of variance procedure (SAS, 2000) computer program using the following fixed model:

$$Yi = \mu + Ti + ei$$

Where Yi = The individual observation; μ = Overall mean; Ti = Effect of treatments. (i = 1, 2 and 3); ie = Random error component assumed to be normally distributed. Significant differences between treatment means were determined at $P<0.05$ by Duncan's multiple-range test (Duncan 1955).

RESULTS AND DISSCUSSION

***Chemical composition of the experimental diets*:**

Chemical analysis of broccoli by-products is presented in Table (2). Result showed that dried broccoli by-products have acceptable values of CP, CF, EE, NFE and ash, therefore it can be potentially added value to the rabbit diets when supplemented into it. Data showed that BB had high contents of CP 24.86% and ash 16.23% on dry matter (DM) basis. Also findings here are similar to those obtained by Alpuche-Solis and Paredes-Lo´pez (1992) who found a relatively high crude protein content in floret flours (36.6 g /100 g dry weight) and also stalk flours contained (18.6 g /100 g dry weight). Additionally, they also reported that the crude protein level measured in the floue of whole plant was ranged from 23.2 to 32.0 g / 100 g dry weight for four cultivars of broccoli. Moreover, results obtained by Ibrahim *et al*. (2011) revealed that the chemical composition of BB for CP, CF, EE, NFE and ash, being 14.26, 23.87, 2.35, 45.96 and 13.56%, respectively, being fairly similar in respect of EE and NFE with those recorded in the present work. In other study, Hu *et al*. (2012) reported higher CP content (27.13%) and lower CF content (8.85%), than those obtained in the present study (Table 2) for broccoli by-product meal on DM basis. They also confirmed that BB had significant concentrations of Vit. E and C, Ca and P minerals, as well as most valuable amino acids like Methionin, Lysine, Cystine, Threonine, Leucine, Isoleucine, Arginine, Phenylalanine, Valine, Tryptophan and Tyrosine. Likewise, Gerendas *et al*. (2008) pointed that glucosinolates represent bioactive compounds of *Brassica* vegetables whose having health promoting effects.

Table (2): Proximate chemical analysis of broccoli by-product used in the experimental diets (as DM basis, %).

	Component						
Broccoli by-product	DM	OM	CP	CF	EE	NFE	Ash
	92.50	83.77	24.86	12.95	1.16	44.80	16.23

***Digestibility and feeding value*s:**

The effect of broccoli by-product inclusion in the diets of rabbits on digestibility coefficients and feeding values are summarized in Table (3). Data cleared that digestibility of most nutrients and feeding values (TDN and DCP) were significant (P<0.05) higher for tested rations (G2 and G3) than those of the control ration (G1), with no significant difference respecting CF digestibility among the experimental treatments. Also, no significant differences respecting digestion coefficients of CP and EE between tested ration (G2) and those of control (G1). These results are reflected on the feeding values in terms of total digestible nutrient (TDN) and digestible crude protein (DCP) values that behaved similar trend to that of nutrient digestibilities among the dietary treatments of the experiment. The best feeding value of G2 and G3 might be used to the synergistic interaction between the nutrients that released from the two suitable levels of both roughage kinds in this rations. It is also well known nutritionally as a kind of positive associated effect that potentially affect positively on feed utilization and consequently on productive performance of ruminant animals (Huhtanen, 1991). Furthermore, in many circumstances two feeds may be of similar nutritive value but of differing feeding value, because of their effects on feed intake or their synergistic or antagonistic interaction with other feeds in the ration (Thomas, 1990). Additionally, such additive could be provide a suitable environment for the growth of beneficial microflora in the rumen. Similar results were reported by Mahmoud (2016) who indicated that digestion coefficients of (CP) and (NFE) and subsequently feeding values in terms of (TDN) and (DCP) were significantly (P<0.05) higher for lambs received diets containing different levels of BB in replacing berssem hay in their diets. Also, Ibrahim *et al*. (2011) fed rabbits on diets contained 3% broccoli by-product replacing to alfalfa hay. They found significant (P<0.05) increases in digestion coefficients of DM, CP and CF and feeding values TDN and DCP compared to those of control diet, but, no significant effect on digestibility coefficients of OM, EE and NFE. Additionally, improved digestion coefficients may be due to the large bowel ecosystem in rabbits fed BB and conversely to be protected by fermentable oligosaccharides as recorded by Paturi *et al*. (2010). Also, Yi *et al*. (2008) found that broccoli residues were possibly suitable feedstuffs because of their high protein content. They were found little effect on in vitro gas production and ruminal fermentation in ruminant diets after replacing soybean meal with pelletized BPP.

Table (3): Digestion coefficients of nutrients and feeding values as affected by broccoli by-products in the experimental diets for growing NEW rabbits.

Item	G1(control)	G2	G3	±SE
Digestibility (%)				
DM	66.05 [b]	69.36 [a]	71.08 [a]	± 0.809
OM	66.32 [b]	69.82 [a]	71.21 [a]	± 0.841
CP	63.37 [b]	66.43 [ab]	67.77 [a]	± 0.720
CF	37.88	39.93	43.17	± 1.14
EE	74.49 [b]	77.07 [ab]	78.54 [a]	± 0.686
NFE	74.07 [c]	78.28 [b]	80.15 [a]	± 0.926
Feeding values, on DM,%				
TDN	64.52 [b]	67.85 [a]	80.15 [a]	± 0.800
DCP	12.06 [c]	12.77 [b]	13.10 [a]	± 0.176

Means bearing different letter superscripts (a, b and c) within the same row are significantly (P ≤ 0.05).
G1 = fed the basal diet (control), G2= fed the basal diet with (10 g BB) and G3 = fed the basal diet with (30 g BB).

Blood biochemical Parameters:

Result of blood plasma biochemical parameters of rabbits are presented in Table (4). Total protein (TP), albumin (AL) and globulin (G) concentrations were significantly higher (P<0.05) for rabbits received both levels of BB than those of control one, being the highest value was occurred with (G3) ration, and the differences between the two groups were significant. Inversely, plasma glucose, total cholesterol (TC), uric acid and creatinine (Cr) concentrations were significantly (P<0.05) lower with both tested rations than those of control one, being the lowest value was associated with (G3), and the mostly the differences between the G2 and G3 treatments did not significant respecting these items. Increased crude protein digestibility (Table 3), could explain the rise in blood plasma total protein and its fraction (Kassab, 2007). Generally, Onifade and Abu (1998) have been revealed that the levels of protein and albumin in blood plasma are directly related to the intake and quality of protein in the diet. Similar results were reported by Mahmoud, (2016) who showed that lambs received forage supplemented with BB instead of berssem hay gave the highest concentrations (P < 0.05) of (TP), (AL) and triglyceride (TG), but the same author added that the values of (G), (Cr) and (TC) were increased (P < 0.05) with decreasing broccoli supplementation. On a favorable response, Kummer *et al*. (1981) showed that blood plasma TP and its fractions can be used as indicator to estimate the ruminant nutritional and physiological cases. So, an increasing in globulin level by the liver

Table (4): Blood parameters as affected by broccoli by-products in the experimental diets for growing NZW rabbits.

Item	G1 (control)	G2	G3	±SE
Total protein (g/dl)	6.00 ^{c}	6.53 ^{b}	6.79 ^{a}	±0.116
Albumin (g/dl)	3.64 ^{c}	3.71 ^{b}	3.81 ^{a}	±0.027
Globulin (g/dl)	2.36 ^{c}	2.81 ^{b}	2.97 ^{a}	±0.092
Glucose (mg/dl)	100.00 ^{a}	95.32 ^{b}	94.43 ^{b}	±1.05
Total cholesterol (mg/dl)	115.60 ^{a}	101.10 ^{b}	95.0 ^{b}	±3.27
Uric acid (mg/ dl)	9.82 ^{a}	7.16 ^{b}	6.34 ^{c}	±0.527
Creatinine (mg/dl)	2.06 ^{a}	1.93 ^{ab}	1.89 ^{b}	±0.033
AST (U/ l)	38.67 ^{c}	45.32 ^{a}	49.41 ^{a}	±1.58
ALT (U/ l)	30.64 ^{c}	34.21^{b}	37.37 ^{a}	±0.998

Means bearing different letter superscripts (a, b and c) within the same row are significantly (P ≤ 0.05) different.
G1 = fed the basal diet (control), G2= fed the basal diet with (10 g BB) and G3 = fed the basal diet with (30 g BB).

could be reflect a good hepatic functions and correlated very well with high immunity of these animals (Griminger, 1986). In relation to these results, Craig (1999) mentioned that albumin as one of the important proteins fractions could be keeping the osmotic pressure stable in the blood. Both (AL) and (G) status could be reflecting the ability of animals to store reserve proteins even after their bodies have reached maximum capacity of depositing tissues (Stroev, 1989). The present results are in harmony with those reported by Cox-Ganser *et al*. (1994) who recorded that transfer of sheep from grazing grass to *Brassica* forage result in a reduction in plasma cholesterol. Finally, results of (Table 4) showed that BB supplement was significantly increased Aspartate AST and Alanine ALT aminotransferase enzyme. Hu *et al*. (2011) mentioned that hepatic hydroxymethylglutaryl-coenzyme A (HMG-CoA) reeducates activity was decreased (P<0.05) linearly and quadratically with increasing dried broccoli leaves and stems meal supplementation in the diet of laying hens. Similar results were observed by Suido *et al.* (2002) who found that daily consumption of broccoli may be useful in lowering the low density lipoprotein cholesterol levels in hypercholesterolemic status.

In general, the present blood plasma constituents indicate that all rabbit groups were under normal physiological and healthy status.

Growth performance:

Results of growing NZW rabbits fed diets supplemented with different levels of broccoli by-product (BB) are presented in Table (5). Initial live body weight (LBW) was nearly similar over all experimental dietary treatment groups, and ranged between 729.17 g and 760.00 g. In perspective, the addition of BB into ration (G3) that received 3.0 % (BB) gave significantly (P<0.05) the highest values of live body weight (LBW), total weight gain (WG) and feed intake (FI) for different age intervals of the feeding experiment, followed by those in G2 that received 1.0 % (BB) versus the lowest values that was associated with (G1) control diet. The differences between G2 and G3 respecting LBW and total (WG) were not significant, but difference between them respecting (FI) was significant. Additionally, such additive could be provide a suitable environment for the growth of beneficial microflora in the rumen and thus have a positive effect on growth performance and production. On earlier study with rabbits, Ibrahim *et al*. (2011) found that rabbits fed diets contained 3% broccoli by-product replacing to alfalfa hay in their diet led to significant (P<0.05) improvement in the final body weight and daily gain compared to those of control diet that free from broccoli residues, however, such treatment had no significant effect on (FI) of (DM, CP, DCP, TDN and DE). Also, they found that replacement 3% level of lucerne hay with BB in rabbit diet insignificantly increased the ADG by 3.50% and these results may be due to its higher contents in vitamin C, phenolic substances and other many favorable factors which promote the productive performance (Vallejo *et al*., 2004). These findings are in agreement with those reported by Mahmoud (2016) who pointed that LBW and daily gain were significantly (P<0.05) higher for lambs received diets containing different levels of BB in replacing berssem hay in their diets. Regarding the feed conversion (FC) and performance index (PI), results showed non-significant effect due to the addition of both levels of BB into the diet of rabbits. It is worthy to note that the addition of BB into the diets caused a slightly improvement in FC and PI especially with 3.0 % BB-diet. While, Mueller *et al*. (2012) demonstrated that growing piglets that received broccoli extract additives had influenced positively on (WG) and (FC) in the 1st week of the beginning of the experiment. While, over the whole trial period no significant differences in piglet's productive performance were existed between the tested groups and control. In contrary Mahmoud (2016) concluded that the best (P<0.05) (FC) was found with diets that included BB in replacing berssem hay for lambs, while the poorest one was associated with the control one. Thus, the growth-promoting effect of BB might be due to their good nutrients profile and their high content of bioactive compounds that promote productive performance (Gerendas *et al*. 2008; Hu *et al*. 2012; Vallejo *et al*. 2004). Beneficially, Madhu and Kochhar (2014) revealed that broccoli leaves are available at no cost and are rich in most micronutrients and macronutrients for the biological processes in animal metabolic functions that reflected on maximizing productive performance and economic profitability too.

Finally, with the increment pressure of feed-food resources, the utilization of vegetable residue is a sustainable move in animal production that decreases a negative environmental impact.

Table (5): Growth performance as affected by broccoli by-products in the experimental diets for growing NZW rabbits at different ages.

Item	G1 (control)	G2	G3	±SE
Live body weight (g):				
Initial wt. (6 weeks)	729.17	760.00	754.58	±7.18
10 weeks	1347.50 ^{b}	1385.00 ^{ab}	1410.83 ^{a}	±10.03
14 weeks	1958.75 ^{b}	2024.17 ^{ab}	2097.92 ^{a}	± 17.52
Total weight gain (g):				
6-10 weeks	618.33	626.00	656.25	± 22.17
10-14 weeks	611.25 ^{b}	639.17 ^{ab}	687.09 ^{a}	± 22.25
6-14 weeks	1229.58 ^{b}	1265.17 ^{ab}	1343.34 ^{a}	±27.94
Total feed intake (g):				
6-10 weeks	1965.83 ^{b}	1942.08 ^{c}	1982.50 ^{a}	±6.75
10-14 weeks	3094.58 ^{b}	3237.09 ^{b}	3412.92 ^{a}	±17.17
6-14 weeks	5060.42 ^{c}	5179.17 ^{b}	5395.42 ^{a}	±22.73
Feed conversion ratio (g feed/g gain):				
6-10 weeks	3.18	3.10	3.02	±0.162
10-14 weeks	5.06	5.06	4.97	±0.280
6-14 weeks	4.12	4.09	4.02	±0.110
Performance index %				
6-10 weeks	42.37	44.68	46.72	±2.37
10-14 week	38.71	40.00	42.21	±2.02
6-14 weeks	47.54	49.49	52.18	±1.78

$^{a, b}$ and ^{c} : means in the same row with different superscripts are significantly ($P \leq 0.05$) different.
G1 = fed the basal diet (control), G2= fed the basal diet with (10 g BB) and G3 = fed the basal diet with (30 g BB).

Carcass traits:

Data of carcass traits of slaughtered NZW rabbits are presented in Table (6). Results revealed that insignificant differences were observed for pre-slaughter and non-edible parts weights due to the addition of different levels of (BB) into the diets of rabbits. But the other results indicated that the weights of empty carcass (with head), giblets and dressing (total edible parts) were significantly (P<0.05) higher for both tested rations (G2 and G3) than those of the control one (G1). Similar trend among the dietary treatments was observed with the measurements of head, liver, heart and kidney weights, being the highest values were found with G3-ration and the lowest ones were associated with control ration (G1). Ibrahim *et al*. (2011) revealed that rabbits fed diet contained 3% BB in replacing to lucerne hay in their diet had no significant effects on weights of inedible offal's and carcass, digestive tract and chemical analysis of the 9, 10 and 11th ribs) in comparing to those of control rabbits. This preference may be due to the ability of BB in preventing fats accumulation especially in inedible offal's. Also, they found that BB significantly decreased the dressing percentages that may be attributed to the ability of BB in preventing fat disposition. Physiologically, An *et al*. (2010) showed that *Brassica campestris* spp. Rapa roots prevent a high-fat diet-induced obesity via beta (3)-adrenergic regulation of white adipocyte lipolytic activity of mice.

Table (6): Carcass traits as affected by broccoli by-products in the experimental diets for growing NZW rabbits.

Item	G1 (control)	G2	G3	±SE
Pre-slaughter (Fasted), g	1981.67	2106.67	2133.33	±33.81
Empty carcass wt. (g)	1058.33 ^{b}	1182.33 ^{a}	1256.33 ^{a}	±32.15
(%)	53.40 ^{b}	56.10 ^{ab}	58.97 ^{a}	±0.905
Giblets (g)	96.70 ^{c}	104.40 ^{b}	107.27 ^{a}	± 1.60
(%)	4.88	4.96	5.037	±0.054
Dressing (Total edible parts)	1155.03 ^{b}	1286.73 ^{a}	1363.60 ^{a}	±33.62
(%)	58.28 ^{b}	61.05 ^{ab}	64.00 ^{a}	±0.929
Non edible parts	826.63	819.93	769.73	±17.27
(%)	41.72 ^{a}	38.95 ^{ab}	36.00 ^{b}	±0.929
Head wt. (g)	98.33 ^{b}	116.67 ^{a}	125.00 ^{a}	±4.17
(%)	5.07 ^{b}	5.53 ^{ab}	5.90 ^{a}	±0.146
Liver wt. (g)	75.33 ^{c}	81.27^{b}	83.67 ^{a}	±1.28
(%)	3.80	3.86	3.93	±0.038
Heart wt. (g)	7.20 ^{b}	7.97 ^{ab}	8.27 ^{a}	±0.164
(%)	0.36	0.38	0.39	±0.007
kidneys wt. (g)	14.17 ^{b}	15.17 ^{a}	15.33 ^{a}	±0.200
(%)	0.715	0.721	0.720	±0.011

$^{a, b}$ and ^{c} : means on the same column with different superscripts are significantly (P ≤ 0. 05) different
Total edible parts wt. = Empty carcass wt. (with head) + edible giblets Wt. *Edible giblets Wt. = Liver wt. + Kidneys wt. + Heart wt.*
*Total edible parts % = Total edible parts wt. / Fasted wt. *100*

Cecaum activity:

Results concerning the caecal activities in terms of *pH* value, concentrations of TVFAs and NH_3-N are presented in Table (7). Results revealed non-significant differences among treatments in respect of caecal *pH* value. Regarding the concentration of TVFAs, the ration G3 that have 3.0 % BB had significant higher value than that of control one (T1), while, 1.0 % BB ration (G2) had insignificant higher value than that of control one. Otherwise, concentration of ammonia followed the opposite trend to that of TVFAs among dietary treatments, but no significant differences were observed with those received (G1 and G2) diets and both were significant higher than that of G3-ration. These results may be due to the glucosinolates content that are considering an important class of bio-organic compounds includes nitrogen and sulfur in BB which considering as health-promoting compounds that may be submitted to digestion under in vitro gastrointestinal conditions as *pH*, temperature, chemical compounds and enzymes (Vallejo *et al*. 2004).

Similarly, Mahmoud (2016) recorded that the value of rumen *pH* and TVFAs concentration were increased (P<0.05) and concentration of NH3-N was decreased (P<0.05) with increasing of BB supplementation in the diet of lambs compared with those fed the control one. These results are disagreed with those of Yi *et al*. (2015) who cleared that replacing concentrate mixture with pelletized BBP for lactating dairy cows did not adverse effects on rumen fermentation. Also, Yi *et al*. (2008) found that BPP had been possibly employed as suitable feedstuffs because of their high crude protein content. They found little effect on in vitro gas production and ruminal fermentation in ruminant diets after replacing soybean meal with pelletized BPP. Additionally, BB protected the large bowel ecosystem by fermentable oligosaccharide which may be useful to some microbiota in caecum of rat, altered caecal short-chain fatty acids (FA) and increased the colon crypt depth and the number of goblet cells per crypt as cleared by Paturi *et al.* (2010). Also, they revealed that BB improved the utilization of low crude protein diet by conferred some protection in terms of colon morphology, via its antimicrobial properties against several microorganisms of clinical importance (Brandi *et al*. 2006).

Table (7): Caecum activities as affected by broccoli by-products in the experimental diets for growing NZW rabbits.

Treatment	Caecum activity traits		
	pH	TVFAs (mq/dl)	Ammonia (mq/dl)
G1	7.17	1.10 [b]	23.52 [a]
G2	7.17	1.20 [b]	23.05 [a]
G3	7.18	1.40 [a]	16.80 [b]
±SE	± 0.029	±0.049	±1.105

Means bearing different letter superscripts ([a] and [b]) within the same column are significantly (P ≤ 0.05) different.

G1 = fed the basal diet (control), G2= fed the basal diet with (10 g BB) and G3 = fed the basal diet with (30 g BB).

Economic efficiency:

Data of economical evaluation of using BB, as one of the most important additives source, in rabbit diets are presented in Table (8). Rabbits in tested rations G2 and G3 were found to have a better economic efficiency in comparison with control one (T1), and also the values of G3 were higher than those of G2 respecting these item. Addition of BB in the basal experimental ration at the rates of (1.0 and 3.0 %) could be improved markedly the feed cost/kg gain compared with G1 (control) which affected by the low price of BB. Similar results were obtained in rabbits by, Ibrahim, *et al.* (2011) who recorded that rabbits received 3% BB replacing to lucerne hay in their diet lead to achieving the highest values of net revenue, economical efficiency and relative economic efficiency as well as the lowest value of feed cost/kg LBW, compared to that control ration. Finally, Mutetikka*et al.* (1990) found that the use of untraditional feedstuffs such as the agricultural byproducts in the diets may help in solving the problem of acute feed shortage and decrease the cost of feeding.

Table (8): Economical efficiency as affected by broccoli by-products in the experimental diets for growing NZW rabbits.

Item	Treatment			±SE
	G1	G2	G3	
Price/ kg diet (L.E)	4.37	4.34	4.27	
Total feed intake/ rabbit (g)	5060.42 [c]	5179.17 [b]	5395.42 [a]	±22.73
Total feed cost /rabbit (L.E)	22.13	22.48	23.06	
Total weight gain/ rabbit (g)	1229.58 [b]	1265.17 [ab]	1343.34 [a]	±27.94
Total feed cost / kg gain (L.E)	18.00	17.78	17.17	
Total revenue / rabbit (L.E)	52.87	54.36	57.76	
Net revenue/ rabbit (L.E)	30.74	31.88	34.70	
Economical efficiency (L.E /h/d)	2.39	2.42	2.51	
Relative economical efficiency (L.E /h/d)	100	101.22	104.84	

Based on prices of the Egyptian market during the experimental period (2020).
The price of one ton of clover hay (12% CP), barley grains, yellow corn, soybean meal (44%CP), wheat bran, molasses, methionine, Vitamins & minerals mixture, Salt, limestone and Di-calcium phosphate were 3550, 4300, 3600, 6700, 3350, 2800, 50000, 42000, 1200, 500, 11000 L.E, respectively. Prices of one kg broccoli and body weight on selling were 3 and 43 L.E, respectively.
Net revenue/ rabbit (L.E) = (Total revenue / rabbit (L.E)) - Total feed cost /rabbit (L.E)).
Economical efficiency = Net revenue/ rabbit (L.E)/ Total feed cost /rabbit (L.E).
Total feed cost / kg gain= Total feed cost / rabbit (L.E) × 1000/ Total weight gain/ rabbit (g).

CONCLUSION

Based on the results of using broccoli by-products as an additive in diets of growing rabbits, It could be concluded that 3.0 % BB levels have considerably improved productive performance, nutrient digestibility and carcass traits as well as realized a good liver functions and relative economic efficiency. This implies that 3.0 % BB may be useful as a suitable un-traditional feed additive in feeding growing rabbits.

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التأثير الغذائي لمخلفات البروكلي كإضافات غذائية على أداء الأرانب النيوزيلندى

ياسمين محمود محمد محمود[1] وعبد القادر محمود خليف[2]

[1] معهد بحوث الإنتاج الحيوانى- مركز البحوث الزراعية- وزارة الزراعة- الدقى، جيزة- مصر.

[2] قسم الألبان- المركز القومى للبحوث- دقى- جيزة- مصر.

أجريت هذه الدراسة بمحطة بحوث الإنتاج الحيوانى (بسخا - كفر الشيخ) بهدف دراسة تأثير المنتج الثانوي للبروكلي كأحد المضافات العلفية الواعدة على معاملات الهضم والقيمة الغذائية، وكذلك تأثير ذلك على أداء نمو الأرانب النيوزيلندية البيضاء، بالإضافة إلى خصائص الذبيحة، تم أيضًا دراسة بعض القياسات الفسيولوجية للدم، وكذلك التأثير على النشاط الميكروبى فى أعور الأرانب والكفاءة الاقتصادية.

تم توزيع عدد (48) أرنب نامى نيوزيلندى أبيض فى عمر 6 أسابيع ، بمتوسط وزن 747.92 جم فى التصميم الكامل العشوائية على ثلاثة مجاميع عشوائيا متماثلة بكل منها (16 أرنب / مجموعة). تم تصميم ثلاث مجاميع غذائية تجريبية باستخدام العليقة الأساسية مع إضافة منتج ثانوي من البروكلي بمستويات 0.0 و 1.0٪ و 3.0٪ من (العلف المركز)، المجموعة الأولى "المجموعة الضابطة" (ج1) والمجموعات المختبرتان (ج2) و (ج3) على التوالي. وغذيت المجموعات كلها على عليقة أساسية موحدة تفى بالإحتياجات الغذائية للأرانب وتحتوى على (17%) بروتين واستمرت التجربة لمدة 8 أسابيع. أدت المستويات المختلفة من مخلفات البروكلي فى الغذاء (ج2 وج3) على وجود زيادة معنوية (P<0.05) فى نسب معاملات الهضم وأيضاً فى قيم مجموع المركبات الغذائية المهضومة بالمقارنة مع مجموعة الكنترول. وسجلت النتائج أن المعاملات التجريبية المختبرة عند مستوى 3.0% من مخلفات البروكلي أدت إلى زيادة معنوية (P<0.05) فى أوزان الأرانب وأيضا معدلات الزيادة اليومية وفى كميات المأكول اليومي طول فترة التجربة لمدة 8 أسابيع، تلتها المجموعة التى تغذت على 1.0 % من مخلفات البروكلي بينما كانت أقل القيم مع المجموعة الأولى (الضابطة) خلال فترة التجربة. أظهرت النتائج أن هناك تحسن ملحوظ (P>0.05) ولكن غير معنوي فى معدل الكفاءة التحويلية ودليل النمو بين مجموعات الأرانب التى تغذت على المستويات المختلفة من مخلفات البروكلي ومجموعة الكنترول. فيما يتعلق بخصائص الذبيحة، أظهرت المجموعتان (ج2 وج3) معنوياً (P<0.05) أعلى أوزان للذبيحة الفارغة (مع الرأس) بالإضافة إلى نسبة التصافي مقارنة بالمجموعة الضابطة (ج1). ولوحظ اتجاه مماثل مع قياسات االأجزاء الصالحة للأكل (الكبد والقلب والكلى) بين المعاملات التجريبية. كما تحسنت الكفاءة الاقتصادية بشكل ملحوظ نتيجة إضافة منتجات البروكلي الثانوية كمصدر مضاف خاصة على المستوى الأعلى (3.0%). وأيضاً تم فحص مكونات الدم البيوكيميائية وأنشطة القولون مثل الأس الهيدروجيني، الأحماض الدهنية الكلية الطيارة، والأمونيا - النيتروجين.

يمكن استنتاج أنه يمكن تغذية ما يصل إلى 3.0 % من مخلفات البروكلي للأرانب النامية دون أي تأثير سلبي على معاملات الهضم، أداء الأرانب، خصائص الذبيحة أو الوظائف الفسيولوجية للدم وكذلك التأثير على النشاط الميكروبى فى الأعور أو الكفاءة الاقتصادية.