

Growth Performance of Rabbits Fed Diets Containing Different Levels of Energy and Mixture of Some Medicinal Plants

H. A. A. Omer

Animal Production Department, National Research Centre, Dokki, Giza, Egypt

Tel: 20-11-408-9312 E-mail: hamedomer2000@yahoo.com

Sh. A. M. Ibrahim (Corresponding author)

Animal Production Department, National Research Centre, Dokki, Giza, Egypt

Tel: 20-10-169-4188 E-mail: shawki_nrc@yahoo.com

A. A. Abedo

Animal Production Department, National Research Centre, Dokki, Giza, Egypt

Tel: 20-11-237-3380 E-mail: abedoaa@yahoo.com

F. A. F. Ali

Animal Production Department, National Research Centre, Dokki, Giza, Egypt

Tel: 20-10-652-7044 E-mail: mf_ahmed@live.com

Received: April 29, 2011

Accepted: May 12, 2011

Online Published: December 21, 2011

doi:10.5539/jas.v4n2p201

URL: <http://dx.doi.org/10.5539/jas.v4n2p201>

Abstract

A total number of 48 male growing New Zealand rabbits were used to study the effect of two different levels of ration energy supplemented with mixture of *Lupinus albus L*, *Trigonella foenum-graecum L* and *Cassia senna L* as feed additives. Rabbits were classified into four equal groups (G₁-G₄). The 1st and 3rd groups received basal ration with 100 % and 90 % energy requirement and served as first and second control respectively. The 2nd and the 4th groups received basal ration with 100 % and 90 % energy requirement supplemented with mixture at the level of 1.5 %, respectively. The results showed that decreasing energy requirements level by 10% in rabbit diets significantly (P<0.05) increased the digestibility coefficients of DM, OM, CP and NFE & DCP values. The 90% energy level insignificant increased (P>0.05) CF and EE digestibility coefficients and TDN value. The 90% energy requirement with 1.5 % additives mixture (G₄) recorded the best digestibility coefficients of DM, OM, CP, CF, EE, NFE and nutritive values of TDN and DCP.

The 90% energy level significantly (P<0.05) improved feed conversion (g intake /g gain) of DM, CP, DCP, TDN and DE, respectively compared to control. Adding mixture at 1.5 % level significantly (P<0.05) improved feed conversion (g intake /g gain) of DM, CP, DCP, TDN and DE, respectively compared to control. The 90% energy with 1.5% additives mixture (G₄) recorded the best values of final body weight, body weight gain, and average daily gain as well as feed conversion.

Additives mixture at 1.5% level significantly (P>0.05) increased the total inedible offal's (weight and % of SW) and Dm contents of the 9, 10 and 11th ribs. The 90% energy level with 1.5% additives mixture (G₄) diet recorded the highest value of relative economic efficiency (145.1%) and the lowest value of feed cost/ kg live body weight (3.97 LE).

It can be concluded that this mixture of medicinal plants can be considered as growth promoter that is effective for improving the utilization of low energy diet by lowering circulating glucose levels through enhancing insulin sensitivity.

Keywords: Medicinal plants, Rabbits, Growth performance, Digestibility, Carcass characteristics, Economic evaluation

1. Introduction

Recently use of some herbal medicines, have been considered as an alternative for therapeutic usage or to evaluate the hypoglycemic and hypolipidemic effects (Kassaiyan *et al.*, 2009). Protein and fiber derived from lupin kernel significantly lower influences energy intake acutely (Lee *et al.*, 2006). Fenugreek fiber significantly increased satiety and reduced energy intake (Mathern *et al.*, 2009).

Lupinus albus L. used is the dried sweet white lupine seeds belonging to the leguminosae family. Lupin (*Lupinus spp.*) seed improve the livestock production efficiency (Van Barneveld, 1999). Lupin had a good nutritional quality; alpha-galactoside-free lupin that can be used as an excellent dietary source for the preparation of dietetic products (Porres *et al.*, 2006). Exogenous enzyme products could lead to lupin non-starch polysaccharides being used as an energy source for poultry (Hughes *et al.*, 2000 and Sami *et al.*, 2010).

Trigonella foenum graecum L., used is the dried fenugreek seeds belonging to the leguminosae family. Fenugreek has a long history of medical uses in folklore medicine, and has been used for numerous indications, including labor induction, aiding digestion, and as a general tonic to improve metabolism and health (Basch *et al.*, 2003). Preliminary animal and human trials suggest possible hypoglycemic and antihyperlipidemic properties of oral fenugreek seed powder (Basch *et al.*, 2003). Fenugreek is traditionally used to treat the diabetes disorders (Raju *et al.*, 2004).

Cassia senna L. used is the dried senna leaves belonging to the leguminosae family. *Cassia senna L.* used for thereby decreasing the likelihood of adverse effects and for relax the intestines (Müllera and Basedow, 2006) due to a metabolic effect involving energy production (Nadal *et al.*, 2003).

Low dietary energy requirements may cause imbalance in the body metabolism and growth performance. The hypothesis that if any component lowered circulating glucose levels indicating that this component is enhancing insulin sensitivity as well as improving the utilization of low energy diet. Some essential oils lowered circulating glucose levels and systolic blood pressure, suggesting that these natural products are enhancing insulin sensitivity (Talpur, 2005). Lupins have unique carbohydrate properties characterized by high levels of raffinose oligosaccharides, all of which can lower the utilization of energy (Van Barneveld, 1999). Lupin kernel flour significantly lower influences energy intake acutely (Lee *et al.*, 2006). Fenugreek seeds exert antidiabetic effects mediated through enhancement of peripheral insulin action (Hannan *et al.*, 2007), with possible hypoglycemic and antihyperlipidemic properties of oral fenugreek seed powder (Basch *et al.*, 2003) as well as fenugreek fiber significantly increased satiety and reduced energy intake (Mathern *et al.*, 2009). Carbohydrates in senna include 2% polysaccharides and approximately 10% mucilage consisting of galactose, arabinose, rhamnose, and galacturonic acid (Bisset *et al.*, 1994). Other carbohydrates in senna include mannose, fructose, glucose, pinitol, and sucrose (Newall *et al.*, 1996).

This work aimed to evaluate the efficacy of lupine, fenugreek and senna as feed additives in improving the utilization of low energy rabbit diet as well as growth performance.

2. Materials and Methods

A total number of 48 male New Zealand White rabbits aged 5 weeks with an average body weight of 796 ± 19.19 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). Additives mixture used in this study are composed of *Lupinus albus L.*, *Trigonella foenum-graecum L.* and *Cassia senna L.* at ratio of (1:1: 0.25), respectively. The feeding period was extended for 56 days, and the experimental groups were classified as follow:

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

Group 2 basal diet with 100 % energy requirement + 1.5% additives mixture (G_2),

Group 3 basal diet with 90 % energy requirement and served as control (G_3) and

Group 4 basal diet with 90 % energy requirement + 1.5% additives mixture (G_4).

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, six rabbits from each treatment 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 of feces was dried at 60°C for 48 hrs, ground and stored for later chemical analysis.

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 and digestive tract contents were calculated by differences between full and empty digestive tract. Weights of giblets 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 later chemical analysis. 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'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). 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) were calculated according to Calsamiglia *et al.* (1995) using the following equation: $NFC = 100 - \{CP + EE + Ash + NDF\}$. Diets were offered pelleted and diameter of the pellets was 4 mm. 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.

3. Results and discussion

3.1 Chemical analysis and cell wall constituents of the experimental diets

Digestible energy for the four tested rations (G₁-G₄) was 2.507, 2.503, 2.251 and 2.253 (Mcal/ kg DM), respectively (Table 2). These variations were related to differ in ingredients that used in ration formulations. The 90% of energy level containing diets showed slightly increase in NDF, and hemicellulose contents, while ADF, cellulose and non fibrous carbohydrates (NFC) contents were slightly decreased compared to control diet with 100% energy requirements. As well as ADL content of experimental rations showed approximately the same trend (Table 2). These results suggest that alterations in metabolism involved in adaptation to a diet high in hemicellulose may indicating an increased propensity for oxidative metabolism occurred in the intestine, similar result observed by Weber *et al.*, (2010).

3.2 Nutrient digestibility and nutritive values of the experimental diets

Decreasing energy requirements level by 10% in rabbit diets significantly increased ($P < 0.05$) the digestibility coefficients of DM, OM, CP, NFE and DCP value (Table 3). The 90% energy level slightly increased ($P < 0.05$) CF and EE digestibility coefficients and TDN value. The significant results may be due to that the rabbits received the low energy requirements, shift must have different digestive efficiencies for diets that correspond to its diet shift, so that nutrient and energy extraction are maximized, similar results observed by Durtsche (2004). Adding mixture of medicinal plants at 1.5% showed insignificantly ($P > 0.05$) improved all nutrient digestibility coefficients and nutritive values (Table 3). These results may be due to that lupin can supply rapidly degradable protein for microbial protein synthesis and contribute to the pool of amino acids available for the synthesis and retention in the body, similar result noticed in cow by Boguhn *et al.* (2008). Or may be due to that fenugreek has been used for numerous indications, including aiding digestion, and as a general tonic to improve metabolism and health as observed by Basch *et al.* (2003) and Chevassus *et al.* (2010). On the other hand may be due to that senna have a marked choleric effect and helps improve the condition of digestion (Zhu *et al.*, 1997).

The 90% energy requirement with 1.5 % additives mixture (G₄) recorded the best digestibility coefficients of DM, OM, CP, CF, EE, NFE and nutritive values of TDN and DCP (Table 4). This best digestibility coefficients values at the 90% energy requirement may be due to the ability of rabbit to maximize the extraction nutrient and energy. At the same time these results may be due to the relatively high water-binding capacity and viscosity of lupin may elicit more beneficial physiological effects in the upper gastrointestinal tract, similar result in human observed by Turnbull *et al.* (2005). Also, may be due to trigonelline effect of fenugreek that showed a middle

rate of absorption and fast rate of elimination in rabbit with a good reproducibility, similar result obtained by Zhao *et al.* (2003). On the other hand may be due to the ability of *Cassia senna L.* when converted in the large intestine by gut bacteria to the active metabolite, rheinanthrone, which increases colonic motility and fluid secretion (Vanderperren *et al.*, 2005).

There were significant ($P < 0.05$) interactions between the energy and additives mixture levels on DM digestibility coefficient and DCP value, while there were no interactions between the energy and additives mixture levels on the other digestibility coefficients OM, CF, EE, NFE and TDN value (Table 4). These results in agreement with those obtained by Gross *et al.* (1976) who noticed that sweet lupine has been digestible without complications in all cases.

3.3 Growth performance of the experimental groups

The 90% energy level slightly improved ($P > 0.05$) the final body weight, total weight gain and ADG (g) compared to control 100% energy level (Table 5). The 90% energy level significantly ($P < 0.05$) decreased feed intake as DM, CP, TDN (g/day) and DE (kcal/head/day), while insignificantly ($P > 0.05$) decreased DCP intake (g/day) (Table 5). The 90% energy level significantly ($P < 0.05$) improved feed conversion (g intake/g gain) of DM, CP, DCP, TDN and DE, respectively compared to control (Table 5). These results suggested that if the animal with an ontogenetic or low energy diet shift must have different digestive efficiencies for foods that correspond to its diet shift, so that nutrient and energy extraction is maximized, as explained by Durtsche (2004).

Adding mixture at 1.5 % level slightly decreased ($P < 0.05$) DM, CP and DE intakes, while insignificantly ($P > 0.05$) decreased the DCP and TDN intakes compared to control (Table 5). This result may suggest that the use of sweet lupin seed meal in diets for growing rabbits might enhance the growth of lactic acid fermenting bacteria in the gut, similar result in brioler observed by Rubio *et al.* (1998). However adding mixture at 1.5 % level slightly improved ($P > 0.05$) final weight, total body weight gain and ADG (g).

Adding mixture at 1.5 % level significantly ($P < 0.05$) improved feed conversion (g intake/g gain) of DM, CP, DCP, TDN and DE, respectively compared to control (Table 5). These results may be due to that the amino acids from lupin globulins proteins are probably absorbed at rates lower than in other proteins of animal origin such as casein (Rubio and Seiquer 2002). Also, may be due to the high bioaccessibility of beta-carotene from fenugreek (Veda *et al.*, 2006). On the other hand, may due to the effect of Senna (*Cassia senna L.*) for enhanced permeability of disruption of tight junctions between colonic epithelial cells (Soyuncu *et al.*, 2008).

There were no interactions between energy and additives mixture levels on rabbit performance (Table 6). The 90% energy with 1.5% additives mixture (G_4) recorded the best values of final body weight, body weight gain, and average daily gain as well as feed conversion. These best values may be due to the high palatability of lupin as observed in human by Hall *et al.* (2005). Or may be due to understanding the nutritional chemistry of lupin (*Lupinus spp.*) seed to improve livestock production efficiency (Van Barneveld 1999). On the other hand may be due to the or may due to the treating metabolic and nutritive dysfunctions effect of fenugreek seeds, as observed by Chevassus *et al.* (2010).

3.4 Carcass characteristics of the experimental groups

Energy level had insignificant ($P > 0.05$) effect on total inedible offal's (weight and % of SW); total edible offal's weight, carcass weight; carcass cuts and chemical analysis of CP, EE and ash contents of the 9, 10 and 11th ribs (Table 7). Supplementation additives mixture at 1.5% level significantly ($P < 0.05$) increased the total inedible offal's (weight and % of SW); and DM content 9, 10 and 11th ribs. While it had no significant effect ($P > 0.05$) on total inedible offal's, carcass weight; dressing percentages carcass cuts, and CP, EE and ash contents of the 9, 10 and 11th ribs (Table 7). These results may be due to that lupin seeds diet affected the fatty acid profile of rabbit hind leg meat and perirenal fat in a favourable manner (Volek and Marounek, 2011). On the other hand these results may be due to the beneficial effect of fenugreek as dyslipidemia, similar result in diabetic rats observed by Hannan *et al.* (2003); Kassaian *et al.* (2009) and Uemura *et al.* (2011).

There were no interaction between energy and additives mixture levels on total inedible offal's (weight and % of SW); empty body weight (EBW); carcass weight and carcass cuts. While there were interactions between energy and additives mixture level on digestive tract; total edible offal's (weight and % of SW); dressing percentages and DM & ash contents of the 9, 10 and 11th ribs (Table 8). Also, the 90% energy and 1.5% additives mixture containing diet (G_4) recorded the best values of carcass weight including edible offal's (CW_2) (Table 8). These results may be due to that Lupin resulting in moderate changes in both protein and fibre intakes can benefit body weight and composition or blood lipids, glucose and insulin concentrations in overweight with mildly elevated cholesterol concentrations as reported by Hodgson *et al.* (2010). Or may be due to the purified fenugreek seeds seems to decrease lipid content as showed by Moorthy *et al.*, (2010) and Chevassus *et al.* (2010).

3.5 Economical evaluation

The profitability of using additives mixture depends upon the price of tested diets and the growth performance of rabbits fed these diets (Table 9). The cost of one kg feed, (LE) was decreased by 10.88% and 5.49% % in G₃ and G₄, respectively compared to control diet G₁. This result was due to the lowered energy level by 10% as quantity which under this study was considered the expensive components in diet.

The 90% energy requirements with or without additives mixture showed the high values of net revenue, economical efficiency and relative economic efficiency as well as the low value of feed cost/ kg live body weight (LE). This high values was due to the ability of additives mixture in raising the ration value by improving the utilization of low energy diet as our hypothesis via enhancing pancreatic insulin sensitivity.

The 90% energy level with 1.5% additives mixture (G₄) diet recorded the highest value of relative economic efficiency (145.1%) and the lowest value of feed cost/ kg live body weight (3.97 LE). These results are in agreement with those obtained by Ibrahim *et al.* (2009) who fed rabbits on two different levels of energy supplemented with herbs mixture of *Artemisia herba-alba*, *Matricaria recutita* L. and *Chrysanthemum coronarium*.

4. Conclusion

Under this conditions of this study it can be concluded that lowering the dietary energy level in rabbit diets from 100% to 90% of requirements with adding 1.5 % medicinal mixture of (*Lupinus albus* L., *Trigonella foenum-graecum* L and *Cassia senna* L.) as feed additives improved nutrient digestibility coefficients and nutritive values as well as realized the highest value of relative economic efficiency and lowered value of feed cost/ kg live body weight. Also, our data suggest that this mixture of medicinal plants can be considered as growth promoter that is effective for improving the utilization of low energy diet by lowering circulating glucose levels through enhancing insulin sensitivity.

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

Item	100% Energy requirements		90% Energy requirements	
	G ₁	G ₂	G ₃	G ₄
Yellow corn	220	220	----	----
Barley grain	60	60	150	150
Wheat bran	270	270	270	270
Soybean meal 44% CP	150	150	150	150
Alfalfa hay	270	255	260	260
Clover straw	----	----	140	125
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
Plants mixture supplement	---	15	----	15
Price, L.E/Ton	2096	2191	1868	1981

* 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. B₁, 1.0 g Vit. B₂, 0.33g Vit. B₆, 8.33 g Vit.B₅, 1.7 mg Vit. B₁₂, 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.

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

Item	100% Energy requirements		90% Energy requirements	
	G ₁	G ₂	G ₃	G ₄
Dry matter	91.32	91.37	91.00	91.58
Chemical analysis on dry matter basis				
Organic matter (OM)	90.82	90.68	89.32	89.03
Crude protein (CP)	14.14	14.18	14.12	14.16
Crude fiber (CF)	12.89	12.40	12.69	12.76
Ether extract (EE)	3.46	3.38	3.34	3.34
Nitrogen-free extract (NFE)	60.33	60.72	59.17	58.77
Ash	9.18	9.32	10.68	10.97
Gross energy (Mcal/ kg DM) ¹	4.163	4.154	4.095	4.083
Digestible energy (kcal/kg DM) ²	2507	2503	2251	2253
Non fibrous carbohydrates (NFC) ³	33.53	34.17	32.33	32.38
Cell wall constituents				
NDF	39.69	38.95	39.53	39.15
ADF	18.26	17.93	16.45	16.15
ADL	6.46	6.30	6.86	6.77
Hemicellulose	21.43	21.02	23.08	23.00
Cellulose	11.80	11.63	9.59	9.38

¹Gross 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.

²Digestible 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					SEM
		Energy levels		SEM	Supplementation		
		100%	90%		0%	1.5%	
Nutrient digestibility coefficients							
Dry matter (DM)	71.95 ^b	77.31 ^a	1.04	74.42	74.84	1.04	
Organic matter (OM)	63.88 ^b	68.94 ^a	1.24	65.68	67.14	1.24	
Crude protein (CP)	68.40 ^b	74.45 ^a	1.25	71.24	71.61	1.25	
Crude fiber (CF)	28.61	33.00	2.79	27.42	34.19	2.79	
Ether extract (EE)	76.68	78.88	0.99	77.63	77.92	0.99	
Nitrogen-free extract (NFE)	69.49 ^b	74.80 ^a	1.14	71.87	72.42	1.14	
Nutritive values							
TDN%	61.26	64.78	1.04	62.45	63.59	1.04	
DCP%	9.69 ^b	10.53 ^a	0.17	10.07	10.15	0.17	

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				SEM
	100%		90%		
	Energy requirements	Energy requirements	Energy requirements	Energy requirements	
	G ₁	G ₂	G ₃	G ₄	
Nutrient digestibility coefficients					
Dry matter (DM)	71.92 ^c	71.98 ^{bc}	76.92 ^{ab}	77.69 ^a	1.04
Organic matter (OM)	63.55	64.22	67.80	70.07	1.24
Crude protein (CP)	68.32	68.48	74.15	74.74	1.25
Crude fiber (CF)	28.82	28.24	26.05	39.97	2.79
Ether extract (EE)	75.45	77.90	79.81	77.94	0.99
Nitrogen-free extract (NFE)	69.17	69.81	74.57	75.03	1.14
Nutritive values					
TDN%	60.99	61.52	63.90	65.65	1.04
DCP%	9.66 ^b	9.71 ^{ab}	10.47 ^{ab}	10.59 ^a	0.17

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					SEM
	Energy levels		SEM	Supplementation		
	100%	90%		0%	1.5%	
Initial weight, g	796	795	18.19	794	797	18.19
Final weight, g	2514	2548	47.24	2497	2566	47.24
Total body weight gain, g	1718	1753	48.24	1703	1769	48.24
Duration period (days)	56	56	----	56	56	----
Average daily gain (ADG), g	30.68	31.30	0.86	30.41	31.59	0.86
Feed intake as:						
DM, g/head/day	105.05 ^a	89.46 ^b	3.05	101.67 ^a	92.84 ^b	3.05
CP, g/head/day	13.29 ^a	11.38 ^b	0.40	13.01 ^a	11.66 ^b	0.40
DCP, g/head/day	10.17	9.42	0.25	10.20	9.39	0.25
TDN, g/head/day	64.34 ^a	57.90 ^b	1.61	63.36	58.88	1.61
DE, Kcal/head/day	263 ^a	201 ^b	9.66	243 ^a	222 ^b	9.66
Feed conversion (g intake /g gain) of						
DM	3.43 ^a	2.86 ^b	0.11	3.35 ^a	2.94 ^b	0.11
CP	0.43 ^a	0.37 ^b	0.01	0.43 ^a	0.37 ^b	0.01
DCP	0.33 ^a	0.30 ^b	0.01	0.34 ^a	0.30 ^b	0.01
TDN	2.10 ^a	1.85 ^b	0.06	2.08 ^a	1.86 ^b	0.06
DE (Kcal intake /g gain)	8.59 ^a	6.45 ^b	0.34	8.00 ^a	7.05 ^b	0.34

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

Item	Experimental rations				
	100%		90%		SEM
	Energy requirements		Energy requirements		
	G ₁	G ₂	G ₃	G ₄	
Initial weight, g	797	795	791	799	18.19
Final weight, g	2497	2532	2496	2601	47.24
Total body weight gain, g	1700	1737	1705	1802	48.24
Duration period (days)	56	56	56	56	---
Average daily gain (ADG), g	30.36	31.02	30.45	32.18	0.86
Feed intake as:					
DM, g/head/day	109.6 ^a	100.5 ^{ab}	93.70 ^{bc}	85.00 ^c	3.05
CP, g/head/day	14.13 ^a	12.46 ^{ab}	11.89 ^b	10.87 ^b	0.40
DCP, g/head/day	10.59 ^a	9.76 ^{ab}	9.81 ^{ab}	9.02 ^b	0.25
TDN, g/head/day	66.85 ^a	61.83 ^{ab}	59.87 ^{ab}	55.93 ^b	1.61
DE, Kcal/head/day	275 ^a	252 ^a	211 ^b	192 ^b	9.66
Feed conversion (g intake /g gain) of					
DM	3.61 ^c	3.24 ^{bc}	3.08 ^{ab}	2.65 ^a	0.11
CP	0.47 ^c	0.40 ^b	0.39 ^{ab}	0.34 ^a	0.01
DCP	0.35 ^b	0.31 ^{ab}	0.32 ^{ab}	0.28 ^a	0.01
TDN	2.20 ^b	1.99 ^{ab}	1.97 ^{ab}	1.74 ^a	0.06
DE (Kcal intake /g gain)	9.06 ^b	8.12 ^b	6.93 ^a	5.97 ^a	0.34

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

SEM, standard error of the mean.

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

			Experimental diets				SEM	
			Energy levels		SEM	Supplementation		
			100%	90%		0%		1.5%
Item			100%	90%	SEM	0%	1.5%	SEM
Slaughter weight (SW), g			2342 ^b	2623 ^a	69.71	2414	2551	69.71
Inedible offal's								
1- External offal's*								
weight, g			263	524	18.44	488	500	18.44
% of SW			19.8	20.00	0.25	20.21	19.60	0.25
2- Head								
weight, g			127	130	2.68	130	127	2.68
% of SW			5.42	4.94	0.16	5.93	4.96	0.16
Total inedible offal's								
weight, g			590	654	19.56	617	626	19.56
% of SW			25.21	25.39	0.34	25.60	25.00	0.34
Digestive tract								
Full, g			351 ^b	460 ^a	20.14	384 ^b	427 ^a	20.14
Empty, g			165 ^b	216 ^a	9.44	180 ^b	200 ^a	9.44
Contents			186 ^b	245 ^a	10.70	204 ^b	227 ^a	10.70
Empty body weight, g (EBW)			2156 ^b	2378 ^a	61.08	2210	2334	61.08
Edible offal's**								
Liver	weight, g		86.83	82.83	3.91	75.50 ^b	94.17 ^a	3.91
	%		3.71 ^a	3.16 ^b	0.13	3.15 ^b	3.72 ^a	0.13
of SW			7.33	8.00	0.47	6.50 ^b	8.83 ^a	0.47
Heart	weight,		0.30	0.30	0.01	0.27 ^b	0.33 ^a	0.01
g			21.50	20.67	0.80	19.83	22.33	0.80
	%		0.92 ^a	0.80 ^b	0.02	0.83	0.89	0.02
of SW			8.83	8.33	0.42	8.17	9.00	0.42
Kidneys	weight, g		0.39 ^a	0.31 ^b	0.02	0.34	0.36	0.02
% of SW			125	120	5.22	110 ^b	134 ^a	5.22
Testes	weight,		5.31 ^a	4.57 ^b	0.17	4.59 ^b	5.29 ^a	0.17
g			1278	1389	33.19	13.03	1364	33.19
% of SW			1402	1509	36.32	1413	1498	36.32
Total edible offal's								
			54.51 ^a	52.99 ^b	0.41	53.96	53.54	0.41
weight, g			59.21	58.43	0.34	58.93	58.71	0.34
			64.97 ^a	63.47 ^b	0.38	63.93	64.51	0.38
% of SW								
Carcass weight (CW ₁), g								
Carcass weight including edible offal's (CW ₂)								
Dressing percentages (DP)%								
DP ¹ (CW ₁ / SW)								
DP ² (CW ₁ / EBW)								
DP ³ (CW ₂ / EBW)								
Carcass cuts								
Fore part, g			381	414	9.62	388	406	9.62
Middle part, g			404	439	10.48	412	431	10.48
Hind part, g			493	536	12.79	503	526	12.79
Chemical analysis of the 9,10 and 11 th ribs								
Dry matter (DM)			35.03 ^a	31.33 ^b	0.99	31.60 ^b	34.75 ^a	0.99
Crude protein (CP)			50.34	57.86	2.17	54.38	53.81	2.17
Ether extract (EE)			42.03	33.93	2.26	36.56	39.40	2.26
Ash			7.63	8.21	0.40	9.05 ^a	6.79 ^b	0.40

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.

* External offal's: included Fur, ears, legs and blood. **Edible offal's: included 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

Experimental groups			Experimental rations				
			100%		90%		SEM
			Energy requirements		Energy requirements		
Item			G ₁	G ₂	G ₃	G ₄	
Slaughter weight (SW), g			2263 ^b	2422 ^{ab}	2565 ^{ab}	2680 ^a	69.71
Inedible offal's							
1- External offal's *							
weight, g			457	470	519	530	18.44
% of SW			20.19	19.40	20.23	19.78	0.25
2- Head							
weight, g			132	121	127	132	2.68
% of SW			5.83 ^a	5.00 ^{ab}	4.95 ^b	4.92 ^b	0.16
Total inedible offal's							
weight, g			589	591	646	662	19.56
% of SW			26.02	24.40	25.18	24.70	0.34
Digestive tract							
Full, g			345 ^c	356 ^c	423 ^b	498 ^a	20.14
Empty, g			162 ^c	167 ^c	198 ^b	234 ^a	9.44
Contents			183 ^c	189 ^c	225 ^b	264 ^a	10.70
Empty body weight, g (EBW)			2080	2233	2340	2416	61.08
Edible offal's**							
Liver	weight, g		78.00 ^{ab}	96.00 ^a	73.00 ^b	93.00 ^{ab}	3.91
%			3.45 ^b	3.96 ^a	2.85 ^c	3.47 ^b	0.13
of SW			6.00 ^b	8.00 ^a	7.00 ^{ab}	9.00 ^a	0.47
Heart	weight, g		0.27 ^b	0.33 ^a	0.27 ^b	0.33 ^a	0.01
%			20.00	23.00	20.00	22.00	0.80
of SW			0.88 ^{ab}	0.95 ^a	0.78 ^b	0.82 ^b	0.02
Kidneys	weight, g		9.00	9.00	7.00	9.00	0.42
% of			0.40 ^a	0.37 ^a	0.27 ^b	0.34 ^{ab}	0.02
SW							
Testes	weight, g		113 ^{ab}	136 ^a	107 ^b	133 ^{ab}	5.22
% of			5.00 ^b	5.61 ^a	4.17 ^c	4.96 ^b	0.17
SW			1216	1339	1390	1388	33.19
Total edible offal's							
weight, g			1329	1475	1497	1521	36.32
% of			53.73 ^b	55.28 ^a	54.19 ^{ab}	51.79 ^c	0.41
SW			58.46 ^{bc}	59.96 ^a	59.40 ^{ab}	57.45 ^c	0.34
Carcass weight (CW ₁), g			63.89 ^b	66.05 ^a	63.97 ^b	62.96 ^b	0.38
Carcass weight including edible offal's (CW ₂)							
Dressing percentages (DP)%							
DP ¹ (CW ₁ / SW)							
DP ² (CW ₁ / EBW)							
DP ³ (CW ₂ / EBW)							
Carcass cuts							
Fore part, g			362	399	414	414	9.62
Middle part, g			384	423	439	439	10.48
Hind part, g			470	517	537	535	12.79
Chemical analysis of the 9,10 and 11 th ribs							
Dry matter (DM)			33.67 ^{ab}	36.39 ^a	29.54 ^b	33.12 ^{ab}	0.99
Crude protein (CP)			52.52	48.15	56.24	59.46	2.17
Ether extract (EE)			38.64	45.42	34.99	33.38	2.26
Ash			8.84 ^a	6.43 ^b	9.27 ^a	7.16 ^b	0.40

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

SEM, standard error of the mean.

* External offal's: included Fur, ears, legs and blood.

** Edible offal's: included 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%		90%	
	Energy requirements		Energy requirements	
	G ₁	G ₂	G ₃	G ₄
Marketing weight, Kg	2.497	2.532	2.496	2.601
Feed consumed / rabbit, kg	6.720	6.160	5.768	5.208
Costing of one kg feed, (LE) ¹	2.096	2.191	1.868	1.981
Total feed cost, (LE)	14.09	13.50	10.77	10.32
Management/ Rabbit, (LE) ²	4	4	4	4
Total cost, (LE) ³	34.09	33.50	30.77	30.32
Total revenue, (LE) ⁴	54.93	55.70	54.91	57.22
Net revenue	20.84	22.20	24.14	26.90
Economical efficiency ⁵	0.6113	0.6627	0.7845	0.8872
Relative economic efficiency ⁶	100	108.4	128.3	145.1
Feed cost / kg LBW (LE) ⁷	5.64	5.33	4.31	3.97

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 16/ 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.