Performance of Rabbits Fed Diets Containing Different Levels of Energy and Lesser Galangal *(Alpinia Officinarum)*

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Abstract

This work aimed to study the effect of two different levels of ration energy supplemented with *Alpinia officinarum.* Rabbits were classified into six equal groups (G1-G6). The 1st and 4th groups received basal ration with 100 % and 90 % energy requirement and served as first and second control respectively. The 2nd and the 3rd groups received basal ration with 100 % energy requirement supplemented with *Alpinia officinarum* at the level of 0.5 and 1.0 %, respectively. The 5th and 6th groups received basal ration with 90 % energy requirement *with Alpinia officinarum* at the level of 0.5 and 1.0 %, respectively.

The 90% energy containing diet showed significant increased ($P<0.05$) in DM and CF digestibility, while EE digestibility was significantly ($P<0.05$) decreased. *Lesser galangal* as feed additives showed significant ($P<0.05$) increased in DM, OM, CF, NFE digestibility and TDN value. There were significant interaction values between energy and supplementation levels on digestibility coefficient of DM, OM, CF, EE, NFE and TDN value. Supplementation of *Lesser galangal* at 0.5 % or 1% significantly increased final body weight gain, ADG, feed conversion, while slightly decreased feed intake. The 90% energy and 1% *lesser galangal* (G_6) recorded the best values of final body weight, body daily weight gain and feed conversion.

The interaction values between energy and *lesser galangal* levels significantly increased ($P<0.05$) the carcass weight, dressing percentages and carcass cuts. The 90% energy and 1% *lesser galangal* (G_6) recorded the best values of carcass weight, dressing percentages and carcass cuts. *Lesser galangal* significantly ($P<0.05$) decreased the lungs (weight and % of SW); content of stomach and empty of small intestine (weight and % of SW). The interaction values between energy and *lesser galangal* levels significantly ($P<0.05$) increased the liver and total internal offal's (% of SW); lungs, full and content of stomach as well as digestive tract content (weight, g and % of SW).

Dietary 90% energy requirements with 0.5 % or 1% *lesser galangal* showed the high values of net revenue, economical efficiency and relative economic efficiency, while recorded the low value of feed cost/ kg live body weight (LE). Rabbits received the 90 % energy requirement with 0.5 % lesser galangal recorded the highest value of relative economic efficiency (111.4%) and the lowest value of feed cost/ kg live body weight (5.45 LE).

Keywords: Alpinia officinarum, Galangal, Rabbits, Growth performance, Digestibility, Carcass characteristics, 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 either of growth performance, immunity and the viability (El-Hindawy *et al.,* 1996). *Alpinia officinarum* rhizome has long been used as an anti-inflammatory, an analgesic, a stomachic and a carminative in traditional medicine (Lee *et al.,* 2009).

Lesser galangal (Kholengan) used is the dried rhizomes of *Alpinia officinarum* (AO) belonging to the family zingeberaeceae (Srividya *et al.,* 2010). The major component of lesser galangal is 1, 8-cineole (50%) with the balance largely made up of terpenes. The root contains a volatile oil resin, galangol, kaempferid, galangin and alpinin, starch, etc. The active principles are the volatile oil and acrid resin. (Srividya *et al.,* 2010). Methanol extract of (AO) rhizome showed a majority of the compound including tannins, alkaloids, flavonoids and saponins (Subramanian *et al.,* 2009).

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 *et al.,* 2005). Darylheptanoid isolated from lesser galangal suppressed the lipopolysaccharide (Yadav *et al.,* 2003). Six diarylheptanoids isolated from the rhizome of (AO) inhibitors of nitric oxide production in the lipopolysaccharide-activated macrophage cell (Lee *et al.,* 2006). Pancreatic lipase inhibitors from the rhizome of (AO) may be effective as hypolipidemic agents (Shin *et al.,* 2004). Galangin could lead to the development of new combination antibiotics against methicillin-resistant Staphylococcus aureus infection (Lee, 2008). Diarylheptanoid could interact with subunit A of Escherichia coli DNA gyrase (Subramanian *et al.,* 2009).

Alpinia officinarum has hemostatic actions that may provide a therapeutic potential for the management of deficient primary hemostasis (Subramanian *et al.,* 2009). *Alpinia officinarum* rhizomes is viable therapeutic for the treatment of acute and chronic arthritis (Lee *et al.,* 2009). All diarylheptanoids exhibited potential antiviral activity against influenza virus in vitro (Sawamura *et al.,* 2010). *Alpinia officinarum* rhizome as anti-inflammatory drug may be explained by the inhibition of nitric oxide production in activated macrophages (Lee *et al.,* 2006). Galangin may be agent for prevention of skin cancer (Lu *et al.,* 2007). *Alpinia officinarum* may be the potential source of free radical scavengers from natural plant (Kim *et al.,* 1997). The three new diarylheptanoids isolated from the ethanol extract from the rhizomes of *Alpinia officinarum* are antibacterial active (Zhang *et al.,* 2010).

This work aimed to evaluate the efficacy of the mixture of (AO) 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 54 male New Zealand White rabbits aged 4 weeks with an average body weight of 409 ± 4.92 g, 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 56 days, and the experimental groups were classified as follow:

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

Group 2 basal diet with 100 % energy requirement + 0.5% lesser galangal (G2),

Group 3 basal diet with 100 % energy requirement + 1 % lesser galangal (G3),

Group 4 basal diet with 90 % energy requirement and served as control (G4),

Group 5 basal diet with 90 % energy requirement + 0.5 % lesser galangal (G5) and

Group 6 basal diet with 90 % energy requirement + 1 % lesser galangal (G6).

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 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, lungs, liver, testes, kidneys and spleen were removed and individually weighed. Digestive tract was separated into stomach, small and large intestine, where full and empty weights were recorded. Weights of carcass, 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 11^{th} 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.

Digestible energy (DE) was calculated according to Cheek (1987) as following:

DE (MJ/ kg DM) = 4.36 – 0.04 x NDF%. Non fibrous carbohydrates (NFC), 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.

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 six tested rations (G1-G6) was 2.516, 2.512, 2.507, 2.254, 2.252 and 2.256 (MJ/ kg DM), respectively (Table 2). These variations were related to differ in ingredients that used in ration formulations. The 90% of energy level showed slightly increase in NDF, ADF, ADL and hemicellulose contents as well as cellulose content of experimental rations showed approximately the same trend (Table 2).

3.2 Nutrient digestibility and nutritive values of the experimental diets

Either 100% or 90% of energy level showed insignificant effects (P>0.05) on OM, CP and NFE digestibility and TDN value (Table 3). Lesser galangal as feed additives at 0.5 % or 1 % significantly (P>0.05) increased the DM, OM, CF, NFE digestibility's and TDN value, while showed insignificant effects on CP and EE digestibility's and DCP value (Table 3). These significant improvements may be due to the hard fiber nature of branched pieces of powdered rhizome are from 1.5 to 3 inches in length, and seldom more than 0.75 inch thick as noticed by (Srividya *et al.,* 2010).

The 90% energy level significantly improved (P<0.05) the DM and CF digestibility while EE digestibility was significantly (P<0.05) decreased (Table 3). This significant improved in DM and CF at the lesser energy level indicated that decreasing the dietary energy 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-fibre 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.

There were significant ($P<0.05$) interaction between the energy and lesser galangal levels on digestibility coefficient of DM, OM, CF, EE, NFE and TDN value (Table 4). These significant coefficient may be due to the diarylheptanoids isolated from the rhizome of (AO) inhibitors of nitric oxide production in lip polysaccharide (Lee *et al.,* 2006).On other hand may be due to the antibacterial effect of *lesser galangal*, as shown by (Eumkeb *et al.,* 2010) who said that galangin caused damage to the ultra structures of the cells of penicillinase and β-lactamase penicillinase and β-lactamase strain.

However, it had no significant effect on CP digestibility and DCP value, rabbits that received 100% energy requirement + 0.5 % *lesser galangal* (G_2) showed that the best digestion coefficients of CP, EE, NFE and nutritive values TDN and DCP (Table 4). This may be due to the completely covered energy requirement of rabbit. On the other hand rabbits received 90 % energy requirement + 1% *lesser galangal* (G_6) recorded the best DM, OM and CF digestibility. This may be due to the moderate potent antimicrobial activity of lesser galangal against the Bacillus cereus, Staphylococcus aureas, Pseudomonas auroginosa and Escherichia coli (Srividya *et al.,* 2010), or may be due to the ability of lesser galangal on enhancing insulin sensitivity (Talpur *et al.,* 2005).

3.3 Growth performance of the experimental groups

The energy levels showed insignificant effect on final weight, total body weight gain, ADG (g); feed intake as DM, TDN, CP, and DCP, (g/day) and feed conversion (g intake /g gain) of DM, TDN, CP and DCP, respectively (Table 5). *Lesser galangal* supplementation at 0.5 % or 1% significantly increased final body weight gain, ADG, feed conversion, while slightly decreased feed intake. These significant increases may be due to the damage repairing effect in digestive tract as reporting by (Purnak *et al.,* 2010) who reported that, (AO) is considered adjunctive drug for treated acute gastrointestinal bleeding case with a low platelet count and defective hemostasis.

Addition of *Lesser galangal* at 1% significantly ($P<0.05$) improved the final body weight gain by (2.31%), and average daily gain by (2.54%) compared to the control group. This significant increased in body weight may be due to the lesser galangal pleasantly aromatic and mildly spicy taste, and is suitable for all conditions where the central areas of the body need greater warmth, as noticed by (Srividya *et al*., 2010).

There were no interactions between energy and *lesser galangal* levels (Table 6). The 90% energy with 1% lesser galangal (G_6) 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 hypolipidemic activity of (AO) is due to the inhibition of pancreatic lipase. Similar result obtained by (Shin *et al.,* 2003).

3.4 Carcass characteristics of the experimental groups

Both energy and lesser galangal levels had no significant effect ($P>0.05$) on digestive tract, carcass cuts and chemical analysis of the 9, 10 and 11^{th} ribs (Table 7).

There were insignificant interaction values between energy and lesser galangal levels on digestive tract empty body weight, edible offal's and chemical analysis of the 9, 10 and 11^{th} ribs (Table 8). The 90% energy and 1% lesser galangal (G_6) recorded the best values of carcass weight, dressing percentages and carcass cuts. These best values may be due to the effective of lesser galangal as hypolipidemic agents (Shin *et al.,* 2004).

The significant ($P<0.05$) interaction may be due to the ability of lesser galangal on repairing damage protein as shown by (Tabata *et al.,* 2009) who cleared that diarylheptanoids derived from (AO) have marked antitumor activities activity against neuroblastoma cells. In other words, may be due to its effect for dyspepsia biliary symptoms, bowel spasm and angina as reported by (Shin *et al.,* 2003).

3.5 External, internal offal's (Giblets) and digestive tract measurements

The energy levels showed insignificant effect on external, internal offal's (Giblets) and digestive tract measurements (Table 9). Lesser galangal also showed insignificant effect on external offal's; internal offal's (Giblets) except for lungs (weight and % of SW) that showed significant decreased compared to control; digestive tract except for content of stomach and empty of small intestine (weight and % of SW) were significant decreased compared to control. The significant decrease in both lungs and empty of small intestine (weight and % of SW), may be due to the inhibitory effect of fatty acid syntheses of lesser galangal as reported by (Shin *et al.,* 2004). Similar results cleared by (Li and Tian 2003) who noted that, *galangal* extract can potently inhibit fatty-acid syntheses.

The interaction values between energy and lesser galangal levels showed significant increase ($P<0.05$) on liver and total internal offal's (% of SW); lungs, full & content of stomach and digestive tract content (weight, g and % of SW) (Table 10). These results may be due to that galangin with anti-oxidative and free radical scavenging activities is capable of modulating enzyme activities as cleared by (Heo *et al.,* 2001).

3.6 Economical evaluation

The profitability of using *lesser galangal* depends upon the price of tested diets and the growth performance of rabbits fed these diets (Table 11). The cost of one kg feed, (LE) was decreased by 6.92, 4.42 and 3.23 % in G_4, G_5 and G_6, respectively compared to control diet G_1. 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 0.5 % or 1% *lesser galangal* 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 lesser galangal 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 0.5% lesser galangal (G_5) diet recorded the highest value of relative economic efficiency (111.4%) and the lowest value of feed cost/ kg live body weight (5.45 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 at level of (1:1:1) of *Artemisia herba-alba, Matricaria recutita L.* and *Chrysanthemum coronarium.*

4. Conclusion

Lowering the dietary energy level from 100% to 90% of requirements with 0.5 % lesser galangal as feed additives improved the DM, OM, CP, CF, NFE digestibility's and TDN and DCP values as well as realized the highest value of relative economic efficiency followed by the lowest value of feed cost/ kg live body weight. Our data suggest that AO 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	G_5	G_6
Yellow corn	190.00	190.00	190.00	----	----	----
Barley grain	100.00	100.00	100.00	100.00	100.00	100.00
Wheat bran	185.00	185.00	185.00	300.00	300.00	300.00
Soybean meal 44% CP	150.00	150.00	150.00	115.00	115.00	115.00
Alfalfa hay	350.00	350.00	350.00	460.00	460.00	460.00
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	4.00	4.00	4.00	5.00	5.00	4.00
Anti fungal agent	4.00	4.00	3.00	4.00	4.00	3.00
Bone meal	9.00	4.00	----	8.00	3.00	----
Supplement	----	5.00	10.00	----	5.00	10.00
Price, L.E / Ton	2197	2252	2298	2045	2100	2126

** 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	G_5	G_6
Dry matter	91.18	91.47	92.65	92.34	92.39	92.47
Organic matter	89.93	90.02	88.94	88.51	88.61	89.29
Crude protein	16.86	16.91	16.81	16.67	16.73	16.59
Crude fiber	13.18	13.57	13.47	14.29	14.21	14.19
Ether extract	4.09	4.02	3.97	3.89	3.75	3.68
Nitrogen free extract	55.80	55.52	54.69	53.66	53.92	54.83
Ash	10.07	9.98	11.06	11.49	11.39	10.71
NFC*	22.87	22.88	21.83	15.31	15.43	16.42
DE (MJ/kg DM)	2.516	2.512	2.507	2.254	2.252	2.256
Cell wall constituents						
NDF	46.11	46.21	46.33	52.64	52.70	52.60
ADF	18.30	18.42	18.51	20.02	19.93	19.85
ADL	6.28	6.33	6.44	7.43	7.65	7.82
Hemicellulose	27.81	27.79	27.82	32.62	32.77	32.75
Cellulose	12.02	12.09	12.07	12.59	12.28	12.03

Digestible energy (DE) was calculated as following equation: 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.

** Non fibrous carbohydrates (NFC), calculated using the following equation:*

NFC = 100 – {CP + EE + Ash + NDF}.

Table 3. Effect of energy and supplementation levels on digestibility coefficients and nutritive values

Item	Experimental diets						SEM
	Energy levels		SEM	Supplementation			
	100%	90%		0%	0.5 %	1 %	
Digestibility coefficients							
DM	79.45^{b}	83.62^{a}	1.23	78.72^{b}	80.54^{b}	85.34^{a}	1.23
OM	75.43	75.97	0.77	72.45^{b}	77.46^{a}	77.19^{a}	0.77
CP	81.48	81.88	0.57	80.27	82.81	81.95	0.57
CF	47.40^{b}	54.57^{a}	1.93	42.21^{b}	54.11^{a}	56.63^{a}	1.93
EE	94.82^{a}	91.35^{b}	0.71	93.91	92.47	92.87	0.71
NFE	78.94	78.71	0.75	76.01^{b}	80.64^{a}	79.82^{a}	0.75
Nutritive values							
TDN%	72.38	71.79	0.70	69.33^{b}	73.68^{a}	73.24^{a}	0.70
DCP%	13.74	13.64	0.10	13.46	13.93	13.69	0.10

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 digestibility coefficients and nutritive values

Item	Experimental diets						SEM
	100% Energy requirements			90% Energy requirements			
	G_1	G_2	G_3	G_4	G_5	G_6	
Digestibility coefficients							
DM	79.86^{b}	79.00^{b}	79.49^{b}	77.59^{b}	82.09^{b}	91.18^{a}	1.23
OM	72.06^{c}	77.90^{a}	76.33^{abc}	72.85^{bc}	77.01^{ab}	78.05^{a}	0.77
CP	79.58	83.11	81.74	80.97	82.51	82.16	0.57
CF	36.86^{d}	51.59^{bc}	53.76^{abc}	47.56^{d}	56.63^{ab}	59.51^{a}	1.93
EE	96.80^{a}	95.03^{ab}	92.64^{bc}	91.02^{c}	89.91^{c}	93.11^{a}	0.71
NFE	76.28^{b}	81.49^{a}	79.05^{ab}	75.74^{b}	79.79^{ab}	80.60^{ab}	0.75
Nutritive values							
TDN%	69.75^{b}	74.89^{a}	72.50^{ab}	68.91^{b}	72.47^{ab}	73.98^{a}	0.70
DCP%	13.14	14.05	13.74	13.50	13.80	13.63	0.10

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 5. Effect of energy and supplementation levels on growth performance of the experimental groups

Item	Experimental diets						SEM
	Energy levels		SEM	Supplementation			
	100%	90%		0%	1%	2%	
Initial weight, g	406	411	4.92	413	411	401	4.92
Final weight, g	2416	2433	7.09	2403	2432	2437	7.09
Gain, g	2010	2022	8.21	1990^{b}	2021^{ab}	2036^{a}	8.21
ADG, g	35.9	36.1	0.15	35.5^{b}	36.1^{ab}	36.4^{a}	0.15
Feed intake as:							
DM, g/day	104.04	107.90	4.83	109.10	104.25	105.10	4.83
TDN, g/day	75.57	77.36	3.47	75.62	76.81	76.97	3.47
CP, g/day	17.60	17.98	0.81	18.28	17.53	17.55	0.81
DCP, g/day	14.21	14.72	0.66	14.49	14.52	14.38	0.66
Feed conversion (g intake /g gain) of							
DM	2.91	2.99	0.13	3.07	2.89	2.89	0.13
TDN	2.11	2.14	0.10	2.13	2.13	2.12	0.10
CP	0.49	0.50	0.02	0.52	0.49	0.48	0.02
DCP	0.40	0.41	0.02	0.41	0.40	0.39	0.02

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 diets: 100% Energy requirements			90% Energy requirements			SEM
	G_1	G_2	G_3	G_4	G_5	G_6	
Initial weight, g	411	409	398	416	413	404	4.92
Final weight, g	2396	2424	2427	2411	2440	2449	7.09
Gain, g	1985	2015	2029	1995	2027	2045	8.21
ADG, g	35.4	36.0	36.2	35.6	36.2	36.5	0.15
Feed intake as:							
DM, g/day	103.80	104.00	105.44	114.41	104.49	104.77	4.83
TDN, g/day	72.40	77.89	76.44	78.84	75.72	77.51	3.47
CP, g/day	17.50	17.59	17.72	19.07	17.48	17.38	0.81
DCP, g/day	13.92	14.61	14.49	15.45	14.42	14.28	0.66
Feed conversion (g intake /g gain) of							
DM	2.93	2.89	2.91	3.21	2.89	2.87	0.13
TDN	2.05	2.16	2.11	2.21	2.09	2.12	0.10
CP	0.49	0.49	0.49	0.54	0.48	0.48	0.02
DCP	0.39	0.41	0.40	0.43	0.40	0.39	0.02

SEM, standard error of the mean.

Table 7. Effects of energy and supplementation levels on dressing percentages, carcass cuts and chemical analysis of the 9, 10 and 11 th ribs of the experimental groups

Item	Experimental diets: Energy levels		SEM	Supplementation			SEM
	100%	90%		0%	1%	2%	
Slaughter weight (SW), g	2451	2449	5.42	2467	2440	2443	5.42
Digestive tract, g							
Full	386	361	12.42	379	369	373	12.42
Empty	141	130	5.28	126	142	138	5.28
Content	235	231	10.10	253	227	235	10.10
Empty body weight (EBW), g	2216	2218	9.86	2214	2213	2208	9.86
Edible offal's, g (Giblets)	123	130	8.47	116	135	128	8.47
Carcass weight (CW), g	1126	1132	13.00	1104	1132	1151	13.00
Carcass weight*	1249	1262	9.97	1210	1267	1279	9.97
Dressing percentages (DP)%							
DP ^{1}	45.92	46.24	0.54	44.77	46.38	47.11	0.54
DP ^{2}	50.78	51.06	0.52	49.97	51.13	51.74	0.52
DP ^{3}	56.97	56.92	0.41	56.08	57.25	57.50	0.41
Carcass cuts							
Fore part							
Weight, g	389	390	4.95	382	390	397	4.95
% of CW	34.55	34.44	0.09	34.55	34.47	34.46	0.09
Middle part							
Weight, g	237	238	3.02	232	239	241	3.02
% of CW	21.03	21.02	0.16	21.08	21.04	20.94	0.16
Hind part							
Weight, g	500	504	5.86	490	503	513	5.86
% of CW	44.42	44.54	0.12	44.37	44.49	44.60	0.12
Chemical analysis of the 9,10 and 11 th ribs							
Dry matter	33.58	32.75	0.90	32.14	33.17	34.18	0.90
Chemical composition on DM basis							
CP	55.62	62.28	1.76	59.69	58.45	58.71	1.76
EE	36.95	29.51	1.97	32.02	33.96	33.71	1.97
Ash	7.43	8.21	0.29	8.29	7.60	7.58	0.29

** Carcass weight: included edible offal's (Liver, heart, kidneys, lungs, spleen and testes).*

DP 1 : Dressing percentages calculated as (carcass weight / slaughter weight).

DP 2 : Dressing percentages calculated as (carcass weight / empty body weight).

DP 3 : Dressing percentages calculated as (carcass weight + edible offal's / empty body weight)

EBW: Empty body weight = Slaughter weight – digestive tract content..

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

Item	Experimental diets						SEM
	100% Energy requirements			90% Energy requirements			
	G_1	G_2	G_3	G_4	G_5	G_6	
Slaughter weight (SW), g	2467	2440	2447	2467	2440	2440	5.42
Digestive tract, g							
Full	354	390	381	403	348	331	12.42
Empty	125	159	139	127	125	137	5.28
Content	229	231	242	276	223	194	10.10
Empty body weight (EBW), g	2238	2209	2204	2190	2217	2246	9.86
Edible offal's, g (Giblets)	131	136	144	144	134	112	8.47
Carcass weight (CW), g	1129^{abc}	1149^{ab}	1099^{bc}	1080^{c}	1114^{bc}	1203^{a}	13.00
Carcass weight*	1260	1285	1243	1223	1248	1315	9.97
Dressing percentages (DP)%							
DP ^{1}	45.76^{bc}	47.09^{ab}	44.91^{bc}	43.78^{c}	45.66^{bc}	49.30^{a}	0.54
DP ^{2}	50.45^{ab}	52.01^{ab}	49.86^{b}	49.32^{b}	50.25^{ab}	53.56^{a}	0.52
DP ^{3}	56.30	58.17	56.40	55.84	56.29	58.55	0.41
Carcass cuts							
Fore part							
Weight, g	393^{ab}	397^{ab}	377^{b}	370^{b}	383^{ab}	417^{a}	4.95
% of CW	34.84^{ab}	34.51^{ab}	34.27^{b}	34.27^{b}	34.40^{b}	34.65^{a}	0.09
Middle part							
Weight, g	236	242	232	230	234	250	3.02
% of CW	20.87	21.08	21.15	21.28	21.04	20.74	0.16
Hind part							
Weight, g	500^{b}	510^{ab}	490^{b}	480^{b}	497^{b}	536^{a}	5.86
% of CW	44.29	44.41	44.58	44.45	44.56	44.61	0.12
Chemical analysis of the 9,10 and 11 th ribs							
Dry matter	33.45	33.38	33.91	30.82	32.96	34.46	0.90
Chemical composition on DM basis							
CP	54.75	56.95	55.17	64.64	59.94	62.25	1.76
EE	37.42	35.99	37.44	26.61	31.93	29.99	1.97
Ash	7.83	7.06	7.39	8.75	8.13	7.76	0.29

** Carcass weight: included edible offal's (Liver, heart, kidneys, lungs, spleen and testes).*

DP ^{1} : Dressing percentages calculated as (carcass weight / slaughter weight).

DP ^{2} : Dressing percentages calculated as (carcass weight / empty body weight).

DP ^{3} : Dressing percentages calculated as (carcass weight + edible offal's / empty body weight)

EBW: Empty body weight = Slaughter weight – digestive tract content..

a ,b and c: Means in the same row having different superscripts differ significantly (P<0.5).

Table 9. Effects of energy and supplementation levels on external, internal offal's (Giblets) and digestive tract measurements of the experimental groups

Item		Experimental diets						
		Energy levels		SEM	Supplementation			SEM
		100%	90%		0%	0.5 %	1%	
Slaughter weight (SW), g		2451	2449	5.42	2467	2440	2443	5.42
External offal's:								
	weight, g	666	678	14.12	698	656	662	14.12
	% of SW	24.94	27.69	1.15	24.97	26.87	27.11	1.15
Internal offal's(Giblets):								
Liver	weight, g	80.78	73.89	3.79	80.33	80.83	70.83	3.79
	% of SW	7.22	6.60	0.38	7.29	7.21	6.24	0.38
Heart	weight, g	10.11	10.33	0.48	9.33	10.83	10.50	0.48
	% of SW	0.90	0.92	0.05	0.85	0.96	0.92	0.05
Lungs	weight, g	15.00	14.78	0.63	17.17[a]	13.33[b]	14.17[b]	0.63
	% of SW	1.34	1.32	0.06	1.56[a]	1.18[b]	1.24[b]	0.06
Kidneys	weight, g	20.67	20.00	0.82	19.67	19.67	21.67	0.82
	% of SW	1.84	1.77	0.08	1.79	1.74	1.90	0.08
Spleen	weight, g	1.22	1.22	0.10	1.33	1.00	1.33	0.10
	% of SW	0.11	0.11	0.01	0.12	0.09	0.12	0.01
Tests	weight, g	9.33	8.56	0.53	9.50	7.67	9.67	0.53
	% of SW	0.83	0.85	0.03	0.86	0.83	0.84	0.03
Total	weight, g	137	130	4.85	137	135	128	4.85
	% of SW	12.24	11.57	0.51	12.46	12.00	11.26	0.51
Digestive tract measurements								
Stomach:								
Full	weight, g	110.67	95.89	6.28	106.83	110.33	92.67	6.28
	% of SW	4.52	3.91	0.26	4.33	4.52	3.79	0.26
Empty	weight, g	31.56	27.56	1.57	27.17	30.17	31.33	1.57
	% of SW	1.29	1.13	0.07	1.10	1.24	1.29	0.07
Content	weight, g	79.11	68.33	5.68	79.67[a]	80.17[a]	61.33[b]	5.68
	% of SW	3.23	2.79	0.23	3.23[a]	3.29[a]	2.51[b]	0.23
Small intestine:								
Full	weight, g	100.00	103.44	4.56	97.17	111.33	96.83	4.56
	% of SW	4.09	4.22	0.19	3.94	4.56	3.97	0.19
Empty	weight, g	60.00	62.56	2.90	53.83[b]	68.67[a]	61.33[ab]	2.90
	% of SW	2.45	2.55	0.12	2.18[b]	2.82[a]	2.51a[b]	0.12
Content	weight, g	40.11	40.89	3.48	43.33	42.67	35.50	3.48
	% of SW	1.64	1.67	0.14	1.76	1.75	1.46	0.14
Large intestine:								
Full	weight, g	164.11	161.56	7.94	174.50	147.50	166.50	7.94
	% of SW	8.70	6.59	0.32	7.08	6.05	6.81	0.32
Empty	weight, g	49.22	39.56	2.45	45.00	43.00	45.17	2.45
	% of SW	2.01	1.62	0.10	1.83	1.76	1.85	0.10
Content	weight, g	114.89	122.00	6.81	129.50	10.50	121.33	6.81
	% of SW	4.69	4.98	0.27	5.25	4.29	4.96	0.27
Digestive tract:								
Full	weight, g	374.88	360.88	12.43	378.50	369.17	356.00	12.43
	% of SW	15.31	14.73	0.51	15.34	15.14	14.57	0.51
Empty	weight, g	140.78	129.67	5.28	12.600	141.83	137.83	5.28
	% of SW	5.75	5.30	0.22	5.11	5.82	5.65	0.22
Content	weight, g	235.13	231.22	10.71	257.80	227.33	218.17	10.71
	% of SW	9.56	9.43	0.41	10.24	9.32	8.92	0.41

External offal's: included (Head, fur, legs and ears).

a, and b: Means in the same row within each treatment having different superscripts differ significantly ($P<0.5$).

Table 10. Effect of interactions between energy and supplementation levels on external, internal offal's (Giblets) and digestive tract measurements of the experimental groups

Item	Experimental diets						SEM
	100% Energy requirements			90% Energy requirements			
	G_1	G_2	G_3	G_4	G_5	G_6	
Slaughter weight (SW), g	2467	2440	2447	2467	2440	2440	5.42
External offal's	706	613	679	690	698	646	14.12
weight, g % of SW	28.63	24.14	27.75	27.97	28.62	26.46	1.15
Internal offal's(Giblets):							
Liver weight (g)	77.33	81.67	83.33	83.33	80.00	58.33	3.79
% of SW	6.85^{ab}	7.23^{ab}	7.59^{ab}	7.73^{a}	7.19^{ab}	4.89^{b}	0.38
Heart weight(g)	8.67	10.00	11.67	10.00	11.67	9.33	0.48
% of SW	0.77	0.87	1.06	0.93	1.05	0.78	0.05
Lungs weight(g)	16.67^{ab}	13.33^{b}	15.00^{ab}	17.67^{a}	13.33^{b}	13.33^{b}	0.63
% of SW	1.48^{ab}	1.17^{b}	1.37^{ab}	1.64^{a}	1.19^{b}	1.12^{b}	0.06
Kidneys weight(g)	17.67	21.00	23.33	21.67	18.33	20.00	0.82
% of SW	1.56	1.84	2.12	2.01	1.64	1.67	0.08
Spleen weight(g)	1.33	1.00	1.33	1.33	1.00	1.33	0.10
% of SW	0.12	0.09	0.12	0.12	0.09	0.11	0.01
Tests weight(g)	9.33	9.00	9.67	9.67	9.67	9.67	0.53
% of SW	0.83	0.79	0.88	0.89	0.86	0.81	0.03
Total weight (g)	131	136	144	144	134	112	4.85
% of SW	11.61^{ab}	11.99^{ab}	13.14^{a}	13.32^{a}	12.02^{ab}	9.38^{b}	0.51
Digestive tract measurements							
Stomach:							
Full weight(g)	97.33^{a}	110.33^{a}	124.33^{a}	116.33^{a}	110.33^{a}	61.00^{b}	6.28
% of SW	3.95^{a}	4.52^{a}	5.08^{a}	4.71^{a}	4.52^{a}	2.50^{b}	0.26
Empty weight(g)	27.33	34.00	33.33	27.00	26.33	29.33	1.57
% of SW	1.11	1.40	1.37	1.10	1.08	1.20	0.07
Content weight(g)	70.00^{a}	76.33^{a}	91.00^{a}	89.33^{a}	84.00^{a}	31.67^{b}	5.68
% of SW	2.84^{a}	3.12^{a}	3.71^{a}	3.61^{a}	3.44^{a}	1.30^{b}	0.23
Small intestine:							
Full weight(g)	83.33	115.00	102.00	111.00	107.67	91.67	4.56
% of SW	3.37	4.72	4.17	4.50	4.41	3.76	0.19
Empty weight(g)	49.33^{b}	73.33^{a}	57.3^{ab}	58.3^{ab}	64.0^{ab}	65.3^{ab}	2.90
% of SW	2.00^{ab}	3.01^{a}	2.34^{b}	2.36^{ab}	2.62^{ab}	2.68^{ab}	0.12
Content weight(g)	34.00^{ab}	41.67^{ab}	44.7^{ab}	52.67^{a}	$43.\ 7^{ab}$	26.34^{b}	3.48
% of SW	1.37^{ab}	1.71^{ab}	1.83^{ab}	2.14^{a}	1.79^{ab}	1.08^{b}	0.14
Large intestine:							
Full weight(g)	173.00	164.67	154.67	176.00	130.33	178.33	7.94
% of SW	7.02	6.76	6.33	7.13	5.34	7.30	0.32
Empty weight(g)	48.33	51.33	48.00	41.67	34.67	42.33	2.45
% of SW	1.96	2.11	1.97	1.69	1.42	1.74	0.10
Content weight(g)	124.67	113.34	106.67	134.33	95.66	136.00	6.81
% of SW	5.06	4.65	4.36	5.44	3.92	5.56	0.27
Digestive tract:							
Full weight(g)	354.00	390	381.00	403.00	348.00	331.00	12.43
% of SW	14.34	16.00	15.58	16.35	14.28	13.56	0.51
Empty weight(g)	125.00	159.00	139.00	127.00	125.00	137.00	5.28
% of SW	5.07	6.51	5.68	5.15	5.12	5.62	0.22
Content weight, g	229^{ab}	231^{ab}	242^{ab}	276^{a}	223^{ab}	194^{b}	10.71
% of SW	9.27^{ab}	9.49^{ab}	9.90ab	11.20^{a}	9.16^{ab}	7.94^{b}	0.41

External offal's: included (Head, fur, legs and ears).

a, and b: Means in the same row having different superscripts differ significantly (P<0.5).

Table 11. Economical evaluation of the experimental groups

Item	Experimental diets					
	100% Energy requirements			90% Energy requirements		
	G_1	G_2	G_3	G_4	G_5	G_6
Marketing weight, Kg	2.396	2.424	2.427	2.411	2.440	2.449
Feed consumed / rabbit, kg	6.373	6.367	6.373	6.938	6.334	6.345
Costing of one kg feed, (LE)[1]	2.197	2.252	2.298	2.045	2.100	2.126
Total feed cost, (LE)	14.00	14.34	14.65	14.19	13.30	13.49
Management/ Rabbit, (LE)[2]	4	4	4	4	4	4
Total cost, (LE)[3]	30.00	30.34	30.65	30.19	29.30	29.49
Total revenue, (LE)[4]	47.92	48.48	48.54	48.22	48.80	48.98
Net revenue	17.92	18.14	17.89	18.03	19.50	19.49
Economical efficiency[5]	0.5973	0.5979	0.5837	0.5972	0.6655	0.6609
Relative economic efficiency[6]	100	100.1	97.7	99.98	111.4	110.6
Feed cost / kg LBW (LE)[7]	5.84	5.92	6.04	5.89	5.45	5.51

[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 12/ rabbit + management.*

[4] *Body weight x price of one kg at selling which was LE 20.*

[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.*