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Performance of Sinai Laying Hens Fed Tow Levels of Energy in Diets Containing Three Levels of Protein

Alderey, A. A. and O. A. El-Weshahy
Animal Production Research Institute, Agriculture Research Center, Ministry of Agriculture, Dokki, Cairo, Egypt.

ABSTRACT

This experiment aimed to study effects of metabolizable energy and protein levels on the productive and reproductive performance of Sinai laying hens from 24 to 40 wk. A total of 180 Sinai laying hens was randomly assigned to six experimental diets of 2,850 (H_{ME} = high ME), or 2,700 = low ME) kcal of ME/kg, each containing CP levels of 18% (H_{CP} = high CP), 16% (M_{CP} = medium CP), or 14% (L_{CP} = low CP) in a 2× 3 factorial arrangement of treatments. Each dietary treatment contained 30 single-caged birds. The results were obtained as follows: final body weight (FBW), change in body weight (CBW), daily protein intake, daily energy intake, protein efficiency ratio (PER), energy efficiency ratio (EER), feed conversion ratio (FCR), egg number (EN), egg weight (EW), daily egg mass (EM), hen-day egg production rate (HDEP), were significantly improved in birds fed the high-energy-diets ($P<0.01$) compared with those fed the low-energy-diets. However, birds fed the low-ME diets consumed more feed compared with fed on high-energy-diets. Birds fed the diets termed as (H_{CP} or M_{CP}) displayed significantly higher ($P\leq0.01$) final body weight (FBW) and change in body weight, egg number and hen-day egg production rate than those received the low-CP diet ($P<0.01$). Increasing dietary protein level led to a gradual improvement in FBW (g), CBW, daily protein intake, EER, FCR, egg number, egg weight, daily egg mass and hen-day egg production rate. Interactions between ME and CP levels in the previously mentioned criteria were significant ($P<0.05$). Plasma cholesterol was significantly increased as a result of feeding on the high-ME diets compared with those given the low-ME diets. The same trend was also observed in respect of protein levels where there were significant differences on plasma activity of ALT which significantly increased ($P\leq0.01$) when hens were fed on the high-CP diets compared with those fed on the diets containing L_{CP} and M_{CP}. Plasma cholesterol was significantly increased ($P\leq0.01$) by increasing ME level in the diet with any dietary protein level compared with other treatment groups.The present results revealed that the diets containing ME level of 2,850 kcal/kg with 18 or 16% protein can improve egg production characteristics of Sinai laying hens. From the economic view point it can be suggested that a diet containing 16% protein with 2850 kcal/kg is optimal for Sinai laying hens to achieve the highest profitability compared with other treatments during studied period from 28-40 weeks of age.

Keywords: Dietary Metabolizable energy and Crude protein levels, Sinai laying hens productive and Reproductive Performance.

INTRODUCTION

It is well known that dietary energy and protein are the most important nutrients in layer diets. The laying hens utilize the nutrients provided in their diets to produce eggs, so, the formulation of the diets is very important to producers since feed cost account for 65 to 75% of the cost of egg production (Bell and Weaver, 2002). Dietary energy levels can affect the cost of the production, because increasing energy by the addition of fat can significantly decrease feed intake, increase egg weight, and improve feed conversion ratio (Grobas *et al.*, 1999, Wu G. *et al.*, 2005). Feeding inadequate energy levels may result in a reduction in egg production and body weight, and poor egg quality (Araujo and Peixoto, 2005). In this respect of Hussein *et al.* (2010) reported that productive performance, egg quality or egg fertility and hatchability of Sinai laying hens were not significantly affected as a result of increasing protein content from 14-18% in the diets. Meanwhile, Mareiy *et al.* (2009) fed local laying hens from 24-40 wks of age on diet with different nutrient densities (CP, ME, lysine, methionine, Ca and available P) and observed that body weight gains, feed intake of hens were significantly affected by experimental treatments. They also reported that egg production, egg mass, egg weight and feed intake were ($P<0.05$) improved with increasing nutrient density of diet by 5 or 10% over the control diet. They also found that fertility %, hatchability % and chick weight at hatch were positively affected by elevating the dietary nutrient density. Tesfaye *et al.* (2019) observed no significant variations in final body weight, egg production, egg weight, FC, egg quality, fertility and hatchability when hens fed on diets different protein-energy levels (16-2750, 16.5-2800, 17-2900 and 16% CP-2700 ME kcal/kg diet) but egg mass, feed efficiency and profitability were significantly better in hens fed the diet had at 16.5% CP and ME at 2800 kcal /kg compared with other diets.

Technically laying hens, like other organisms, do not have a requirement for the molecule of crude protein itself. However, adequate CP content must be available in the diet to provide them with the essential amino acids (NRC, 1994). A lot of nutritionists have studied how the egg weight is influenced by diet characteristics. Increasing diet protein has resulted in an improvement in egg size (Keshavarz and Nakajima, 1995). Shim *et al.* (2013) demonstrated that dietary protein level is a limiting factor for body weight, daily feed intake, egg weight, egg production, and feed conversion ratio.

Numerous studies have been carried out on the nutrient requirements of laying hens, but few studies have been done using the local chickens Sinai. Therefore, the aim of this experiment was to study effects of different concentrations of dietary ME and CP on productive and reproductive performance of Sinai laying hens from 24 - 40 weeks of age.

MATERIALS AND METHODS

An experiment was conducted at Gimmizah Research Station, Animal Production Research Institute, Agriculture Research Center, Ministry of Egypt. One hundred and eighty Sinai laying hens (24-wk-old) were used in this experiment. The hens were distributed at random to six equal experimental treatments, each with 30 hens. All birds were weighed individually and kept in wire cages (40 × 35 × 60 cm) under the same managerial condition. The experimental design used was completely randomize with factorial arrangement of treatments (2X3). Six experimental diets containing two metabolizable energy (ME) levels 2700 (L_{ME} = low ME) and 2850 (H_{ME} = high ME) kcal/kg, and three crude protein levels being 18% (H_{CP} = high CP), 16% (M_{CP} = medium CP), or 14% (L_{CP} = low CP) were formulated as shown in Table 1. The suggested dietary energy and protein levels for Sinai laying hens were intended to define the optimal levels of dietary energy and protein which can optimize their productive and reproductive performance. The experiment period was terminated at 40 weeks of age. Feed and water was offered *ad-libitum* through the entire experimental period. A constant daily photoperiod of 16 hours was used.

Table 1. The composition and calculated analysis of the experimental diets fed to Sinai laying hens

Ingredients	Experimental diets					
	1	2	3	4	5	6
Yellow corn	62.00	62.00	57.40	63.50	62.75	59.30
Soy bean meal 44% CP	18.50	18.00	25.40	19.40	20.50	25.32
Corn gluten meal 62% CP	0.00	4.00	3.00	0.00	3.00	3.70
Wheat bran	8.30	6.10	3.60	4.50	2.10	0.0
Limestone	7.70	7.70	7.70	7.70	7.70	7.60
Di-calcium phosphate	1.60	1.60	1.60	1.60	1.60	1.60
Soya Oil	1.30	0.00	0.70	2.70	1.75	1.88
NaCl	0.30	0.30	0.30	0.30	0.30	0.30
*Vit. + Min. Premix	0.30	0.30	0.30	0.30	0.30	0.30
Total	100	100	100	100	100	100
**Calculated analysis						
Crude Protein %	14.16	16.09	17.9	14.10	16.00	17.92
ME (kcal/kg)	2701	2702	2703	2853	2852	2845
Crude fiber %	3.69	3.497	3.629	3.372	3.28	3.28
Ether Extract%	4.26	2.958	3.42	5.31	4.58	4.47
Calcium %	3.281	3.279	3.40	3.279	3.28	3.25
Non-phytate P.%	0.442	0.440	0.432	0.432	0.431	0.423
Lys., %	0.749	0.759	0.938	0.751	0.797	0.926
Meth., %	0.30	0.32	0.32	0.29	0.31	0.346
Meth. & Cyst.	0.516	0.608	0.644	0.510	0.591	0.650
Feed cost (L.E/kg)	4.549	4.763	4.974	4.747	4.958	5.212

***Premix at 0.3 % of the diet supplies, the following per kg of the diets: Vit. A 10000 IU; Vit. cholecalciferol 3120 IU; Vit. E., 36 IU; menadione, 24 mg; Thiamine, 1.2 mg; Pyridoxine, 2.4 mg; Pantothenic acid, 14.4 mg; Vit. B12, 0.02 mg; Riboflavin, 7.2 mg; Folic acid, 0.72 mg; Niacin, 60 mg; Biotin, 0.06 mg; Choline, 250 mg; Zn, 100 mg; Fe, 80 mg; Copper 12 mg; Cobalt 100 mg; Iodine, 1 mg; Se, 0.3 mg; Mn, 55 mg; ethoxyquin 3000 mg.**

**** according to NRC,1994.**

Criteria response:

Live body weight for each hen was recorded at the beginning and the end of the experimental period (24 and 40 wks); hence change in body weight (CBW) was calculated. Egg number (EN) was recorded daily but feed intake and egg weight (EW) were determined once a week. Egg mass (EM), feed conversion ratio (FCR) (g feed intake: g egg mass), protein efficiency ratio (PER) (g CP intake / g egg mass), energy efficiency ratio (EER) (kcal ME intake/ g egg mass) were also calculated.

Egg quality measurements were performed to determine some external and internal indices, and egg components. At 30, 31 and 32 weeks of age 30 freshly-laid eggs were randomly collected from each treatment. After that they were weighed individually and the widths and lengths were measured to determine egg shape index. Then, they were broken onto a smooth level surface to measure albumen height, yolk height and yolk diameter were measured. The weights of shell and yolk for individual eggs were determined while; shell thickness was measured using a standard micrometer. Yolk index was calculated as yolk height × 100 divided by yolk diameter. Egg-shape index was calculated as egg width × 100 divided by egg length. Egg specific gravity was calculated according to Harms *et al.* (1990). Egg surface area (ESA) = $3.9782EW^{0.7056}$ (Carter, 1974, 1975).

The thick albumen height and egg weight were used to calculate the Haugh unit score for each egg as indicated by Larbier and Leclercq (1994), as follows:

$$\textbf{Haugh units} = 100 \log (H + 7.57 - 1.7w^{0.37})$$

Where H is thick albumen height (mm) and W is egg weight (g).

Hens of each experimental group were artificial inseminated with a fixed volume of freshly collected semen from cockerels fed a diet containing 16% CP and 2750 kcal / kg diet. Three hatches were done at 33, 34 and 35 weeks of age. Percentage of egg fertility and hatchability were calculated.

The optimal protein and energy levels used in hens diets was evaluated in terms of productivity, change in body weight, hatch weight of chicks and feed cost throughout 28-40 wk. of age. Economical efficiency of feed (EEF) was calculated according to the following equation:

$$\text{EEF} = \frac{(\text{sale price of body weight change} + \text{price of hatch chicks}) - \text{total feed cost}}{\text{total feed cost}} \text{X100}$$

Blood samples were collected from each treatment in heparinized test tubes at the end of experimental period, and then plasma were separated and stored at -20 ^{0}C for later analyses. Plasma levels of total protein, albumin, globulin, cholesterol and glucose, and activity transaminases (AST and ALT) were determined by colorimetric methods using available commercial kits.

Statistical Analysis

Data obtained were statistically analyzed using the General Liner Model (GLM) procedure by means of two-way analysis of variance using SPSS computer program (SPSS, 2011). The following model was used: $Y_{ijk} = \mu + ME_i + P_j + (ME\ P)_{ij} + e_{ijk}$. Where Y_{ijk} = observed traits. μ = The overall mean. ME_i = The effect of metabolizable energy (i= 1, 2), P_j = The effect of protein level (j=1, 2 and 3), $(ME \times P)_{ij}$ = Interaction between the energy and protein and e_{ijk} = Random error. The differences between experimental groups were tested for significant by Duncan's multiple range test. (Duncan,1955).

RESULTS AND DISCUSSION

Productive performance:

Body weight and feed intake:

Data presented in Table 2 show the effect of ME and CP levels and their interactions on FBW, CBW, daily feed intake (DFI), protein intake and energy intake. All birds were similar in initial body weight at 24 weeks of age with no significant differences among them while, at the end of the experiment (at 40 weeks of age), the hens fed the diet of H_{ME} content had the heavier FBW than that of the hens fed L_{ME}-diet. The birds fed L_{ME} diet consumed more feed (P<0.01) than those fed H_{ME}^{-} diet. Also the daily protein intake (P≤0.05) and daily energy intake (P<0.01) of the former were significantly higher than those fed the H_{ME} diet. Our results are in accordance with those of Nofal *et al.* (2018), who demonstrated that hens fed on a high-energy diet (2800 ME kcal/kg) were significantly (P≤0.01) increased in FBW and body weight gain than those fed on a low-energy diet (2600 ME 2600 kcal/kg) and they added that hens consumed more feed in response to feeding on the diet containing lower ME content (2600 kcal /kg) than those fed on the diet containing higher ME content (2800 kcal/kg) In harmony with our result, Omara *et al.* (2009), reported that body weight gain for Lohmann Brown hens, were significantly increased as a result of feeding the energy-sufficient diets, than the birds fed diets with lower energy contents. This may be due to the fact low dietary ME levels reduced available energy for fat deposition resulting in decreasing body weight gain. Ding *et al.* (2016) indicated that hens fed diet with 2750 kcal ME/kg displayed higher DFI than birds fed on diet with 2650 kcal ME/kg diet.

It is clearly that FBW, CBW and daily protein intake were significantly increased with increasing the protein level in the diet. Neither DFI nor daily energy intake were been affected by dietary CP levels studied (Table, 2). This result was agreed with the findings by Kumari *et al.* (2016) who found that increasing protein content of the diet resulted in increases in the body weight. In the same trend Yakout (2010) indicated that the best value of body weight gain was obtained by layers fed high-CP diets. Bouyeh and Gevorgian (2011) reported that the hens fed diet high-protein content (14%) gave the highest value of body weight as compared to those fed the low-protein level (13%) throughout egg production period. Bunchasak *et al.* (2005) indicated that the feed intake of laying hens was not significantly affected by dietary CP levels (14, 16 and 18% CP). Hussein *et al.* (2010) illustrated that neither dietary energy levels (2600, 2650, 2700, 2750 and 2800 kcal ME/kg) nor protein levels (14, 15, 16, 17 and 18%) affected body weight, and feed intake of Sinai laying hens. On the other hand, Sohail *et al.* (2003) noticed that reducing dietary CP levels were not significant effect on body weight of laying hens, this effect may be attributed to the balance and availability of amino acids used in experimental diets studied. On the other hand, Singh *et al.* (2019) reported FBW of hens fed 18%-CP diet was significantly increased than hens fed 21%-CP (P≤0.05). This may be attributed to significantly higher quantity of feed consumption or higher of fat deposition as compared to other dietary treatments.

Table 2. Effect of dietary metabolizable energy and protein levels and their interactions on live body weight, feed intake, daily protein intake and daily energy intake of Sinai laying hens

Treatments	Initial BW (g)	Final body weight (g)	Body weight change (g)	Daily feed intake (g)	Daily protein intake (g)	Daily energy intake (kcal)
Energy levels (E)						
E 1 2700 kcal/kg	1449.09±7.99	1565.40±7.38^{b}	116.31±7.02^{b}	103.44±0.55^{a}	16.64±0.24^{a}	279.96±1.49^{a}
E 2 2850 kcal/kg	1453.53±8.83	1592.64±6.60^{a}	139.11±7.28^{a}	95.80±0.72^{b}	15.38±0.25^{b}	273.20±1.99^{b}
Significance level	NS	**	*	**	*	**
Protein levels (P)						
P 1 14%	1451.40±10.80	1540.53±7.98^{b}	89.13±5.91^{b}	100.80±1.08	14.24±0.16^{c}	280.17±2.42
P 2 16%	1448.27±10.84	1593.97±6.97^{a}	145.70±7.91^{a}	98.93±1.21	15.89±0.20^{b}	274.53±2.55
P 3 18%	1454.27±09.40	1602.07±7.72^{a}	148.30±8.46^{a}	99.13±0.81	17.89±0.14^{a}	274.98±1.58
Significance level	NS	**	**	NS	**	NS
Interactions						
E1XP1	1446.33±12.96	1525.33±10.37^{d}	79.00±6.26^{b}	104.40±1.13^{a}	14.78±0.16^{d}	283.03±3.06^{a}
E1XP2	1455.47±16.61	1581.33±11.45^{bc}	135.87±11.19^{a}	103.80±0.83^{a}	16.70±0.13^{c}	280.78±2.24^{a}
E1XP3	1455.47±12.38	1589.53±10.01^{ab}	134.07±12.28^{a}	102.13±0.80^{a}	18.42±0.15^{a}	276.07±2.71^{ab}
E2XP1	1456.47±17.65	1555.73±11.09^{c}	99.27±9.54^{b}	97.20±1.30^{b}	13.71±0.18^{e}	277.31±3.72^{ab}
E2XP2	1451.07±14.50	1606.60±6.88^{ab}	155.53±10.96^{a}	94.07±1.41^{b}	15.07±0.23^{d}	268.28±4.03^{b}
E2XP3	1453.07±14.58	1615.60±9.57^{a}	162.53±10.81^{a}	96.13±0.87^{b}	17.35±0.16^{b}	273.97±2.33^{ab}
Significance level	NS	**	**	**	**	*

[a,b] …. For each of the main effects, means in the same column bearing different superscripts differ significantly (P≤0.05) NS = not significant *:P≤ 0.05, **:P≤ 0.01

The effects of interaction between ME and CP contents were significantly (P≤ 0.01) on both FBW and positively correlated in body weight change, DFI and protein intake since the hens fed the diet with H_{cp} and H_{ME} gave the heavier FBW and CBW than those hens fed on the L_{ME} and L_{CP}-diets. On the other side, the hens fed on diets of L_{ME} content consumed more (P≤0.01) DFI and daily protein intake than those fed H_{ME}-diets regardless of protein levels. However, the hens fed on L_{ME} and H_{CP}-diets recorded the highest daily protein intake (P≤0.01) compared with other treatment groups, while the lowest daily protein intake was obtained by feeding on diets containing L_{ME} and L_{CP}-diets. Feed consumption in poultry is regulated by nutrient density in the diet and more specifically to meet their requirements of energy and protein.

Feed conversion ratio (FCR):

Effect of dietary energy and protein levels and their interaction on protein efficiency ratio (PER), energy efficiency ratio (EER) and feed conversion ratio (FCR), is listed in Table 3. The results reveal that (PER), (EER) and (FCR were significantly (P≤0.01) affected by both CP and ME levels, and there were significant (P≤0.01) interaction effects between ME and CP on these parameters (Table, 3). The results showed that feeding the H_{ME}-diets resulted in highest means of efficiency FCR, EER and PER. On the same manner, the FCR and EER were significantly improved by feeding hens on diets of higher CP levels, meanwhile, lower dietary CP level showed better PER than the higher one. Our results are in agreement with those results reported by Hassan *et al.*, (2000) and Yakout *et al.*, (2004), who reported that increasing protein level in layer diets improved FCR. Salah Uddin *et al.* (1992) reported that feed conversion efficiency of commercial layers increased as the dietary CP and ME levels increased. Also, Nofel *et al.* (2018) showed that feed conversion of laying hens was significantly (P≤0.01) improved with increasing energy content in the diets. The same trend was observed by some of researchers who found that increasing dietary energy or fat decreased FI and improved FCR of laying hens (Bryant *et al.*, 2005, and Wu *et al.*, 2005). Chaiyapoom and Taweesak (2005), from data on laying hens, found that protein conversion ratio was significantly improved with decreasing the protein intake (P≤0.01). Zeweil *et al.* (2011) reported that decreasing protein and increasing methionine levels in laying hen diets significantly increased apparent CP digestibility.

There were significant interactions (P≤0.01) between dietary protein and energy levels on PER, EER and FCR as presented in Table, 3. The EER and FCR were significantly improved linearly with increasing protein and energy levels in the diet. Hens fed the diets containing M_{CP} and H_{ME}

achieved the best values of EER and FCR than those of other treatment groups, while the worst values of the two traits were obtained from hens fed on diets of low energy and protein content (L_{CP} and L_{ME}). On the other side, the best value of PER was obtained by feeding hens on diets containing H_{CP} and M_{CP} with L_{ME} than other treatments.

Table 3. Effect of dietary metabolizable energy and protein levels and their interactions on protein efficiency ratio (PER), energy efficiency ratio (EER), and feed conversion ratio (FCR) of Sinai laying hens

Treatments	PER	EER	FCR
	Energy levels (E)		
E 1 2700 kcal/kg	0.549±0.006[a]	9.26±0.10[a]	3.42±0.04[a]
E 2 2850 kcal/kg	0.481±0.007[b]	8.57±0.10[b]	3.01±0.04[b]
Significance level	**	**	**
	Protein levels (P)		
P 1 14%	0.479±0.007[c]	9.42±0.12[a]	3.39±0.05[a]
P 2 16%	0.5107±.011[b]	8.81±0.15[b]	3.18±0.07[a]
P 3 18%	0.554±0.006[a]	8.52±0.07[c]	3.07±0.04[b]
Significance level	**	**	**
	Interactions		
E1XP1	0.507±0.007[c]	9.71±0.13[a]	3.58±0.05[a]
E1XP2	0.558±0.009[b]	9.39±0.15[ab]	3.47±0.06[a]
E1XP3	0.580±0.006[a]	8.69±0.09[c]	3.22±0.03[b]
E2XP1	0.452±0.008[d]	9.14±0.16[b]	3.21±0.06[b]
E2XP2	0.463±0.009[d]	8.24±0.17[d]	2.89±0.06[c]
E2XP3	0.528±0.006[c]	8.34±0.10[cd]	2.93±0.03[c]
Significance level	**	**	**

[a,b] …. For each of the main effects, means in the same column bearing different superscripts differ significantly (P≤ 0.05) **:P≤ 0.01).

Laying performance:

Data presented in Table 4 show that dietary CP and ME levels significantly (P≤0.01) affected egg production parameters (EP); including EN, EW (g), EM (g/day) and hen day egg production rate (HDEPR). There were positive correlation between dietary energy and protein levels in the previously mentioned traits which were significantly improved by increasing dietary energy and protein levels. Hens fed on low-energy diet (L_{ME}) caused significant reduction in all EP parameters; EN, EW, EM and HDEPR than those fed on the high-energy diet (H_{ME}) content. Similarly the previously mentioned traits were gradually increased by increasing dietary protein level and that hens fed on the low-protein diets (L_{CP}) had significantly poorer EP parameters compared with other treatments. However, there were no significant differences in EN, EW and HDEPR when hens were fed on the diet containing 16 or 18% CP. The reduction in EP parameters of on hen fed the L_{CP}-diet may be attributed to reducing energy level may have been caused, at least partly, by the associated with reduction in essential amino acid intake.

There were significant effects in interaction between CP and ME levels on EP that the diets of H_{CP} and M_{CP} with any ME level improved utilization of CP and EP traits (Table 4). While the best EP parameters were achieved by hens fed diet containing H_{ME} and M_{CP} or H_{CP} compared with other treatment groups. On the other hand, hens fed on the diets L_{ME} and L_{CP} recorded the worst value of EP parameters compared with the other diets. These results are in accordance with results obtained by Rama Rao and Tirupathi Reddy (2016) whom found that reduction in egg production rate, FCR, EW and EM in response to reducing dietary protein level when fed white leghorn layers at 17.5, 16.5 and 15.5 % CP. They added that FI was not affected by dietary CP. The egg production rate was lower in the group fed with 15.5% CP diet than those fed 17.5 and 16.5% CP. They also found that EW was reduced with lowering in dietary CP level. Keshavarz and Nakajima, (1995) and Mareiy *et al.*, (2009) reported that EP parameters of laying hens were improved by improving the nutrients utilization of diets of high nutrient concentrations. Also, some researchers concluded that EP was improved significantly by increasing dietary protein level (Hassan *et al.*, 2000; and Yakout *et al.*, 2004). On the other contrary, Zeweil *et al.* (2011) and Hussein *et al.* (2010) suggested that EP was not affected significantly by different dietary levels of protein.

The improvement of EP parameters due to feeding high nutrient-density diets, might be due to providing a satisfactory supply of essential and non essential amino acids to layers (NRC, 1994), and consequently improving the nitrogen utilization (Zeweil *et al.* 2011; Phuoc *et al.*, 2019), and possibly increasing energy by the addition of fat can significantly decrease FI, increase EW, and improve FCR (Wu G. *et al.*, 2005).

Table 4. Effect of dietary metabolizable energy and protein levels and their interactions on egg number, egg weight, daily egg mass and egg production rate of Sinai laying hens

Treatments	Egg number	Egg weight (g)	Daily egg mass (g)	Hen-day egg production rate %
	Energy levels (E)			
E 1 2700 kcal/kg	64.02±0.38[b]	49.64±0.29[b]	30.28±0.22[b]	60.97±0.36[b]
E 2 2850 kcal/kg	65.75±0.39[a]	50.88±0.27[a]	31.87±0.23[a]	62.62±0.37[a]
Significance level	**	**	**	**
	Protein levels (P)			
P 1 14%	63.19±0.41[b]	49.43±0.35[b]	29.75±0.21[c]	60.18±0.39[b]
P 2 16%	65.13±0.58[a]	50.36±0.39[ab]	31.25±0.33[b]	62.02±0.53[a]
P 3 18%	66.34±0.33[a]	51.00±0.27[a]	32.23±0.18[a]	63.18±0.31[a]
Significance level	**	**	**	**
	Interactions			
E1XP1	62.56±0.45[b]	48.93±0.56[d]	29.15±0.22[d]	59.58±0.43[b]
E1XP2	63.50±0.78[b]	49.50±0.40[cd]	29.94±0.38[c]	60.48±0.74[b]
E1XP3	66.00±0.38[a]	50.50±0.44[abc]	31.74±0.27[b]	62.86±0.36[a]
E2XP1	63.81±0.66[b]	49.93±0.41[bcd]	30.34±0.31[c]	60.77±0.63[b]
E2XP2	66.75±0.58[a]	51.21±0.60[ab]	32.55±0.30[a]	63.57±0.55[a]
E3XP3	66.69±0.54[a]	51.50±0.25[a]	32.71±0.27[a]	63.51±0.51[a]
Significance level	**	**	**	**

[a,b] ….. For each of the main effects, means in the same column bearing different superscripts differ significantly (P≤0.05) **:P≤ 0.01).

Egg quality and reproductive parameters:

Results in Tables 5 and 6 showed that neither ME nor CP levels affected hatchability characteristics or any of egg quality measurements. The same trend was observed in interaction between studied factors. These results are in accordance with the finding of Ding *et al.* (2016) whom found that the parameters related to egg quality was insignificantly affected by the interaction between the levels of ME at 2650 and 2750 kcal of ME/kg diet and CP at 14.5%, 15% and 15.5%) , or by the CP levels (P≤0.05). The same response was noticed by Hussein *et al.* (2010), who reported that CP and ME levels had no significant effect on reproductive traits and egg quality of Sinai laying hens. But Mareiy *et al.* (2009) found that feeding Sinai hens diets of high nutrient density improved egg fertility, hatchability, post-hatch chick weight, yolk index, and Haugh Unit score. On the contrary, data on Baheij hens by Zeweil *et al.* (2011) showed that increasing CP level significantly decreased hatched percentage of chicks.

Blood parameters:

As presented in Table 7, results indicated that dietary energy level had no significant effect on most blood traits; plasma total protein, albumin, globulin, glucose and activity of ALT. However plasma cholesterol was significantly increased in response to feeding on H_{ME} diet compared with those received the low-energy diet. These results consistent with the result of Nofal *et al.* (2018), who indicated that feeding H_{ME}-diet (2800 kcal/kg diet) to laying diets resulted in increasing cholesterol in blood plasma compared with the L_{ME}-diets (2600 kcal/kg diet) but plasma levels of albumin, glucose and activity of AST were not affected.

In the present study, dietary protein levels had no significant effect on plasma total protein, albumin, globulin, cholesterol and glucose or activity of AST except for the activity of ALT which significantly increased (P≤0.01) when hens fed on the H_{CP}-diet compared with those fed on the L_{CP} and M_{CP}-diets. Similar results were obtained by Kout Elkloub *et al.* (2005) who reported that different protein and energy levels in layer diets had no significant effect on blood parameters. On the other side Zeweil *et al.* (2011) noticed a significant increase in plasma total protein and globulin concentrations of layers fed the 16% CP-diet compared with those fed 12 or 14% CP-diet.

Table 5. Effect of dietary metabolizable energy and protein levels and their interactions on egg fertility, hatchability and chick weight at hatch of Sinai laying hens

Treatments	Fertility (%)	Hatchability of fertile eggs (%)	Hatchability of total eggs (%)	Chick weight at hatch (g)
Energy levels (E)				
E 1 2700 kcal/kg	87.37±0.64	86.64±0.35	76.44±0.77	35.13±0.38
E 2 2850 kcal/kg	88.10±0.69	88.68±1.00	78.14±1.17	35.57±0.21
Significance level	NS	NS	NS	NS
Protein levels (E)				
P 1 14%	87.21±0.49	87.56±1.08	76.37±1.20	35.15±0.44
P 2 16%	88.04±1.17	86.87±0.91	77.63±1.55	35.65±0.41
P 3 18%	87.97±0.72	88.55±1.03	77.88±1.01	35.25±0.26
Significance level	NS	NS	NS	NS
Interactions				
E1XP1	86.92±0.67	86.46±0.21	75.16±0.72	35.00±0.82
E1XP2	87.26±1.28	85.73±0.32	77.05±2.09	35.40±0.73
E1XP3	87.94±1.61	87.72±0.59	77.12±0.97	35.00±0.39
E2XP1	87.49±0.82	88.66±2.13	77.59±2.28	35.30±0.37
E2XP2	88.83±2.15	88.01±1.64	78.20±2.72	35.90±0.38
E3XP3	88.00±0.14	89.37±2.07	78.65±1.88	35.50±0.34
Significance level	NS	NS	NS	NS

All means in the same column were not significantly different.

Table 6. Means of egg quality measurements as affected by dietary metabolizable energy and dietary protein levels and their interaction in Sinai laying hens

Treatments	Egg shape Index %	Egg components Albumen %	Yolk %	Shell %	Shell thickness (mm)	Haugh Unit	Yolk index %	Egg specific gravity	ESA
Energy levels (E)									
E1 2700 Kcal / kg	78.66±1.15	54.91±0.65	30.77±0.56	14.31±0.31	34.44±0.50	76.39±0.99	46.74±0.81	1.111±0.0	63.17±1.27
E2 2850 Kcal / kg	76.48±1.52	53.57±1.28	32.46±0.85	13.98±0.56	34.89±0.26	74.28±0.74	45.91±0.76	1.109±0.0	63.12±1.63
Protein levels (P)									
Significance level	NS	NS	NS	NS	NS	NS	NS	NS	NS
P 1 14%	77.68±1.26	54.05±1.99	31.08±1.26	14.85±0.76	31.83±0.17	79.86±1.13	45.17±1.03	1.115±0.0	63.30±2.38
P 2 16%	74.75±1.80	54.08±0.86	31.82±0.91	14.09±0.37	32.00±0.37	80.41±1.31	45.93±0.44	1.110±0.0	62.79±1.51
P 3 18%	80.29±1.25	54.57±0.69	31.94±0.63	13.49±0.28	31.17±0.75	80.00±0.91	47.87±1.02	1.106±0.0	63.33±1.50
Significance level	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interactions									
E1XP1	77.77±1.12	54.88±1.96	30.25±1.24	14.87±0.68	34.67±0.33	80.27±2.34	45.25±0.74	1.115±0.0	59.94±2.07
E1XP2	77.20±3.17	55.03±0.63	30.37±0.71	14.60±0.14	35.00±0.58	81.01±1.64	46.67±0.49	1.113±0.0	67.34±1.31
E1XP3	80.99±0.70	54.83±1.00	31.71±1.01	13.46±0.27	.33.67±1.45	80.77±1.84	48.28±2.20	1.106±0.0	64.67±2.02
E2XP1	77.58±2.58	53.23±3.94	31.92±2.38	14.85±1.57	35.00±0.00	79.46±0.84	45.09±2.18	1.115±0.0	66.96±3.29
E2XP2	72.29±0.34	53.15±1.57	33.28±1.24	13.57±0.63	35.00±0.58	79.80±2.36	45.19±0.44	1.107±0.0	60.39±1.97
E3XP3	79.58±2.61	55.31±1.16	32.17±0.95	13.51±0.57	34.67±0.67	79.24±0.40	47.46±0.39	1.107±0.0	62.00±2.31
Significance level	NS	NS	NS	NS	NS	NS	NS	NS	NS

All means in the same column were not significantly different.

Table 7. Effect of dietary metabolizable energy and protein levels and their interactions on some blood parameters of Sinai laying hens

Treatments	Total protein (g/dl)	Albumin (g/dl)	Globulin (g/dl)	AST (U/L)	ALT (U/L)	Cholesterol (mg / d)	Glucose (mg/dl)
Energy levels (E)							
E 1 2700 kcal/kg	4.28±0.05	2.44±0.04	1.83±0.03	21.67±0.7[a]	26.10±1.23	114.78±0.6[b]	248.33±0.75
E 2 2850 kcal/kg	4.33±0.04	2.48±0.05	1.86±0.06	17.00±0.6[b]	26.18±0.74	124.11±1.2[a]	249.89±0.51
Significance level	NS	NS	NS	**	NS	**	NS
Protein levels (P)							
P 1 14	4.25±0.07	2.40±0.05	1.85±0.06	18.00±1.39	24.45±0.74[b]	118.50±2.01	249.17±0.70
P 2 16	4.32±0.03	2.45±0.06	1.87±0.07	21.00±1.46	24.20±0.45[b]	119.83±2.43	248.17±0.87
P 3 18	4.35±0.06	2.53±0.04	1.82±0.05	19.00±0.86	29.77±0.35[a]	120.00±2.77	250.00±0.86
Significance level	NS	NS	NS	NS	**	NS	NS
Interactions							
E1XP1	4.20±0.10	2.37±0.09	1.83±0.03	21.00±0.58[b]	22.97±0.52[d]	114.33±1.20[b]	248.67±1.20
E1XP2	4.30±0.06	2.50±0.06	1.80±0.06	24.00±1.15[a]	24.57±0.84[cd]	115.00±1.73[b]	246.67±0.88
E1XP3	4.33±0.09	2.47±0.03	1.87±0.07	20.00±1.15[b]	30.77±0.58[a]	115.00±1.00[b]	249.67±1.45
E2XP1	4.30±0.12	2.43±0.07	1.87±0.13	15.00±0.58[c]	25.93±0.52[c]	122.67±1.20[a]	249.67±0.88
E2XP2	4.33±0.03	2.40±0.12	1.93±0.12	18.00±0.58[b]	23.83±0.43[d]	124.67±1.76[a]	249.67±0.88
E3XP3	4.37±0.09	2.60±0.06	1.77±0.07	18.00±1.15[b]	28.77±0.26[b]	125.00±3.51[a]	250.33±1.20
Significance level	NS	NS	NS	**	**	**	NS

[ab] ….. For each of the main effects, means in the same column bearing different superscripts differ significantly (P≤0.05), NS = not significant, **:P≤ 0.01).

Data listed in Table 7 illustrate that the interaction between different protein and energy levels had no significant effect on plasma total protein, albumin, globulin, and glucose but plasma cholesterol was significantly increased ($P \leq 0.01$) by increasing ME level in the diet with any dietary protein level compared with other treatment groups.

Economical efficiency of feeding (EEF):

The results of economic efficiency are shown in Table 8, it could be noticed that energy treatments significantly ($P < 0.01$) affected total feed intake per hen (kg), total of feed cost, price of total BWG, price of fertile eggs/hen, total return, net return, and economic efficiency of feeding (EEF), the highest energy level was superior to the lower energy level in all studied criteria. The protein level treatments had the same trends in all estimated criteria except for total feed intake per hen (kg), and EEF where the differences were insignificant. Also, it could be noticed that feeding the H_{CP} and M_{CP}-diets had the same significant effects in studied criteria of economic efficiency. There were significant interactions among dietary energy and protein levels on estimated means of economic efficiency criteria, the best results were obtained by hens received the diets of H_{ME} with either H_{CP} or M_{CP} level.

Table 8. Effect of dietary metabolizable energy and protein levels and their interactions on the economical efficiency of feeding (EEF) of Sinai laying hens

Treatments	Total feed intake of hen(kg)	Total feed cost (L.E)	Change in BW return	Price of fertile eggs/hen (L.E)	Total return (L.E)	Net return (L.E)	EEF (%)
			Energy levels (E)				
E 1 2700 kcal/kg	11.59±0.06^{a}	55.15±0.36^{a}	4.07±0.25^{b}	153.65±0.94^{b}	157.72±1.02^{b}	102.57±0.96^{b}	186.34±2.19^{b}
E 2 2850 kcal/kg	10.73±0.08^{b}	53.34±0.48^{b}	4.87±0.25^{a}	157.80±0.91^{a}	162.67±1.01^{a}	109.33±1.06^{a}	205.95±3.18^{a}
Significance level	**	**	*	**	**	**	**
			Protein levels (P)				
P 1 14%	11.29±0.12	52.43±0.46^{c}	3.12±0.21^{b}	151.65±0.94^{c}	154.77±1.01^{b}	102.34±1.18^{b}	195.94±3.56
P 2 16%	11.08±0.14	53.80±0.53^{b}	5.10±0.28^{a}	156.30±1.38^{b}	161.40±1.43^{a}	107.60±1.73^{a}	201.19±4.87
P 3 18%	11.10±0.09	56.51±0.34^{a}	5.19±0.30^{a}	159.23±0.67^{a}	164.42±0.76^{a}	107.91±0.89^{a}	191.31±2.40
Significance level	NS	**	**	**	**	**	NS
			Interactions				
E1XP1	11.69±0.13^{a}	53.19±0.58^{b}	2.77±0.22^{b}	150.15±1.04^{b}	152.92±1.10^{c}	99.72±1.33^{d}	188.04±4.28^{c}
E1XP2	11.63±0.09^{a}	55.37±0.44^{a}	4.76±0.39^{a}	152.40±1.83^{b}	157.16±1.95^{b}	101.78±1.99^{cd}	184.05±4.06^{c}
E1XP3	11.44±0.09^{a}	56.90±0.45^{a}	4.69±0.43^{a}	158.40±0.93^{a}	163.09±1.02^{a}	106.20±1.19^{bc}	186.93±3.13^{c}
E2XP1	10.89±0.15^{b}	51.68±0.69^{b}	3.47±0.33^{b}	153.15±1.51^{b}	156.62±1.59^{bc}	104.95±1.74^{bc}	203.83±5.02^{b}
E2XP2	10.54±0.16^{b}	52.23±0.78^{b}	5.44±0.38^{a}	160.20±1.54^{a}	165.64±1.46^{a}	113.41±1.88^{a}	218.33±6.30^{a}
E2XP3	10.77±0.10^{b}	56.12±0.51^{a}	5.69±0.38^{a}	160.05±0.95^{a}	165.74±1.07^{a}	109.62±1.22^{ab}	195.70±3.36^{bc}
Significance level	**	**	**	**	**	**	**

a,b …. For each of the main effects, means in the same column bearing different superscripts differ significantly ($P \leq 0.05$).
NS = not significant, *$P \leq 0.05$,:$P \leq 0.01$.**
1-Total feed cost /hen L.E= Feed intake x Price of kg feed. 2-Price of BWG= BWG X Price of kg BW which was 35 L.E
3- Total price of fertile eggs /hen (L. E) = total No .of fertile eggs /hen x price of fertile egg at time of experiment which was 2.25 L.E.
4-Total return = Total Price of fertile eggs /hen L. E+ price of total BWC (L.E).
5- Net return = Total return - Total feed cost. 6- Economic efficiency of feeding = Net return / Total feed cost*100

In conclusion, the current results revealed that the diets containing ME of 2,850 kcal/kg with 18 or 16% CP can improve egg production characteristics of Sinai laying hens.

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أداء دجاج سينا المغذى على علائق تحتوي على مستويين من الطاقة وثلاث مستويات من البروتين

عبد الفتاح عبد الحميد الدرعى و أسامة أحمد الوشاحى
معهد بحوث الإنتاج الحيوانى – مركز البحوث الزراعية

تهدف هذه التجربة الى دراسة تأثير كل من البروتين والطاقة على الاداء الانتاجي والتناسلى لدجاج سينا البياض من 24-40 أسبوع وقد قسمت 180 من دجاج سينا عشوائيا الى 6 معاملات تجريبية 2850 كيلو كالورى (عالية الطاقة) و2700 كيلوكالورى (منخفضة الطاقة) ومع كلا منهم 18% مستوى عالى البروتين , 16% متوسط البروتين , 14% منخفض البروتين فى تصميم عاملى 2 × 3. وكل معاملة بها 30 طائر مسكنة فى أقفاص فردية. و النتائج المتحصل عليها كالآتى: * تحسن معنوى فى وزن الجسم والتغير فى وزن الجسم والمأكول من البروتين والمأكول من الطاقة نسبة كفاءة البروتين (PER) ونسبة كفاءة الطاقة (EER) والتحويل الغذائى (FCR) وعدد البيض ووزن البيض وكتلة البيض ومعدل انتاج البيض للدجاجه التى تغذى على عليقة عالية الطاقة مقارنة بذلك الدجاج الذى تغذى على عليقة منخفضة الطاقة ومع ذلك فالطيور التى تغذت على عليقة منخفضة الطاقة استهلكت عليقة أكثر مقارنة بتلك التى تغذت على عليقة عالية الطاقة. * وجود تحسن معنوى فى وزن الجسم والتغير فى وزن الجسم وعدد البيض ومعدل انتاج البيض للطيور التى تغذت على عليقة عالية أو متوسطة البروتين مقارنة بتلك التى تغذت على عليقة منخفضة البروتين. وأن زيادة مستوى البروتين ادت الى تحسن تدريجي فى الوزن النهائى للجسم والتغير فى وزن الجسم والمأكول اليومى من البروتين وEER, FCR وعدد البيض ووزن البيضة وكتلة البيض اليومى ومعدل انتاج البيض. كان التداخل بين مستويات الطاقة والبروتين معنويا فى الصفات المشار اليها. * زاد مستوى الكوليسترول فى بلازما الدم معنويا نتيجة التغذية على عليقة عالية الطاقة مقارنة بالعليقة منخفضة الطاقة. وقد لوحظ نفس الاتجاه بالنسبة لمستويات البروتين حيث أن هناك اختلافات معنوية فى نشاط ALT الذى زاد معنويا فى بلازما الدم عند تغذية الطيور على عليقة عالية البروتين مقارنة بالعليقة المنخفضة والمتوسطة البروتين. *زاد مستوى الكولسترول فى بلازما الدم معنويا بزيادة مستوى الطاقة فى العليقة عند أى مستوى من البروتين مقارنة بالمعاملات الأخرى. وقد أوضحت الدراسة الحالية أن التغذية على عليقة محتوية على 2850 كيلوكالورى / كجم عليقة مع 16% أو 18% بروتين تستطيع ان تحسن من صفات انتاج البيض لدجاج سينا. **من وجهة النظر الاقتصادية أن العليقة المحتوية على 16% بروتين و 2850 كيلو كالورى/ كجم عليقة هى الامثل لدجاج سينا لكى تكون اعلى ربحية مقارنة بالمعاملات الأخرى خلال فترة الدراسة 24-40 أسبوع.