Response of Growing Rabbits to Diets Containing Different Levels of Protein and Mustard Seeds (*Sinapisalba Linn)*

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Abstract

A total number of 54 male growing New Zealand rabbits were used to study the effect of two different levels of ration protein supplemented with Mustard seeds*(Sinapis alba Linn)*. Rabbits were classified into six equal groups (G_1-G_6). The 1st and 4th groups received basal ration with 100 % and 90 % protein requirement and served as first and second control respectively. The 2nd and the 3rd groups received basal ration with 100 % protein requirement supplemented with*Sinapisalba Linn* at the level of 0.5 and 1.0 %, respectively. The 5th and 6th groups received basal ration with 90 % protein requirement with *Sinapisalba Linn* at the level of 0.5 and 1.0 %, respectively. The low level of protein (90% of protein requirement containing diet) significantly increased (P<0.05) DM, OM, CP, CF and NFE digestibility and TDN value compared to 100% of protein requirement. The high level of supplementation (1% Mustard seeds) significantly (P<0.05) improved all nutrient digestibility coefficients and nutritive values. The 90% protein ration with 1 % mustard seeds (G_6) showed the best digestion coefficients of DM, OM, CP, EE and NFE and TDN value. However, the 100% of protein requirement with 1 % mustard seeds containing diet (G_3) showed the high value of DCP. Inclusion Mustard seeds at 1% in rabbit diets significantly (P<0.05) increased all nutrient digestibility and nutritive values compared to control diet. Inclusion Mustard seeds at 0.5% significantly (P<0.05) increased the DM and EE digestibility and total digestible nutrient compared to control diet. The interaction between the protein and mustard seeds levels significantly (P<0.05) increased the all nutrient digestibility coefficients (DM, OM, CP, CF, EE and NFE) and nutritive values (TDN and DCP). Inclusion Mustard seeds at 0.5% or 1% significantly (P<0.05) improved the final or weight, total body weight gain, average daily gain and feed conversion compared to control diet. On the other hand inclusion of Mustard seeds at 1% significantly (P<0.05) increased the total body weight gain and average daily gain by 24.3% while at 0.5% significantly (P<0.05) increased the total body weight gain and average daily gain by 14.5% compared to the control group. The 90% of protein with 1% mustard seeds recorded the best values of final weight, total body weight gain, average daily gain and feed conversion. The interaction between the protein and mustard seeds levels significantly (P<0.05) increased the final weight, weight gain, average daily gain and feed conversion. Inclusion mustard seeds in rabbit diets clearly decreased the dressing percentages by increasing the level of mustard seeds in rabbit diets. Dietary 90% of protein requirements with 0.5% or 1% mustard seeds showed the higher value ofnet revenue, economical efficiency and relative economic efficiency, as well as the lower value of feed cost/ kg live body weight (LE).

Keywords: Mustard seeds, Rabbits, Growth performance, Digestibility, Carcass characteristics and economic evaluation

1. Introduction

Recently, it has found that some medicinal plants had some properties as growth enhancement. 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 the viability (El-Hindawy*et al.,* 1996). Mustard oil is used as a flavoring in very low quantities (Koppelman*et al.,* 2007). Mustard green/leafy vegetables, when consumed regularly after steam cooking, would lower the risk of cardiovascular disease and cancer, advance nutrition research, and improve public health (Kahlon*et al.,* 2008). Mustard oilhas been successfully applied inprophylactic of hyperacidity, gastric and duodenal ulcer (Gawron*et al.,* 2005). *Sinapisalba Linn* (Commonly called yellow or white mustard) is an entomophilic species included in the Brassicaceae family, and their components have been reported to possess anticancer properties (Eskin*et al.,* 2007). Sinapine is the effective component of *Sinapisalba*that has a great potential in the field of antiageing drugs (Liu *et al.,* 2006) and considered as an important natural antioxidant (Müller *et al.,* 2001). *Sinapisalba* is a good candidate to use for immunotherapy purposes in future (Palomares*et al.,* 2005). Bis-iodo phenol mustard has potential for use in future antibody-directed enzyme pro-drug therapy systems (Francis *et al.,* 2002).

Low dietary protein requirements maycause imbalance in the body metabolism and growth performance. The hypothesis that sulfurcompounds has ability to repair the tissue defection protein of the cells. Sulfur mustard vesicants target thioredoxinreductase and that this may be an important mechanism mediating oxidative stress and tissue injury (Jan *et al.,* 2010 and Gray *et al.,* 2010). Sulfur is indispensable for synthesis of certain compounds-mainly sulphatedmucopolysaccharides in the body (Georgievskii*et al.,* 1982). The requirements of sulfur containing amino acids by monogastric animals is 3-4 percent of the feed protein, and the requirement for sulfur is 0.6-0.8 percent of the protein (Georgievskii*et al.,* 1982). The common albumin isolated from *Sinapis alba* seeds is composed of two disulfide-linked polypeptide chains of 39 and 88 amino acids as well as glutamine-rich large chain, proline-rich zein, a gliadin, and trypsin and alpha-amylase inhibitors isolated from the seeds of several monocotyledons, whose primary structures are reported by Menéndez-Arias *et al.* (1988). Mustard oil glycosides are derived from methionine, phenylalanine and tryptophan (Chavadej*et al.,* 1994).

Tthe main objectives of this study was to evaluate the effect of Mustard seeds*(Sinapisalba Linn)* as feed additives in the diets of growing rabbits on feed utilization, growth performance, carcass characteristics and economic efficiency.

2. Materials and Methods

Fifty four male New Zealand White rabbits aged 5 weeks with an average body weight of 706 ± 4.64g were divided into six 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).The feeding period was extended for 70 days, and the experimental groups were classified as follow:

Group 1 basal diet with 100 % protein requirement and served as control (G_1),

Group 2 basal diet with 100 % protein requirement + 0.50% Mustard seeds (G_2),

Group 3 basal diet with 100 % protein requirement + 1.00% Mustard seeds (G_3),

Group 4 basal diet with 90 % protein requirement and served as control (G_4),

Group 5 basal diet with 90 % protein requirement + 0.50% Mustard seeds (G_5) and

Group 6 basal diet with 90 % protein requirement + 1.00% Mustard seeds (G_6).

Rabbits individually housed in galvanized wire cages (30 x 35 x 40 cm). Stainless steel nipples for drinking and feeders allowing recording 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 managerial conditions and were individually weighed, and feed consumption was individually recorded weekly during the experimental period.

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

At the end of the experimental period, 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 (Giblets) included heart, liver, testes and kidneys were removed and individually weighed. Full and empty weights of digestive tract were recorded. Weights of internal and external offal's were calculated as percentages of slaughter weight (SW). The 9, 10 and 11^{th} ribs were frozen in polyethylene bags for later chemical analysis. The 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'Mary*et al.* (1979). 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).

Non fibrous carbohydrates (NFC), calculated according to Calsamiglia*et al.* (1995) using the following equation: NFC = 100 – {CP + EE + Ash + NDF}. Compositions of the experimental rations have been done according to the NRC (1977) requirements as shown in (Table 1). Diets were offered pelleted at 4 mm diameter.

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 %.

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. Hemicellulose was calculated as the difference between NDF and ADF, while cellulose was calculated as the difference between ADF and ADL.Digestible energy (DE) was calculated according to Cheek (1987) as following:

DE (MJ/ kg DM) = 4.36 – 0.04 x NDF%.

3. Results and discussion

3.1 Chemical analysis and cell wall constituents of the experimental diets

Crude protein contents for the six rations used (G_1-G_6) were 16.04, 16.11, 16.12, 14.48, 14.41 and 14.42 %, respectively (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. The 90% of protein requirement containing diets showed slightly increase in cellulose contents while hemicellulose was slightly decreased. These data may suggest that alterations in metabolism involved in adaptation to a diet high in hemicellulose indicating an increased propensity for oxidative metabolism occurred in the intestine. Similar result was observed by Weber *et al.* (2010). While NDF, ADF and ADL values of the experimental rations showed insignificantly variations (Table 2).

3.2 Nutrient digestibility and nutritive values of the experimental diets

The 90% of protein requirements significantly ($P<0.05$) improved the digestibility coefficient values of DM, OM, CP, CF and NFE digestibility and TDN, while, EE digestibility was in the same trend (Table 3). In contrast, the 100% protein without feed additives (G_1) showed lowest values of DM, OM, CF and NFE digestibility coefficients and nutritive valued (TDN and DCP) (Table 4). Former suggest that 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. Similar results obtained in rabbit by Milis and Liamadis (2008).

Mustard seeds at 1% in rabbit diets significantly ($P<0.05$) increased all nutrient digestibilities and nutritive values compared to control diet (Table 3). Mustard seeds at 0.5% significantly ($P<0.05$) increased the DM and EE digestibilities and total digestible nutrient compared to control diet (Table 3). These data may be due to the ability of *Sinapisalba* on the formation and/or release of antimicrobial substances as reported by Luciano *et al.* (2010). Also, may be due to the mustard oil enhancement of aerobic mesophilic and lactic acid bacteria as noticed by Lemay *et al.* (2002).

The 90% of protein requirement with 1 % mustard seeds (G_6) showed the best digestion coefficients of DM, OM, CP, EE and NFE and TDN value (Table 4). On the other hand 100% protein with 1 % mustard seeds (G_3) showed the best value of DCP. The first result with low dietary protein means that the high dietary fiber promotes the digestion properties. Similar results wasobtained by (Milis and Liamadis 2008). The second result with high dietary protein may be due to the glycosides that are derived from methionine, phenylalanine, or tryptophanin mustard oil (Chavadej*et al.,* 1994). On the other hand these results may be due to the ability of microorganisms to synthesize sulfur-amino acids that has been repeatedly demonstrated by sulfur (Georgievskii*et al.,* 1982). In other words these results in the two cases may be due to the aromatic isothiocyanates isolated from *Sinapisalba* containing phenethyl- benzyl- and benzoyl-groups might be useful in the development of novel preventive and therapeutic agents against diseases caused by harmful intestinal bacteria, as reported by Kim and Lee (2009).

Adding 0.5% or 1% mustard seeds showed insignificant effects on feed intakes of DM, TDN and DCP as well as CP intake (Table 5).This insignificant results may be indicate that mustard seeds is one of some dietary protein, whole grain, and fiber that promote satiety and either reduce energy absorption or stimulate energy expenditure, as explained by Astrup*et al.* (2010).

The interaction between the protein and mustard seeds levels significantly ($P<0.05$) increased the all nutrient digestibility coefficients (DM, OM, CP, CF, EE and NFE) and nutritive values (TDN and DCP) (Table 4). These significant results may be due to the high fiber related with the low protein level used (Milis and Liamadis 2008) as well as the volatile compounds of mustard hydrodistillates exhibited great potential of antibacterial activity as reported by Blazević*et al.* (2010).

3.3 Growth performance of the experimental groups

The experimental diets of protein levels showed insignificant effects on final weight, total body weight gain, average daily gain and feed intake as DM, TDN, CP, DCP as well as feed conversion of DM, TDN, CP and DCP, respectively (Table 5). Inclusion of Mustard seeds in the rabbit diets at 0.5% or 1% significantly ($P<0.05$) improved the final weight, total weight gain, average daily gain and feed conversion compared to control diet (Table 5). These results indicate that mustard seeds may be able to be genetically modified to express high levels of beta-carotene, a precursor to vitamin A as reported by Chow *et al.* (2010).

Supplementation Mustard seeds at 1% level significantly ($P<0.05$) increased the total body weight gain and average daily gain by 24.3% while at 0.5% significantly ($P<0.05$) increased the total body weight gain and average daily gain by 14.5% compared to the control group (Table 6). The interaction between the protein and mustard seeds levels significantly ($P<0.05$) increased the final weight, weight gain, average daily gain and feed conversion (Table 6). These results may be due to the enzymatically synthesized natural antioxidant of mustard that has nutritional properties as cleared by Kanjilal*et al.* (1999). The 90% of protein requirement with 1% mustard seeds (G_6) recorded the best values of final weight, total weight gain, average daily gain and feed conversion (Table 6). In other words this result may due to detailed characterization of single antioxidant components of *Sinapis alba* seeds (i.e., polyphenols, carotenoids, chlorophylls, and ascorbic acid) as noticed by Salvatore *et al.* (2005).

3.4 Carcass characteristics of the experimental groups

The variety of protein or mustard seeds levels showed insignificant ($P>0.05$) effects on digestive tract weight, total inedible offal's weight, carcass weight and chemical analysis of the 9, 10 and 11^{th} ribs (Table 7). Inclusion mustard seeds in rabbit diets clearly decreased the dressing percentages by increasing the level of mustard seeds in rabbit diets. This result may be due to the presence of some fatty acids in mustard oil that are not usually present in edible oils and fats that reduced calorie fats as reported by Kanjilal*et al.* (1999), and by Sengupta and Ghosh (2010) who reported that mustard oil had beneficial effects on energy balance. The protein or mustard seeds supplementation levels showed insignificant effects on digestive tract (% of SW), liver, carcass weight and chemical analysis of the 9,10 and 11^{th} ribs (CP & EE contents), while showed significantly ($P<0.05$) interaction on dressing percentages and chemical analysis of the 9,10 and 11^{th} ribs (DM & ash contents), (Table 8). Rabbits that received 90% protein with 1% mustard seeds (G_6) recorded the best values of carcass weight. This result may be due to the mustard seed content of monounsaturated fatty acids that contribute to decelerating obesity and the metabolic syndrome as reported by Misra*et al.* (2010) and Eskin*et al.* (2007). Or may be due to the high resistance of *Sinapisalba* to trypsin digestion (González De La Peña *et al.,* 1996).

3.5 Economical evaluation

The economical efficiency of dietary treatments is presented in Table (9). The profitability of using mustard seeds depends on upon the price of tested diets and the rabbit's growth performance. Lowering the dietary protein level from 100% to 90% ofrequirements decreased the total cost by 4.63%. Dietary 90% of protein requirements with 0.5% or 1% mustard seeds showed the higher value ofnet revenue, economical efficiency and relative economic efficiency, as well as the lower value of feed cost/ kg live body weight (LE). These results was due to the high weight of carcass and growth performance values that deflexed the high nutritional value of mustard seeds levels of beta-carotene, a precursor to vitamin A as reported by Chow *et al.,* (2010). Rabbits that received 90% protein with 1% mustard seeds (G_6) recorded the best values of carcass weight. Rabbits fed on diet 90% of protein requirements with 1% mustard seeds (G_5) diet recorded the highest value of relative economic efficiency (155%) and the lowest value of feed cost/ kg live body weight (5.23 LE). These results are agreement with those obtained by Ibrahim *et al.* (2009) when rabbits fed on two different levels of energy supplemented with *Artemisia herba-alba, Matricariarecutita L.* and *Chrysanthemum coronarium* as herb mixture.

4. Conclusion

Dietary 90% of protein requirements with 0.5% or 1% mustard seeds showed the high value ofnet 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 digestibility coefficients and growth performance. Mustard seeds at 1% significantly ($P<0.05$) increased the total body weight gain and average daily gain by 24.3% while at 0.5% significantly ($P<0.05$) increased the total body weight gain and average daily gain by 14.5% compared to the control group.Our data suggest that mustard seeds can be considered effectively growth promoter for improving the utilization of low protein diet.

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

Item	Experimental diets					
	100% Protein requirements			90% Protein requirements		
	G_1	G_2	G_3	G_4	G_5	G_6
Yellow corn	230.00	230.00	230.00	270.00	270.00	270.00
Barley grain	50.00	50.00	50.00	50.00	50.00	50.00
Wheat bran	270.00	270.00	270.00	270.00	270.00	270.00
Soybean meal 44% CP	150.00	150.00	150.00	120.00	120.00	120.00
Alfalfa hay	270.00	265.00	260.00	190.00	190.00	190.00
Bean straw	-----	-----	-----	70.00	65.00	60.00
Vit. & Min. mixture*	3.00	3.00	3.00	3.00	3.00	3.00
Sodium chloride	5.00	5.00	5.00	5.00	5.00	5.00
DL-Methionine	1.00	1.00	1.00	1.00	1.00	1.00
Anti fungal agent	1.00	1.00	1.00	1.00	1.00	1.00
Lime stone	10.00	10.00	10.00	10.00	10.00	10.00
Ca- diphosphate	10.00	10.00	10.00	10.00	10.00	10.00
Mustard seed	----	5.00	10.00	----	5.00	10.00
*Price, L.E**/Ton*	2094	2197	2301	1997	2112	2227

* 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 gVit. K, 0.33 gVit. B_1, 1.0 gVit.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 gMn.

** L. E: Livre Egyptiene (Egyptian Pound) = *0.18 American dollars approximately*

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

Item	Experimental diets					
	100% Protein requirements			90% Protein requirements		
	G_1	G_2	G_3	G_4	G_5	G_6
Dry matter	91.28	91.12	91.19	91.58	91.46	91.04
Organic matter	90.52	90.90	90.98	90.46	90.65	90.96
Crude protein	16.04	16.11	16.12	14.48	14.41	14.42
Crude fiber	12.37	12.27	12.02	12.15	12.18	12.07
Ether extract	2.74	2.65	2.73	2.58	2.63	2.68
Nitrogen-free extract	59.37	59.87	60.11	61.25	61.43	61.79
Ash	9.48	9.10	9.02	9.54	9.35	9.04
NFC*	34.17	34.76	34.64	35.76	36.19	36.30
DE (MJ/kg DM)**	2519	2528	2523	2516	2526	2520
Cell wall constituents						
NDF	37.57	37.38	37.49	37.64	37.42	37.56
ADF	18.42	18.20	17.98	19.73	19.31	18.88
ADL	6.46	6.35	6.25	6.41	6.28	6.15
Hemicellulose	19.15	19.18	19.51	17.91	18.11	18.68
Cellulose	11.96	11.85	11.73	13.32	13.03	12.73

** Non fibrous carbohydrates (NFC), calculated using the following equation:NFC = 100 – {CP + EE + Ash + NDF}.** Digestible energy (DE) was calculated as following: DE (MJ/ kg DM) = 4.36 – 0.04 x NDF%.*

NDF: Neutral detergent fiber. ADF: Acid detergent fiber. ADL: Acid detergent lignin.

Hemicellulose = NDF – ADF. Cellulose = ADF – ADL.

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

Item	Experimental diets						SEM
	Protein levels		SEM	Mustard seeds			
	100%	90%		0%	0.5%	1%	
Digestibility coefficients							
Dry matter (DM)	79.08^{b}	84.15^{a}	0.55	80.09^{b}	81.72^{a}	83.03^{a}	0.55
Organic matter (OM)	73.24^{b}	80.13^{a}	0.64	75.48^{c}	76.28^{b}	78.31^{a}	0.64
Crude protein (CP)	79.71^{b}	83.42^{a}	0.40	80.67^{b}	81.29^{b}	82.74^{a}	0.40
Crude fiber (CF)	44.12^{b}	62.39^{a}	1.81	47.54^{c}	53.41^{b}	58.82^{a}	1.81
Ether extract (EE)	89.80	89.69	0.56	86.93^{b}	91.^{71a}	90.61^{a}	0.56
Nitrogen-free extract (NFE)	76.73^{b}	82.52^{a}	0.52	79.34^{b}	78.95^{b}	80.59^{a}	0.52
Nutritive values (%)							
Total digestible nutrient (TDN)	69.55^{b}	75.67^{a}	0.58	71.20^{c}	72.27^{b}	74.36^{a}	0.58
Digestible crude protein (DCP)	12.83^{a}	12.04^{b}	0.08	12.29^{b}	12.39^{b}	12.63^{a}	0.08

a, b and c: 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 protein and supplementation levels on nutrient digestibility and nutritive values of the experimental diets

Item	Experimental diets						SEM
	100% Protein requirements			90% Protein requirements			
	G_1	G_2	G_3	G_4	G_5	G_6	
Digestibility coefficients							
Dry matter (DM)	77.02^{c}	79.26^{b}	80.95^{b}	83.17^{a}	84.18^{a}	85.11^{a}	0.55
Organic matter (OM)	71.42^{e}	72.44^{d}	75.87^{c}	79.54^{b}	80.12^{ab}	80.74^{a}	0.64
Crude protein (CP)	78.05^{c}	79.11^{c}	81.98^{b}	83.29^{a}	83.47^{a}	83.49^{a}	0.40
Crude fiber (CF)	35.62^{e}	42.96^{d}	53.78^{c}	59.45^{b}	63.91^{a}	63.87^{a}	1.81
Ether extract (EE)	89.67^{bc}	91.47^{ab}	88.25^{c}	84.18^{d}	91.94^{a}	92.97^{a}	0.56
Nitrogen-free extract (NFE)	76.25^{d}	75.85^{d}	78.09^{c}	82.43^{ab}	82.04^{b}	83.09^{a}	0.52
Nutritive values							
Total digestible nutrient (TDN)	67.73^{f}	68.89^{e}	72.03^{d}	74.66^{c}	75.65^{b}	76.69^{a}	0.58
Digestible crude protein (DCP)	12.52^{c}	12.75^{b}	13.21^{a}	12.06^{d}	12.03^{d}	12.04^{d}	0.08

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

SEM, standard error of the mean.

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

Item	Experimental diets						SEM
	proteinlevels		SEM	Mustard seeds			
	100%	90%		0%	0.5%	1%	
Initial weight, g	707	705	4.64	705	706	708	4.64
Final weight, g	2232	2268	25.02	2072^{c}	2271^{b}	2408^{a}	25.02
Total body weight gain, g	1525	1563	24.26	1367^{c}	1565^{b}	1700^{a}	24.26
Average daily gain ADG, g	21.79	22.34	0.35	19.53^{c}	22.36^{b}	24.28^{a}	0.35
Feed intake as:							
DM, g/day	75.97	76.93	2.66	79.80	73.00	76.55	2.66
TDN, g/day	52.80	58.37	1.96	56.90	52.70	57.15	1.96
CP, g/day	12.17	11.07	0.40	12.12	11.05	11.70	0.40
DCP, g/day	9.71	9.23	0.33	9.78	8.98	9.67	0.33
Feed conversion(g intake /g gain) of							
DM	3.52	3.47	0.13	4.07^{b}	3.25^{a}	3.15^{a}	0.13
TDN	2.43	2.62	0.09	2.89^{b}	2.35^{a}	2.34^{a}	0.09
CP	0.56	0.50	0.02	0.62^{b}	0.49^{a}	0.48^{a}	0.02
DCP	0.45	0.42	0.02	0.50^{b}	0.40^{a}	0.40^{a}	0.02

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

DM: Dry matter.

TDN: Total digested nutrients.

CP: Crude Protein.

DCP: Digested Crude Protein.

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

Item	Experimental diets						SEM
	100% Protein requirements			90% Protein requirements			
	G_1	G_2	G_3	G_4	G_5	G_6	
Initial weight, g	706	704	710	703	708	705	4.64
Final weight, g	2057^{d}	2242^{c}	2396^{ab}	2087^{d}	2300^{bc}	2419^{a}	25.02
Total body weight gain, g	1351^{d}	1538^{c}	1686^{ab}	1384^{d}	1592^{bc}	1714^{a}	24.26
Average daily gain, g	19.3^{d}	22.0^{c}	24.1^{ab}	19.8^{d}	22.7^{bc}	24.5^{a}	0.35
Feed intake as:							
DM, g/day	78.00	71.00	78.00	81.00	74.00	75.00	2.66
TDN, g/day	53.00	49.00	56.00	60.00	56.00	58.00	1.96
CP, g/day	12.51	11.44	12.57	11.73	10.66	10.82	0.40
DCP, g/day	9.77	9.05	10.30	9.77	8.90	9.03	0.33
Feed conversion(g intake /g gain) of							
DM	4.04^{b}	3.23^{ab}	3.24^{ab}	4.09^{b}	3.26^{ab}	3.06^{a}	0.13
TDN	2.75^{ab}	2.23^{a}	2.32^{a}	3.03^{b}	2.47^{ab}	2.37^{a}	0.09
CP	0.65^{c}	0.52^{ab}	0.53^{abc}	0.59^{bc}	0.47^{ab}	0.44^{a}	0.02
DCP	0.51^{c}	0.411^{abc}	0.43^{abc}	0.49^{bc}	0.39^{ab}	0.37^{a}	0.02

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

SEM, standard error of the mean.

Table 7. Main effects of protein and supplementation levels on dressing percentages, carcass cutsand chemical analysis of the 9,10an 11 th ribs of the experimental groups

Item	Experimental diets						
	Protein levels			Mustard seeds			
	100%	90%	SEM	0%	0.5%	1%	SEM
Slaughter weight (SW), g	2505	2377	50.97	2375	2476	2472	50.97
Inedible offal's							
Feet weight, g	83.00	83.00	0.00	83.00	83.00	83.00	0.00
Feet, % of SW	3.32	3.54	0.08	3.52	3.40	3.36	0.08
Fur weight, g	418	402	14.13	368^{b}	418^{ab}	444^{a}	14.13
Fur, % of SW	16.69	16.80	0.37	15.39^{c}	16.87^{b}	17.98^{a}	0.37
Digestive tract weight, g	319	301	7.05	303	322	305	7.05
Digestive tract, % of SW	12.75	12.71	0.26	12.74	13.14	12.31	0.26
Head weight, g	152^{a}	138^{b}	2.67	149.2	142.5	144	2.67
Head, % of SW	6.09	5.85	0.10	6.29^{a}	5.80^{b}	2.82^{b}	0.10
Lungs weight, g	15.78	14.44	0.53	14.17	16.33	14.83	0.53
Lungs, % of SW	0.63	0.61	0.02	0.60	0.66	0.60	0.02
Total inedible offal's weight, g	988	938	20.41	917	982	991	20.41
Total in edible, % of SW	39.49	39.49	0.45	38.54	39.87	40.07	0.45
Edible offal's							
Liver weight, g	68.44	63.44	2.43	62.17	63.67	72.00	2.43
Liver, % of SW	2.73	2.66	0.07	2.62^{ab}	2.55^{b}	2.92^{a}	0.07
Heart weight, g	8.89	7.89	0.40	8.00	7.83	9.33	0.40
Heart, % of SW	0.35	0.34	0.02	0.33	0.32	0.38	0.02
Kidneys weight, g	18.56	15.78	1.06	15.67	17.00	18.83	1.06
Kidneys, % of SW	0.74	0.66	0.04	0.66	0.68	0.76	0.04
Testes weight, g	10.89	10.44	0.66	8.33^{b}	11.83^{a}	11.83^{a}	0.66
Tests, % of SW	0.44	0.43	0.02	0.36^{b}	0.48^{a}	0.48^{a}	0.02
Total edible offal's weight, g	106.8	97.6	3.71	94.17^{b}	100.33^{ab}	112.00^{a}	3.71
Total edible offal's, % of SW	4.26	4.11	0.10	4.00^{b}	4.04^{b}	4.53^{a}	0.10
Carcass weight (CW1), g	1409	1342	32.17	1363	1395	1369	32.17
Carcass weight including edible offal's (CW2)							
Dressing percentages (DP)%	1516	1440	34.60	1458	1495	14.81	34.60
DP ^{1} (CW1/ SW)							
DP ^{2} (CW2/ SW)	56.26	56.42	0.47	57.52^{a}	56.09^{ab}	55.41^{b}	0.47
	60.51	60.45	0.45	61.38	60.13	59.93	0.45
Chemical analysis of the 9,10 and 11th ribs							
Dry matter	31.62	32.79	0.82	33.21	33.19	30.22	0.82
Chemical composition on DM basis							
Crude protein (CP)	58.97	63.45	1.17	60.97	61.63	61.02	1.17
Ether extract (EE)	33.38	28.51	1.30	31.56	29.87	31.41	1.30
Ash	7.65	8.05	0.22	7.48^{b}	8.50^{a}	7.57^{ab}	0.22

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

SEM, standard error of the mean.

Table 8. Effect of interactions between protein and supplementation levels on dressing percentages, carcass cutsand chemical analysis of the 9,10an 11 th ribs of the experimental groups

	Experimental diets						
	100% Protein requirements			90% Protein requirements			
Item	G_1	G_2	G_3	G_4	G_5	G_6	SEM
Slaughter weight (SW), g	2545	2474	2495	2204	2479	2449	50.97
Inedible offal's							
Feet weight, g	83.00	83.00	83.00	83.00	83.00	83.00	0.00
Feet, % of SW	3.26	3.35	3.33	3.77	3.35	3.39	0.08
Fur weight, g	419^{a}	391^{ab}	444^{a}	316^{b}	445^{a}	444^{a}	14.13
Fur, % of SW	16.46^{bc}	15.80^{c}	17.80^{ab}	14.34^{d}	17.95^{a}	18.13^{a}	0.37
Digestive tract weight, g	355^{a}	307^{abc}	316^{ab}	271^{c}	337^{a}	294^{bc}	7.05
Digestive tract, % of SW	13.16	12.41	12.67	12.30	13.59	12.00	0.26
Head weight, g	159^{a}	150^{ab}	149^{ab}	140^{b}	135^{b}	139^{b}	2.67
Head, % of SW	6.25^{ab}	6.06^{abc}	5.97^{abc}	6.35^{a}	5.45^{c}	5.68^{bc}	0.10
Lungs weight, g	14^{bc}	17^{ab}	17^{a}	15^{abc}	16^{ab}	13^{c}	0.53
Lungs, % of SW	0.55^{b}	0.69^{a}	0.68^{a}	0.68^{a}	0.65^{a}	0.53^{b}	0.02
Total inedible offal's weight, g	1010^{a}	948^{a}	1009^{a}	825^{b}	1016^{a}	973^{a}	20.41
Total in edible, % of SW	39.69^{ab}	38.32^{ab}	40.44^{a}	37.43^{b}	40.98^{a}	39.73^{ab}	0.45
Edible offal's							
Liver weight, g	67.00	64.00	75.00	58.00	64.00	69.00	2.43
Liver, % of SW	2.63	2.59	3.01	2.63	2.58	2.82	0.07
Heart weight, g	8.00^{b}	8.00^{b}	11.00^{a}	8.00^{b}	8.00^{b}	8.00^{b}	0.40
Heart, % of SW	0.31^{b}	0.32^{b}	0.44^{a}	0.36^{ab}	0.32^{ab}	0.33^{ab}	0.02
Kidneys weight, g	16.00^{b}	16.00^{b}	24.00^{a}	16.00^{b}	18.00^{ab}	14.00^{b}	1.06
Kidneys, % of SW	0.63^{b}	0.65^{b}	0.96^{a}	0.73^{b}	0.73^{b}	0.57^{b}	0.04
Testes weight, g	8.00^{b}	12.00^{ab}	13.00^{a}	9.00^{ab}	12.00^{ab}	11.00^{ab}	0.66
Tests, % of SW	0.31^{b}	0.49^{a}	0.52^{a}	0.41^{ab}	0.48^{a}	0.45^{ab}	0.02
Total edible offal's weight, g	99^{ab}	100^{ab}	123^{a}	91^{b}	102^{ab}	102^{ab}	3.71
Total edible offal's, % of SW	3.89^{b}	4.04^{b}	4.93^{a}	4.13^{b}	4.11^{b}	4.16^{b}	0.10
Carcass weight (CW1), g	1436	1426	1363	1288	1361	1374	32.17
Carcass weight including edible offal's (CW2)							
Dressing percentages (DP)%	1535	1526	1486	1379	1463	1476	34.60
DP ^{1} (CW1/ SW)							
DP ^{2} (CW2/ SW)	56.42^{ab}	57.64^{a}	54.63^{b}	58.44^{a}	54.90^{b}	56.10^{ab}	0.47
	60.31^{ab}	61.68^{ab}	59.56^{ab}	62.57^{a}	59.02^{b}	60.27^{ab}	0.45
Chemical analysis of the 9,10 and 11th ribs							
Dry matter	33.24^{a}	34.65^{a}	26.99^{b}	33.19a	31.74^{ab}	33.45^{a}	0.82
Chemical composition on DM basis							
Crude protein (CP)	59.25	59.93	57.72	62.69	63.33	64.32	1.17
Ether extract (EE)	32.83	31.99	35.32	30.28	27.74	27.50	1.30
Ash	7.92^{ab}	8.08^{ab}	6.96^{b}	7.03^{b}	8.93^{a}	8.18^{ab}	0.22

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

SEM, standard error of the mean.

Table 9. Economic evaluation of the experimental groups

Item	Experimental diets					
	100% Protein requirements			90% Protein requirements		
	G_1	G_2	G_3	G_4	G_5	G_6
Marketing weight, Kg	2.057	2.242	2.396	2.087	2.300	2.419
Feed consumed / rabbit, kg	6.006	5.488	6.013	6.223	5.698	5.768
Costing of one kg feed, (LE)[1]	2.094	2.197	2.301	1.997	2.112	2.227
Total feed cost, (LE)	12.577	12.057	13.836	12.427	12.03	12.845
Management/ Rabbit, (LE)[2]	4	4	4	4	4	4
Total cost, (LE)[3]	31.58	31.06	32.84	31.43	31.03	31.85
Total revenue, (LE)[4]	45.25	49.32	52.71	45.91	50.60	53.22
Net revenue	13.67	18.26	19.87	14.48	19.57	21.37
Economical efficiency[5]	0.4329	0.5879	0.6051	0.4607	0.6307	0.6710
Relative economic efficiency[6]	100	135.8	139.8	106.4	145.7	155.0
Feed cost / kg LBW (LE)[7]	6.11	5.38	5.77	5.95	5.23	5.31

[1] *Based on prices of year 2010.*

[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.*