Response of Growing Rabbits to Diets Containing Different Levels of Protein and Radish (*Raphanus sativus L*) Seeds

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Abstract

This work aimed to study the effect of two different levels of ration protein supplemented with Radish (*Raphanus sativus L*) seeds (RS). Rabbits were classified into four equal groups (G1-G4). The1st and 3rd groups received basal ration with 100 % and 90 % of protein requirement level and served as first and second control respectively. The 2nd and the 4th groups received basal ration with 100 and 90% of protein supplemented with RS at the level 1.5%, respectively.

The 90% of protein level significantly ($P<0.05$) increased the DM, OM, CP, CF and EE digestibility and TDN value as well as significantly ($P<0.05$) decreased the digestible CP in comparison with the100% requirements. The 90% of protein level significantly ($P<0.05$) increased the TDN intake. The 100% of protein level significantly ($P<0.05$) improved the feed conversion (g intake /g gain) of DM, TDN and DE (kcal/h/d). The 90% of protein level insignificantly ($P>0.05$) improved the final weight, total body weight gain, ADG (g), feed intake as DM, DCP, DCP (g/day) and DE (kcal/h/d) and feed conversion (g intake /g gain) of CP in comparison with the 100% of protein requirements.

Radish seeds (RS) at 1.5% level significantly ($P<0.05$) increased all nutrient digestibility coefficients and nutritive values compared to the control diet. There were significant ($P<0.05$) interactions between the protein and RS levels on all nutrient digestibility coefficients (DM, OM, CP, CF, EE and NFE) and nutritive values of TDN and DCP. The 90% of protein level + 1.5 % (RS) showed the best digestion coefficients of DM, OM, CP, CF, EE and NFE and TDN value. The 100% of protein level + 1.5 % Radish seeds (G_2) showed the highest value of DCP. Supplementation Radish seeds at 1.5% level significantly ($P<0.05$) improved feed intake as DCP and TDN (g/day) while, it significantly ($P<0.05$) decreased feed conversion (g intake /g gain) of TDN. Adding Radish seeds at 1.5% level insignificantly ($P>0.05$) increased the final weight, total body weight gain, average daily gain (ADG); feed intake as DM, CP (g/day) and DE (kcal/h/d) and feed conversion (g intake /g gain) of DM, CP and DE (kcal/h/d) compared to the control diet. The 90% of protein requirement with supplementation Radish seeds at 1.5% level recorded the best values of final weight, total body weight gain, average daily gain, feed intake (g/h/day) of DM, DCP, TDN and DE and feed conversion feed conversion of DM, CP and TDN (g intake/ g gain) and DE (Kcal intake /g gain). There were interactions between protein and supplementation levels on DM, DP, TDN and DE intakes and feed conversion (g intake/ g gain) of DM, CP, TDN and DE. There were significant ($P<0.05$) interactions between protein and supplementation levels on carcass characteristics such as digestive tract; edible offal's weight (head and testes, weight and % of SW) and dressing percentages expressed as CW1/ SW and DM of the 9, 10 and 11th ribs. Rabbits fed on diet containing the 90% of protein requirements with 1.5% (RS) showed the highest values of net revenue, economical efficiency and relative economic efficiency, Supplementation of radish seeds in rabbit diets improved all nutrient digestibility, growth performance, dressing percentages and economical efficiency indicating that radish seeds can be used as growth promoter for improving the utilization of low protein in rabbit diets.

Keywords: Radish seeds, Rabbits, Growth performance, Digestibility, Carcass characteristics, Economic evaluation

1. Introduction

Radish (figle) used in this study is the dried seeds of *Raphanus sa*tivus *L* (RS), belonging to the Brassicaceae family. Recently, it has been found that some medicinal plants have growth enhancing properties. Some medicinal plants can be used as natural additives, tonic and restoratives in animal and poultry diets (Boulos, 1983), or to improve growth performance, immunity and viability (El-Hindawy *et al.,* 1996). The found inhibitors with their characteristic profiles in radish be useful in biochemical and pathophysiological on granulocyte proteinases and enzymes of the coagulation and fibrinolytic pathways (Ghayur *et al.,* 2005). *Raphanus sa*tivus *L* has laxative and gastrointestinal and uterine tone modulatory activities (Zhang *et al.,* 2010). *Raphanus sa*tivus *L* may be used for the prevention and treatment of neuro degenerative diseases (Bae *et al.,* 2010). *Raphanus sa*tivus *L* provides protection by strengthening the antioxidants like glutathione and catalase (Chaturvedi, 2008). *Raphanus sa*tivus *L* extracts rich in many antioxidant compounds, were safe and successfully countered oxidative stress and provided protection against the toxicity (Salah-Abbès *et al.,* 2009). The antioxidant properties of *Raphanus sa*tivus *L* via induced bile flow in rats (Barillari *et al.,* 2006). *Raphanus sa*tivus *L* exerts potential chemo preventive efficacy and induces apoptosis in cancer cell lines through modulation of genes involved in apoptotic signaling pathway (Beevi *et al.,* 2010). Radish extract may partially prevent hepatotoxicity, possibly by indirectly acting as an antioxidant by improving the detoxification system (Baek *et al.,* 2008). Radish extract contains several compounds that are able to inhibit mycotoxin toxicity (Ben Salah-Abbès *et al.,* 2008).

Low dietary protein requirements may cause imbalance in the body metabolism and growth performance. The hypothesis that sulfur compounds has ability to repair the tissue defection protein of the cells (Georgievskii *et al.,* 1982). Sulfur is indispensable for synthesis of certain compounds-mainly sulphated mucopolysaccharides in the body (Georgievskii *et al.,* 1982). The requirements of sulfur containing amino acids by monogastric animals is 3-4% of the feed protein, and the requirement for sulfur is 0.6-0.8% of the protein (Georgievskii *et al.,* 1982). There are antifungal proteins, isolated from Radish seed or leaves, which consist of 50 or 51 amino acids and belong to the plant defensin family of proteins (Schaaper *et al.,* 2001). The complete primary structure of Japanese radish component was established by sequencing of the whole protein and of peptides generated by protease digestion (Obata *et al.,* 1995). Sulfur-radish extract may prevent hepatotoxicity, possibly by indirectly acting as an antioxidant by improving the detoxification system (Baek *et al.,* 2008).

This work aimed to evaluate the efficacy of Radish (*Raphanus sa*tivus *L)* seeds as feed additive to improve the utilization of low protein rabbit diet as well as growth performance.

2. Materials and Methods

2.1 Experimental animals and feeds

A total number of 36 male New Zealand White rabbits aged 5 weeks with an average body weight of 745.5 ± 20.62 g, were divided into four equal groups. The basal experimental diet was formulated and pelleted to cover the nutrient requirements of rabbits as a basal diet according to (NRC, 1977) as shown in (Table 1). Radish (*Raphanus sativus L*) seeds were used as feed additive. The feeding period was extended for 56 days, and the experimental groups were classified as follow:

Group 1 basal diet with 100 % protein requirement and served as control (G1),

Group 2 basal diet with 100 % protein requirement + 1.5% radish seeds (G2),

Group 3 basal diet with 90 % protein requirement and served as control (G3) and

Group 4 basal diet with 90 % protein requirement + 1.5 % radish seeds (G4).

Rabbits were individually housed in galvanized wire cages (30 x 35 x 40 cm). Stainless steel nipples for drinking and feeders allowing recording of individual feed intake for each rabbit were supplied for each cage. Feed and water were offered *ad libitum*. Rabbits of all groups were kept under the same managemental conditions and were individually weighed. Feed consumption was individually recorded weekly during the experimental period.

2.2 Digestibility trials

All rabbits were used in digestibility trials over period of 7 days to determine the nutrient digestibility coefficients and nutritive values of the tested diets.. Feed intake of experimental rations and weight of feces were recorded daily. Representative samples of feces was were dried at 60°C for 48 hrs, ground and stored for chemical analysis later.

2.3 Carcass traits

Six representative rabbits from each treatment were randomly chosen and fasted for 12 hours before slaughtering according to Blasco *et al.* (1993) to determine the carcass measurements. Edible offal's included head, liver, heart, testes and kidneys. These were removed and individually weighed. Full and empty weights of digestive tract were recorded and digestive tract contents were calculated by differences between full and empty digestive tract. Weights of edible and external offal's were calculated as percentages of slaughter weight (SW). Hot carcass was weighed and divided into fore, middle and hind parts. The 9, 10 and 11th ribs were frozen in polyethylene bags for chemical analysis later. The best ribs of samples were dried at 60 C° for 24 hrs. The air-dried samples were analyzed for DM, EE and ash according to the A.O.A.C. (2000) methods, while CP percentage was determined by difference as recommended by O'Mara *et al.* (1979).

2.4 Analysis procedures

Chemical analysis of experimental rations and feces were analyzed according to A.O.A.C (2000) methods. Neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid detergent lignin (ADL)} were also determined in the experimental rations according to Goering and Van Soest (1970). Hemicellulose was calculated as the difference between NDF and ADF, while cellulose was calculated as the difference between ADF and ADL.

Gross energy (mega calories per kilogram DM) was calculated according to Blaxter (1968), where, each g of crude protein (CP) = 5.65 kcal, each g of ether extract (EE) = 9.40 kcal, and each g crude fiber (CF) and nitrogen-free extract (NFE) = 4.15 kcal.

Digestible energy (DE) was calculated according to Fekete and Gippert (1986) using the following equation: DE (kcal/ kg DM) = 4253 – 32.6(CF %) – 144.4 (total ash).

Non fibrous carbohydrates (NFC) was calculated according to Calsamiglia *et al.* (1995) using the following equation: NFC = 100 – {CP + EE + Ash + NDF}.

Diets were offered pelleted and the diameter of the pellets was 4 mm.

2.5 Economical evaluation

Economical efficiency of experimental diets was calculated according to the local market price of ingredients and rabbit live body weight as following:

Net revenue = total revenue – total feed cost.

Economical efficiency (%) = (net revenue/ total feed cost) – x 100

2.6 Statistical analysis

Collected data were subjected to statistical analysis as two factors-factorial analysis of variance using the general linear model procedure of SPSS (1998). Duncan's Multiple Range Test (1955) was used to separate means when the dietary treatment effect was significant.

3. Results and discussion

3.1 Chemical analysis and cell wall constituents of the experimental diets

Data of Table (2) showed that dietary treatment was isocaloric but differed in protein contents. Protein contents for the tested rations (G_1-G_4) was 16.10, 16.05, 14.52 and 14.49 %, respectively. The 90% of protein containing diet showed slight decrease in cell wall constituents (NDF, ADF, ADL and hemicellulose contents). On the other hand cellulose content of the experimental rations showed approximately the same trend (Table 2). These variations were related to differ in ingredients that used in ration formulations, also to study the effect of decreasing protein level on rabbit performance. These data may suggest that alterations in metabolism involved in adaptation to a diet high in hemicellulose and pectin content of radish indicating an increased propensity for oxidative metabolism occurred in the intestine, similar result observed by Nishimura *et al.* (2000).

3.2 Nutrient digestibility and nutritive values of the experimental diets

Rabbits fed on diets containing 90% protein level showed significant improvement in nutrient digestibilities ($P<0.05$) DM, OM, CP, CF and EE digestibility and TDN value (Table 3). Increase in NFE digestibility was insignificant ($P>0.05$), however, digestible crude protein was significantly decreased ($P<0.05$) in comparison with 100% energy requirements. When CP content is low the CF should be high and therefore the digestive efficiency in the small intestine appeared higher and must lead to improve the properties of digestion (Milis and Liamadis, 2008).

Inclusion of Radish seeds at 1.5% in rabbit diets significantly (P<0.05) increased all nutrient digestibility coefficients and nutritive values compared to the control diets (Table 3).

There were significant (P<0.05) interactions between the protein and RS levels on all nutrient digestibility coefficients (DM, OM, CP, CF, EE and NFE) and nutritive values of TDN and DCP (Table 4).

Rabbits which received 90% of protein requirement + 1.5 % Radish seeds (G_4) showed the best digestion coefficients of DM, OM, CP, CF, EE and NFE and TDN value (Table 4). On the other hand rabbits that received 100% of protein requirement + 1.5 % Radish seeds (G_2) showed the highest value of DCP. These results may be due to the improvement in the epithelial lining, the number of enterocytes as well as increased the numbers of goblet cells that secrete mucin in gut in responses to Radish seeds, as has been observed previously by Sipos *et al.* (2002).

3.3 Growth performance of the experimental groups

Data of Table (5) indicate that feeding rabbits on 90% of protein requirements did not have any significant effect on improvement of the final weight, total body weight gain, ADG (g); feed intake as DM, DCP, DCP (g/day) and DE (kcal/head/day) and feed conversion (g intake/ g gain) of CP in comparison with 100% of protein requirements. However, 90% of protein requirements significantly (P<0.05) increased TDN intake. On the other hand, rabbits which received 100% of protein requirements showed significantly (P<0.05) improved feed conversion (g intake/ g gain) of DM, TDN and DE (kcal/head/day). The insignificant improved at the lesser protein level indicated that decreasing the dietary protein level be against the level of fiber which leads to improve the properties of digestion of rabbits, similar results obtained in rabbit by Gidenne (1992) who reported that adaptation to a high-fiber diet resulted in a higher digestive volume for colon and caecum, related to an improved degradation of cell wall. Furthermore, digestive efficiency in the small intestine appeared higher for rabbits adapted to a high-fibre diet than that for rabbits initially fed on a low-fibre diet, similar results noticed by Rigó (1982).

Though the inclusion of RS at 1.5% in rabbit diet increased the marketing weight, total body weight gain and average daily gain by 5.55% 7.81% and 7.80%, respectively compared to the control group, the increase was not significant(P>0.05). However, the inclusion 1.5% Radish seeds significantly improved (P<0.05) feed intake as DCP and TDN (g/day) while it significantly (P<0.05) decreased feed conversion (g intake /g gain) of TDN. These results may be due to the lactic acid bacterial strain, which is derived from *Raphanus sativus L.* fermentation, holds great promise for use in probiotics and as a food additive since it can reduce the number of some pathogenic bacteria through production of lactic acids, similar results obtained by Chon and Choi (2010).

Data of Table (6) revealed that there were no interactions between protein and supplementation levels (PxS) on final weight, total body weight gain, average daily gain (ADG) and CP intake (g/head/day) and feed conversion (g intake/ g gain) of DCP. While, there were interactions between protein and supplementation levels (PxS) on DM, DP, TDN and DE intakes and feed conversion (g intake /g gain) of DM, CP, TDN and DE. These interactions results may be due to that *Raphanus sativus L* has mediated partially gastrointestinal effects partially through cholinergic receptors in rabbit tissues and providing a scientific basis for its use in gut, as noticed by Ghayur and Gilani (2005).

Rabbits received 90% of protein requirement and 1.5% supplementation of Radish seeds (G_4) recorded the best values of final weight, total body weight gain, average daily gain, feed intake (g/h/day) of DM, DCP, TDN and DE and feed conversion feed conversion of DM, CP and TDN (g intake /g gain) and DE (Kcal intake /g gain). These results in agreement with those found by Jung *et al.* (2000). Who recorded that RS stimulates gastrointestinal motility through activation of muscarinic pathways via induced ileal contraction It may be due to the antibacterial activity of Radish against food borne and resistant pathogens, such as Bacillus subtilis, Staphylococcus aureus, Staphylococcus epidermidis, Enterococcus faecalis, Salmonella typhimurium, Enterobacter aerogenes, Enterobacter cloacae, and Escherichia coli, as reported by Beevi *et al.* (2009).

3.4 Carcass characteristics of the experimental groups

Main effects of protein and supplementation levels on dressing percentages, carcass cuts and chemical analysis of the 9,10 an 11^{th} ribs of the experimental groups are presented in Table (7). The results indicate that that protein or supplementation levels of Radish seeds had no significant effect (P>0.05) on inedible offal's (weight and % of SW); digestive tract empty body weight (EBW); edible offal's (head, liver, heart, kidneys and testes (weight and % of SW); carcass weight; dressing percentages; carcass cuts and chemical analysis of the 9,10 and 11^{th} ribs although protein level or Radish seeds in rabbit diets slightly decreased dressing percentages. These results in agreement with those obtained by Satoh *et al* (1993) who noted that the hypocholesterolemic action of radish may have been due to the inhibition of intestinal absorption of both cholesterol and bile acids.

There were significant ($P<0.05$) interactions between protein and supplementation levels (PxS) on digestive tract; edible offal's (head and testes, weight and % of SW); dressing percentages expressed as CW_1/ SW and DM of the 9,10 and 11^{th} ribs (Table 8),while there were no interaction between protein and supplementation levels (PxS) on the other carcass parameters. Rabbits which received 90% protein and 1.5% supplementation of radish seeds (G_4) recorded the best value of carcass weight. These results in agreement with those noticed by Kwon *et al.* (2009) who indicated that the methylisogermabullone purified from radish differently regulates the spontaneous contractility (tone and/or amplitude) of gastrointestinal segments according to the region of gut and orientation of smooth muscles, and these contractile responses of gastrointestinal tracts by activation of acetylcholinergic receptors.

3.5 Economical evaluation

The economical efficiency of dietary treatments is presented in Table (9). The profitability of using Radish seeds as supplementation depends on upon the price of tested diets and the growth performance of rabbits fed these diets. Costing of one kg feed, (LE) decreased by 9.10% (G_3) and 6.49% (G_4) compared to control diet (G_1). Rabbits fed diet containing 90% protein requirements with 1.5% Radish seeds (G_4) showed the highest values of net revenue (26.64 LE), economical efficiency (0.9064) and relative economic efficiency (111.6%), with the lowest value of feed cost/ kg live body weight (4.08 LE). These results are due to the high weight of carcass and growth performance values that reflect the high nutritional value of radish seeds. Similar results in using golden mustard seeds were reported by (Chow *et al.,* 2010). These results are in agreement with those obtained by Ibrahim *et al.* (2009) when rabbits were fed on two different levels of energy supplemented with *Artemisia herba-alba, Matricaria recutita L. and Chrysanthemum coronarium* as herbs mixture.

4. Conclusion

Dietary 90% of protein requirements with 1.5% radish seeds showed the highest value of net revenue, economical efficiency and relative economic efficiency, the lower value of feed cost/ kg live body weight (LE) as well as the best parameters of growth performance and digestibility coefficients. Our data suggest that radish seeds can be considered as an effective growth promoter for improving the utilization of low protein diet.

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Table 1. Composition of the experimental diets (kg/ton)

Item	100% protein requirements		90% protein requirements	
	G_1	G_2	G_3	G_4
Yellow corn	250	250	280	280
Barley grain	70	70	80	80
Wheat bran	250	225	240	225
Soybean meal 44% CP	140	150	100	100
Alfalfa hay	260	260	180	180
Clover straw	----	----	90	90
Di-Ca-Phosphate	10	10	10	10
Lime stone	10	10	10	10
Sodium chloride	5	5	5	5
Vit. & Min. mixture*	3	3	3	3
Anti fungal agent	1	1	1	1
DL-Methionine	1	1	1	1
Supplementations	---	15	----	15
Price, L.E/Ton	2110	2219	1918	1973

** Vit. & Min. mixture: Each kilogram of Vit. & Min. mixture contains: 2000.000 IU Vit. A, 150.000 IU Vita. D, 8.33 g Vit. E, 0.33 g Vit. K, 0.33 g Vit. B_1, 1.0 g Vit. B_2, 0.33g Vit. B_6, 8.33 g Vit.B_5, 1.7 mg Vit. B_{12}, 3.33 g Pantothenic acid, 33 mg Biotin, 0.83g Folic acid, 200 g Choline chloride, 11.7 g Zn, 12.5 g Fe, 16.6 mg Se, 16.6 mg Co, 66.7 g Mg and 5 g Mn.*

LE: Egyptians pound (local money).

Table 2. Chemical analysis and cell wall constituents of the experimental diets

Item	100% protein requirements		90% protein requirements	
	G_1	G_2	G_3	G_4
Dry matter	91.40	91.71	91.41	91.37
Chemical analysis on dry matter basis				
Organic matter (OM)	90.53	90.46	90.57	90.55
Crude protein (CP)	16.10	16.05	14.52	14.49
Crude fiber (CF)	11.78	11.10	11.46	11.80
Ether extract (EE)	3.46	3.44	3.48	3.56
Nitrogen-free extract (NFE)	59.19	59.87	61.11	60.70
Ash	9.47	9.54	9.43	9.45
Gross energy (Mcal/ kg DM)[1]	4.180	4.176	4.159	4.163
Digestible energy (kcal/kg DM)[2]	2502	2514	2518	2504
Non fibrous carbohydrates (NFC)[3]	31.55	32.23	35.24	35.92
Cell wall constituents				
NDF	39.42	38.74	37.33	36.58
ADF	18.32	18.33	17.92	17.76
ADL	6.22	6.13	5.64	5.54
Hemicellulose	21.10	20.41	19.41	18.82
Cellulose	12.10	12.20	12.28	12.22

*[1]Gross energy (mega calories per kilogram DM) was calculated according to **Blaxter (1968)**, where, each g of crude protein (CP) = 5.65 kcal, each g of ether extract (EE) = 9.40 kcal, and each g crude fiber (CF) and nitrogen-free extract (NFE) = 4.15 kcal.*

*[2]Digestible energy (DE) was calculated according to **Fekete and Gippert (1986)** using the following equation:*

DE (kcal/ kg DM) = 4253 – 32.6 (CF%) – 144.4 (total ash).

*[3] Non fibrous carbohydrates (NFC), calculated according to **Calsamiglia et al. (1995)** using the following equation:*

NFC = 100 – {CP + EE + Ash + NDF}.

NDF: Neutral detergent fiber.

ADF: Acid detergent fiber.

ADL: Acid detergent lignin.

Hemicellulose = NDF – ADF.

Cellulose = ADF – ADL.

Table 3. Main effects of energy and supplementation levels on nutrient digestibility coefficients and nutritive values of the experimental diets

Item	Experimental diets Protein levels 100%	 90%	 SEM	 Supplementation 0%	 1.5%	SEM
Nutrient digestibility coefficients						
Dry matter (DM)	71.76^b	78.54^a	1.82	71.24^b	79.06^a	1.82
Organic matter (OM)	62.75^b	69.90^a	1.81	63.26^b	69.39^a	1.81
Crude protein (CP)	72.16^b	75.32^a	1.22	71.42	76.06	1.22
Crude fiber (CF)	21.21^b	37.39^a	4.83	20.40^b	38.20^a	4.83
Ether extract (EE)	77.92^b	87.33^a	2.17	78.04^b	87.21^a	2.17
Nitrogen-free extract (NFE)	67.29	73.77	1.50	68.59^b	72.46^a	1.50
Nutritive values						
Total digestible nutrient (TDN)%	60.14^b	67.15^a	1.73	60.68^b	66.61^a	1.73
Digestible crude protein (DCP) %	11.60^a	10.92^b	0.20	10.94^b	11.59^a	0.20

a and b: Means in the same row within each treatment having different superscripts differ significantly (P<0.05).
SEM, standard error of the mean.

Table 4. Effect of interactions between energy and supplementation levels on nutrient digestibility coefficients and nutritive values of the experimental diets

Item	Experimental rations 100 % protein requirements G_1	 G_2	 90 % protein requirements G_3	 G_4	SEM
Nutrient digestibility coefficients					
Dry matter (DM)	70.19^b	73.32^b	72.28^b	84.79^a	1.82
Organic matter (OM)	62.23^b	63.27^b	64.30^b	75.50^a	1.81
Crude protein (CP)	71.17^b	73.14^{ab}	71.66^b	78.98^a	1.22
Crude fiber (CF)	22.07^b	20.34^b	18.73^b	56.05^a	4.83
Ether extract (EE)	72.46^c	83.39^b	83.62^b	91.03^a	2.17
Nitrogen-free extract (NFE)	67.19^b	67.38^b	69.99^b	77.54^a	1.50
Nutritive values					
Total digestible nutrient (TDN)%	59.48^b	60.79^b	61.87^b	72.42^a	1.73
Digestible crude protein (DCP) %	11.46^a	11.74^a	10.41^b	11.44^a	0.20

a, b and c: Means in the same row having different superscripts differ significantly (P<0.05).
SEM, standard error of the mean.

Table 5. Main effects of energy and supplementation levels on growth performance of the experimental groups

Item	Experimental diets Protein levels 100%	 90%	 SEM	 Supplementation 0%	 1.5%	SEM
Initial weight, g	745	746	20.62	743	748	20.62
Final weight, g	2386	2432	50.86	2344	2474	50.86
Total body weight gain, g	1641	1686	52.59	1601	1726	52.59
Duration period (days)	56	56	---	56	56	---
Average daily gain (ADG), g	29.30	30.10	0.94	28.59	30.82	0.94
Feed intake as:						
DM, g/head/day	77.37	84.08	1.23	79.07	82.38	1.23
CP, g/head/day	12.44	12.20	0.15	12.08	12.55	0.15
DCP, g/head/day	8.98	9.19	0.15	8.63^b	9.54^a	0.15
TDN, g/head/day	46.54^b	56.55^a	1.59	48.01^b	55.07^a	1.59
DE, Kcal/head/day	194.1	211.2	3.10	198.7	206.6	3.10
Feed conversion (g intake /g gain) of						
DM	2.64^a	2.80^b	0.042	2.77	2.67	0.042
CP	0.42	0.41	0.006	0.42	0.41	0.006
DCP	0.31	0.31	0.003	0.30	0.31	0.003
TDN	1.59^a	1.88^b	0.039	1.68^a	1.78^b	0.039
DE *(Kcal intake /g gain)*	6.61^a	7.03^b	0.107	6.95	6.70	0.107

a and b: Means in the same row within each treatment having different superscripts differ significantly (P<0.05).

SEM, standard error of the mean

Dry matter (DM), Organic matter (OM), Crude protein (CP), Crude fiber (CF), Ether extract (EE), Nitrogen-free extract (NFE). Total digestible nutrient (TDN) and Digestible crude protein (DCP).

Table 6. Effect of interactions between energy and supplementation levels on growth performance of the experimental groups

Item	Experimental rations				
	100 % protein requirements		90 % protein requirements		SEM
	G_1	G_2	G_3	G_4	
Initial weight, g	739	751	748	744	20.62
Final weight, g	2373	2400	2316	2547	50.86
Total body weight gain, g	1634	1649	1568	1803	52.59
Duration period (days)	56	56	56	56	---
Average daily gain (ADG), g	29.20	29.45	28.00	32.20	0.94
Feed intake as:					
DM, g/head/day	75.86^{c}	78.87^{bc}	82.27^{ab}	85.89^{a}	1.23
CP, g/head/day	12.21	12.66	11.95	12.45	0.15
DCP, g/head/day	8.69^{bc}	9.26^{ab}	8.56^{c}	9.83^{a}	0.15
TDN, g/head/day	45.12^{c}	47.95^{bc}	50.90^{b}	62.20^{a}	1.59
DE, Kcal/head/day	190^{c}	198^{bc}	207^{ab}	215^{a}	3.10
Feed conversion (g intake /g gain) of					
DM	2.60^{a}	2.68^{a}	2.94^{b}	2.67^{a}	0.042
CP	0.42^{b}	0.43^{b}	0.43^{b}	0.39^{a}	0.006
DCP	0.30	0.31	0.31	0.31	0.003
TDN	1.55^{a}	1.63^{a}	1.82^{b}	1.93^{b}	0.039
DE *(Kcal intake /g gain)*	6.51^{a}	6.72^{a}	7.39^{b}	6.68^{a}	0.107

a, b and c: Means in the same row having different superscripts differ significantly (P<0.05).

SEM, standard error of the mean.

Dry matter (DM), Organic matter (OM), Crude protein (CP), Crude fiber (CF), Ether extract (EE), Nitrogen-free extract (NFE). Total digestible nutrient (TDN) and Digestible crude protein (DCP).

Table 7. Main effects of energy and supplementation levels on carcass characteristics of the experimental groups

Item	Experimental diets					
	Protein levels			Supplementation		
	100%	90%	SEM	0%	1.5%	SEM
Slaughter weight (SW), g	2405	2385	38.68	2354	2436	38.68
Inedible offal's*						
weight, g	495	478	10.59	471	502	10.59
% of SW	20.58	20.04	0.38	20.01	20.61	0.38
Digestive tract						
Full, g	356	384	12.39	362	379	12.39
Empty, g	167	180	5.81	170	174	5.81
Contents	189	204	6.58	192	201	6.58
Empty body weight, g (EBW)	2216	2181	38.6	2162	2235	38.6
Edible offal's**						
Head weight, g	129.7	137.3	3.86	134.7	132.3	3.86
% of SW	5.41	5.76	0.15	5.74	5.44	0.15
Liver weight, g	76.83	69.17	3.58	69.33	76.67	3.58
% of SW	3.18	2.91	0.11	2.95	3.14	0.11
Heart weight, g	6.00	6.83	0.38	6.33	6.50	0.38
% of SW	0.25	0.29	0.01	0.28	0.27	0.01
Kidneys weight, g	18.83	18.83	0.78	17.33	20.33	0.78
% of SW	0.79	0.80	0.03	0.75	0.84	0.03
Testes weight, g	8.00	9.00	0.54	8.00	9.00	0.54
% of SW	0.34^{b}	0.38^{a}	0.02	0.34	0.37	0.02
Total edible offal's						
weight, g	239.5	242.0	5.90	236.5	245.0	5.90
% of SW	9.97	10.14	0.14	10.05	10.05	0.14
Carcass weight (CW_1), g	1425	1386	33.09	1387	1423	33.09
Carcass weight including edible offal's (CW_2)						
Dressing percentages (DP)%	1664	1626	38.47	16.22	1668	38.47
DP^{1} (CW_1/ SW)						
DP^{2} (CW_1/ EBW)	59.26	58.05	0.65	58.88	58.42	0.65
DP^{3} (CW_2/ EBW)	64.31	63.48	0.54	64.11	63.68	0.54
	75.10	74.52	0.61	75.00	74.62	0.61
Carcass cuts						
Fore part, g	425.0	413.0	9.80	413.3	424.1	9.80
Middle part, g	450.2	438.0	10.42	438.3	450.0	10.42
Hind part, g	550.2	535.0	12.86	535.3	550.0	12.86
Chemical analysis of the 9,10 and 11^{th} ribs						
Dry matter (DM)	34.97	36.58	0.48	35.17	36.37	0.48
Chemical analysis on DM basis						
Crude protein (CP)	53.72	55.77	1.66	54.06	55.43	1.66
Ether extract (EE)	37.63	35.97	1.70	37.55	36.05	1.70
Ash	8.65	8.26	0.15	8.39	8.52	0.15

a and b: Means in the same row within each treatment having different superscripts differ significantly (P<0.05).

SEM, standard error of the mean.

** In edible offal's: included fur, ears, legs and blood.*

***Edible offal's: included head, liver, heart, kidneys and testes.*

Empty body weight (EBW) = slaughter weight – digestive tract contents.

Table 8. Effect of interactions between energy and supplementation levels on carcass characteristics of the experimental groups

Item	Experimental rations				SEM
	100 % protein requirements		90 % protein requirements		
	G_1	G_2	G_3	G_4	
Slaughter weight (SW), g	2400	2410	2308	2463	38.68
Inedible offal's*					
weight, g	479	511	463	493	10.59
% of SW	19.96	21.20	20.06	20.02	0.38
Digestive tract					
Full, g	320^{b}	393^{a}	403^{a}	366^{ab}	12.39
Empty, g	150^{b}	184^{a}	189^{a}	172^{ab}	5.81
Contents	170^{b}	209^{a}	214^{a}	194^{ab}	6.58
Empty body weight, g (EBW)	2230	2201	2094	2269	38.6
Edible offal's**					
Head weight, g	142^{a}	118^{b}	128^{b}	147^{a}	3.86
% of SW	5.92^{a}	4.90^{b}	5.55^{a}	5.97^{a}	0.15
Liver weight, g	73.00	80.00	66.00	73.00	3.58
% of SW	3.04	3.32	2.86	2.96	0.11
Heart weight, g	6.00	6.00	7.00	7.00	0.38
% of SW	0.25	0.25	0.30	0.28	0.01
Kidneys weight, g	17.00	21.00	18.00	20.00	0.78
% of SW	0.71	0.87	0.78	0.81	0.03
Testes weight, g	9.00^{b}	7.00^{c}	7.00^{c}	11.00^{a}	0.54
% of SW	0.38^{b}	0.29^{c}	0.30^{c}	0.45^{a}	0.02
Total edible offal's					
weight, g	247	232	226	258	5.90
% of SW	10.30^{ab}	9.63^{b}	9.79^{ab}	10.47^{a}	0.14
Carcass weight (CW_1), g	1460	1390	1314	1457	33.09
Carcass weight including edible offal's (CW_2)					
Dressing percentages (DP)%	1707	1621	1538	1715	38.47
DP ^{1} (CW_1/ SW)					
DP ^{2} (CW_1/ EBW)	60.83^{a}	57.68^{ab}	56.93^{b}	59.16^{ab}	0.65
DP ^{3} (CW_2/ EBW)	65.47	63.15	62.75	64.21	0.54
	76.55	73.65	73.45	75.58	0.61
Carcass cuts					
Fore part, g	435	414	392	434	9.80
Middle part, g	461	439	415	460	10.42
Hind part, g	564	537	507	563	12.86
Chemical analysis of the 9,10 and 11th ribs					
Dry matter (DM)	34.69^{b}	35.24^{ab}	35.65^{ab}	37.51^{a}	0.48
Chemical analysis on DM basis					
Crude protein (CP)	52.58	54.86	55.54	55.99	1.66
Ether extract (EE)	38.64	36.62	36.46	35.49	1.70
Ash	8.78	8.52	8.00	8.52	0.15

a, b and c: Means in the same row having different superscripts differ significantly ($P<0.05$).

*SEM, standard error of the mean. * In edible offal's: included fur, ears, legs and blood.*

***Edible offal's: included head, liver, heart, kidneys and testes.*

Empty body weight (EBW) = slaughter weight – digestive tract contents.

Table 9. Economical evaluation of the experimental groups

Item	Experimental rations			
	100 % protein requirements		90 % protein requirements	
	G_1	G_2	G_3	G_4
Marketing weight, Kg	2.373	2.400	2.316	2.547
Feed consumed as it is / rabbit, kg	4.648	4.816	5.040	5.264
Costing of one kg feed, (LE)[1]	2.110	2.219	1.918	1.973
Total feed cost, (LE)	9.81	10.69	9.67	10.39
Management/ Rabbit, (LE)[2]	4	4	4	4
Total cost, (LE)[3]	28.81	29.69	28.67	29.39
Total revenue, (LE)[4]	52.21	52.80	50.95	56.03
Net revenue	23.40	23.11	22.28	26.64
Economical efficiency[5]	0.8122	0.7784	0.7771	0.9064
Relative economic efficiency[6]	100	95.80	95.70	111.6
Feed cost / kg LBW (LE)[7]	4.13	4.45	4.10	4.08

[1] Based on prices of year 2011.
[2] Include medication, vaccines, sanitation and workers.
[3] include the feed cost of experimental rabbit which was LE 15/ rabbit + management.
[4] Body weight x price of one kg at selling which was LE 22.
[5] net revenue per unit of total cost.
[6] Assuming that the relative economic efficiency of control diet equal 100.
*[7] Feed cost/kg LBW = feed intake * price of kg / Live weight.*
LE: Egyptians pound (local money).