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Hepatoprotective effect of Artichoke (*Cynara scolymus*) in laying hens

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ABSTRACT: This experiment was conducted to investigate the effect of artichoke plant (Cynara scolymus) at different ratios (0, 5, 10 and 15 g/kg) supplementation into high-energy laying hen diet on performance, egg quality parameters, serum lipid profile, some liver enzymes and liver fat ratio. In total, one hundred and twenty 70-week-old Lohman LSL laying hens with an average weight of 1545.4-1587.7 g were randomly assigned to five groups and each group consisted of six subgroups. The control group was fed the basal feed (2650 kcal/kg ME), and the treatments groups were fed with high energy (2850 kcal/kg ME) including 0, 5, 10 and 15 g/kg artichoke, respectively. The feed and water were given to animals as ad-libitum during the experimental period. The experiment lasted for 8 weeks.

The supplementation of 10 g/kg artichoke to the diet improved feed conversion ratio (FCR) and increased egg production. All additive artichoke diets showed the highest eggshell weight, shell breaking strength, shell thickness and yolk color. The addition of artichoke to the high energy (HE) diet reduced the serum triglyceride, LDL (low density lipoprotein) and VLDL (very low density lipoprotein) concentration. The GSH (glutathione), CAT (catalase) and GPx (glutathione peroxidase) values which are enzymatic antioxidants in serum were found to be highest in the HE+ artichoke 5 g/kg group. The liver fat content was dramatically lower in laying hens fed on HE+artichoke 10 g/kg diet (18.83 %) compared with those fed on the high energy diet (48.26 %).

As s result, dietary supplementation of artichoke could be used in the diets to improve the performance, shell weight, breaking strength, thickness of shell, egg yolk color and reduced to serum triglyceride, LDL and VLDL concentration, liver fat ratio and increased the serum antioxidants enzymes (GSH, CAT and GPx).

Keywords: Artichoke (Cynara scolymus); Antioxidant Enzymes; Fatty Liver; Laying Hen; Performance, Serum Lipid Profile

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INTRODUCTION

For efficient egg production, laying hens are usually raised in cages. However, some health problems occur in caged animals and one of these problems is fatty liver. Fatty liver syndrome (FLS) is a metabolic disorder that affects chickens worldwide. FLS causes sudden death (%10-20) of hens (Targher et al., 2020). Nutritional, genetic, environmental, endocrine, stress and toxicological factors are related to the occurrence of FLS. Among them the nutrition-related factors (low protein high-energy diets) have a significant effect on the acceleration of liver fat (Gao et al., 2019; Liu et al., 2017; Rozenboim et al., 2016). In order to reduce the negative effects of fatty liver, hypolipidemic additives are added to the feeds. Medicinal and aromatic plants play a crucial role in protecting the liver of animals (Bayraktar and Tekce, 2018; Bolukbasi et al., 2018). Much research has been done on the role of medicinal plants in the treatment of diseases of humans and animals, which some of these reported beneficial effects of medicinal plants. *Cynara scolymus* (Artichoke) is a medicinal plant that belongs to the Asteraceae family and is commonly known as an artichoke (Tajodini et al., 2015).

Artichoke, as a rich source of non-enzymatic antioxidants, is a good source of natural antioxidants such as vitamin C, polyphenols, tocopherols, phenolic acids, hydroxycinnamic acids, carotenoids and flavonoids (Michalak, 2022). It is a rich source of inulin and oligofructose. Inulin is an oligomer of fructose present in many plant foods such as artichoke, Jerusalem artichoke, chicory, asparagus, leek, onion and garlic (Rahim et al., 2021). These food constituents have lower caloric values than typical carbohydrates. Inulin and oligofructose are functional food ingredients because these fructans modulate the hormonal level of insulin and glucagon, decrease the blood glucose level, reduce colon cancer and also reduce the risk of many diseases in rats and humans. Such as Artichoke may decrease risks of diabetes, heart diseases, cancer, and osteoporosis (Abdel-Moneim et al., 2021; Moradi et al., 2021).

It contains a lot of bioactive compounds (cynarin, flavonoids, phenolic acids, and caffeic acid) (Farhan et al., 2018; Pandino et al., 2020). Cynarin is the major dicaffeoylquinic acid derivative of artichoke. The other phenolics are the flavones apigenin and luteolin, peonidin, and delphinidin have also been found in artichoke (Salata et al., 2022).

Artichoke is a reliable product with hepatoprotective and hypolipidemic effects and no side effects in nutrition (Ben Salem et al., 2019; Krepkova et al., 2021; Tajodini et al., 2015). However, there has been a limited number of previous research examining the impact of artichokes on the liver in laying hens. In this study, it was aimed to investigate the effects of performance, egg quality, serum lipid profile, some antioxidant enzymes, and liver fat ratio by adding artichokes at different levels to feeds.

MATERIALS AND METHODS

Animals and experimental design

This study was carried out at Atatürk University Food and Livestock Practice and Research Center. The research protocol was approved and applied in accordance with the Veterinary Control Center Research Institute Animal Ethics Committee, Turkey (Protocol number: 2020/01). A total of 120 Lohman LSL hybrid laying hens at the age of 70 weeks were randomly divided into five groups (n=24) and each group consist of 6 replicate cages (4 hens/cage). The first group (control) was fed basal feed (2650 kcal/kg ME), the second group was fed with high energy (2850 kcal/kg ME) feed and the 3rd, 4th and 5th groups were fed with high energy feed with 5, 10 and 15 g/kg artichoke.

Feed

Artichoke (Cynara scolymus) leaf powder was purchased from a commercial company in Turkey. It was mixed to the feed homogeneously by the method of mixing from less to more (Duman, 2016). Feed anaylses (Table 1) were done according to AOAC (2005). Hens were fed and watered as *ad libitum.*

Performance and egg quality measurements

The birds were weighed at the beginning and end of the experiment and their body weights were recorded. Feed intake and egg production were recorded, and feed conversion ratio was calculated daily. Feed conversion ratio was calculated as grams of feed intake per gram of egg mass produced. Egg quality indices including egg weight, Haugh unit (HU), specific gravity, eggshell thickness, shell breaking strength, egg shape index, yolk color and weight of albumen, yolk and shell were measured. Three eggs were collected randomly from each cage for calculation of egg quality. Eighteen eggs were collected from each group.

Serum lipid profile and glucose, ALP, AST, and estrogen levels

At the end of the experiment, 12 animals from

Table 1. Ingredients (%) and chemical analyses of the basal diet

Ingredients	Basal Diet	High Energy Diet
Corn	62.2	63.5
Soybean meal 44-46	17.36	13.15
Corn gluten 60	8.48	10.64
Limestone	9.68	7.65
DCP 18	1.44	1.44
Soy oil	-	2.7
Vitamin-Mineral premix[1]	0.25	0.25
Common salt	0.22	0.33
Sodium bicarbonate	0.16	0.16
L-Lysine HCL	0.11	0.10
DL-Methionine	0.10	0.08
Analysed Chemical composition (%)		
Dry matter	88.41	88.54
Crude Protein	17.52	17.20
Crude fat	2.20	4.84
Crude ash	11.87	10.35
Crude fibre	2.78	2.57
DL- Methionine	0.38	0.38
Methionine	0.40	0.41
Lysine	0.76	0.70
ME kkal/kg	2650	2850

[1] The premix provided per kilogram of diet: 12 000 IU vitamin A; 2 500 IU cholecalciferol (vitamin D3); 30 IU α-tocopheryl acetate (vitamin E); 4 mg menadione sodium (vitamin K3); 3 mg thiamine mononitrate (vitamin B1); 6 mg (riboflavin) vitamin B2; 30 mg niacin (vitamin B3); 10 mg calcium D-pantothenate (vitamin B5); 5 mg pyridoxine (vitamin B6); 0.015 mg cyanocobalamin (vitamin B12); 1 mg folic acid; 0.050 mg D-biotin (vitamin H); 50 mg ascorbic acid (vitamin C); 300 mg choline chloride; 80 mg manganese oxide; 60 mg iron; 60 mg zinc; 5 mg copper; 0.5 mg cobalt; 2 mg iodine; 0.15 mg selenium.

each group were selected, which is 60 animals in total and blood samples were taken from the wing vena into heparinized tubes and centrifuged at 3000 rpm for 10 minutes (Olarotimi, 2020). Serum parameters including triglyceride LDL-C, HDL-C, VLDL, total cholesterol, glucose, ALP, AST, ALT, and estrogen levels were determined by the spectrophotometric method using commercial kits (Roche) in auto-analyzer (Cobas, Japan).

Analysis of oxidants and antioxidants

Blood collected in heparin tubes was centrifuged at 3000 rpm for 10 minutes and serum was removed. Serum malondialdehyde (MDA) levels (Yoshoiko et al., 1979), Superoxide dismutase (SOD) activity (Sun et al., 1988), glutation (GSH) level (Tietze, 1969), glutathione peroxidase (GPx) activity (Matkovics et al., 1988) catalase (CAT) activity (Goth, 1991), total proteins (TP) levels were measured with Biotek Elisa Reader (Bio Single μQuant MQX200 Elisa reader / USA). TP levels were used to calculate SOD and GPx activity.

Weight and fat ratio of liver

Liver lipid was determined by a modification of the method of Folch et al., (1957).'Total lipid was determined by extracting in a Soxhlet type extractor. The samples were kept in petroleum ether for 24 hours. They were dried and weighed and the fat ratio was calculated.

Statistical analyses

Kolomogrov-Smirnov normality test was used to determine whether the data were suitable for normal distribution, and Levene's statistics were used to test the homogeneity of variances. After obtaining the data in accordance with the normal distribution and homogeneous variances, analysis of variance (One Way ANOVA) was applied and the differences between the means were determined by Duncan multiple comparison test. The significance was tested at 0.05 level and SPSS 23.0 package program was used in all analyses (SPSS 23).

RESULTS

Performance

Throughout the experimental period, high energy diets decreased final body weight, egg production and feed intake significantly (P<0.05) (Table 2). In current study, FCR and egg production were significantly (P<0.001) improved by HE+ artichoke 10 g/kg group. The maximum egg production and the best FCR were determined from the hens fed with diet containing HE+artichoke 10 g/kg. Egg weight was not influenced significantly (P>0.05) by any of the treatments (Table 2).

Egg quality (albumen weight, yolk weight, haugh unit, shell breaking strenght, shell weight, shape index, shell thickness)

The impact of artichoke on some egg quality criteria were listed in the Table 3. The difference among the groups was not significant in terms of albumen weight (%), yolk weight (%) and haugh unit in this study (Table 3). Shell weight of egg, yolk color, shell breaking strength, egg shape index and shell thickness were significantly influenced by treatment (P<0.001). The group fed with HE+ 5, 10, 15 g/kg artichoke showed the highest eggshell weight, yolk color, shell breaking strength, egg shape index and shell thickness (Table 3).

Blood serum constituents

Table 4 shows the effects of artichoke supplementation on serum traits. None of the dietary factors did affect serum ALP, AST, ALT, total cholesterol and estrogen concentration. The addition of artichoke to a high-energy diet significantly reduced the serum triglyceride, LDL and VLDL concentration (P<0.05). The HE diet with 10 and 15 g/kg artichoke had induced decreases in triglyceride, LDL and VLDL concentration were found to be similar to the control group (Table 4).

Table 5 shows the effects of artichoke supplementation on serum antioxidant enzymes (MDA, GSH, SOD, CAT, GPx and NEFA). Serum MDA level sig-

Table 2. Effects of dietary artichoke on the productive performance of laying hens

Dietary Treatments	Initial body weight (g)	Final body weight (g)	Feed intake (g)	Egg weight (g)	Egg production (%)	Feed conversion ratio (g:g)
Control	1545.4	1433.4[a]	101.96[a]	59.91	79.85[b]	2.24[ab]
High energy diet	1560.8	1228.0[b]	76.36[b]	58.94	57.88[d]	2.74[a]
HE+ artichoke 5 g/kg	1587.7	1425.3[ab]	105.01[a]	61.17	70.74[c]	2.66[a]
HE+ artichoke 10 g/kg	1576.7	1435.3[ab]	87.72[ab]	61.72	89.41[a]	1.59[b]
HE+ artichoke 15 g/kg	1556.7	1501.2[ab]	102.55[a]	63.45	83.22[ab]	1.96[ab]
SEM	6.44	26.94	3.54	0.71	2.54	0.15
p	0.281	0.000	0.029	0.328	0.000	0.049

[a,b,c,d:] means in columns with different superscripts differ significantly at P<0.05 HE: high energy diet SEM= standard error of the mean. N = 6 replicate cages totaling 24 hens per treatment.

Table 3. Influence of dietary artichoke on egg quality

Dietary Treatments	Albumen weight (%)	Yolk weight (%)	Shell weight (%)	Yolk color score	Haugh units	Shell breaking strength (kg cm^3)	Egg shape index (%)	Shell thickness (µm)
Control	59.83	29.91	10.26[b]	9.50[b]	84.24	2.33[ab]	75.00[a]	0.427[abc]
High energy diet	59.56	30.06	10.38[b]	9.70[b]	76.00	1.36[b]	70.20[b]	0.368[c]
HE+artichoke 5 g/kg	57.00	30.10	12.90[a]	10.92[a]	80.51	2.89[a]	72.46[ab]	0.473[a]
HE+artichoke 10 g/kg	57.48	30.07	12.45[a]	11.25[a]	80.79	2.62[a]	73.42[a]	0.394[bc]
HE+artichoke 15 g/kg	58.07	29.37	12.57[a]	10.50[ab]	78.59	2.62[a]	74.79[a]	0.446[ab]
SEM	0.542	0.407	0.264	0.166	2.166	0.169	0.524	0.012
p	0.405	0.979	0.000	0.000	0.877	0.031	0.021	0.028

[a,b,c:] means in columns with different superscripts differ significantly at P<0.05, HE: high energy diet, SEM= standard error of the mean. N = 6 replicate cages totaling 18 eggs per treatment.

Table 4. Effects of dietary supplementation with different levels of artichoke on serum biochemical parameters of laying hens

Dietary Treatments	ALP (U/L)	AST (U/L)	ALT (U/L)	Trigliserit (mg/dl)	Glucose (mg/dl)	Total cholesterol (mg/dl)	LDL (mg/dl)	HDL (mg/dl)	VLDL (mg/dl)	Estrogen (pg/ml)
Control	261.0	243.5	1.75	257.5^{c}	257.8^{bc}	115.5	69.5^{b}	42.5	72.0^{c}	231.0
High energy diet	252.5	267.8	5.0	645.3^{a}	247.8^{c}	195.5	162.3^{a}	37.0	310.3^{a}	202.3
HE+artichoke 5g/kg	642.0	203.0	3.0	522.0^{ab}	263.0^{abc}	156.3	99.3^{ab}	23.3	168.0^{b}	259.5
HE+artichoke 10 g/kg	677.7	236.0	2.0	345.0^{bc}	277.0^{a}	107.7	74.0^{b}	46.3	92.67^{bc}	180.5
HE+artichoke 15 g/kg	287.7	255.0	1.0	177.0^{c}	269.7^{ab}	116.3	33.7^{b}	51.5	52.3^{a}	306.0
SEM	76.96	12.35	0.51	51.58	3.13	14.32	14.70	3.56	26.82	32.01
p	0.189	0.607	0.061	0.002	0.009	0.210	0.030	0.126	0.000	0.565

^{a,b}: means in columns with different superscripts differ significantly at P<0.05 HE: high energy diet, SEM= standard error of the mean. N = 6 replicate cages totaling 12 hens per treatment.

Table 5. Effects of dietary supplementation artichoke on blood serum biochemical parameters of laying hen

Dietary Treatments	MDA (nmol/L)	GSH (mmol/L)	SOD (U/L)	CAT (KU/L)	GPx (U/L)	NEFA (mmol/L)
Control	7.83^{b}	2.24^{c}	58.32	154.17^{b}	1.45^{b}	0.226
High energy diet	7.57^{b}	2.45^{b}	58.27	152.89^{b}	1.49^{b}	0.215
HE+ artichoke 5 g/kg	7.56^{b}	2.62a	60.85	167.10^{a}	1.64^{a}	0.205
HE+ artichoke 10 g/kg	10.67^{a}	1.74^{d}	54.69	139.30^{c}	1.36^{c}	0.259
HE+ artichoke 15 g/kg	10.32^{a}	1.79^{d}	57.13	143.98^{c}	1.38^{c}	0.256
SEM	0.471	0.11	0.84	3.27	0.033	0.008
p	0.000	0.000	ns	0.002	0.000	ns

$^{a,b,c,d:}$ means in columns with different superscripts differ significantly at P<0.05 HE: high energy diet, SEM= standard error of the mean. N = 6 replicate cages totaling 6 hens per treatment. MDA: malondialdehyde, GSH: glutathione, SOD: superoxide dismutase, CAT: catalase, GPx: glutathione peroxidase

Table 6. Effects of treatment on hepatic variables of laying hens

Dietary Treatments	Liver wet weight (g)	Liver dry weight (g)	Liver fat (%)
Control	24.04^{b}	7.44^{b}	23.66^{b}
High energy diet	36.05^{a}	12.28^{ab}	48.26^{a}
HE+ artichoke 5 g/kg	23.84^{b}	8.84^{b}	22.19^{b}
HE+ artichoke 10 g/kg	38.50^{a}	15.15^{a}	18.83^{b}
HE+ artichoke 15 g/kg	31.43^{ab}	15.63^{a}	22.64^{b}
SEM	1.99	1.05	2.35
p	0.017	0.015	0.000

$^{a,b,c:}$ means in columns with different superscripts differ significantly at P<0.05 HE: high energy diet, SEM= standard error of the mean N = 6 replicate cages totaling 6 hens per treatment.

nificantly decreased in the control, HE and HE+artichoke 5 g/kg groups. The concentration of SOD in all treatment groups did not have any significant difference. The GSH, CAT and GPx values which are enzymatic antioxidants in serum were significantly (P<0.001) increased HE+ artichoke 5 g/kg groups (Table 5). NEFA value was not affected by treatments.

Weight and fat ratio of liver

The treatment effects on liver measurements including liver wet, dry weight and fat content are given in Table 6. The liver weights (dry and wet) of the laying hens on the experimental diet and HE+ 5 g/kg group were significantly lower than the high energy diet and HE+ artichoke 10-15 g/kg group.

The addition of artichoke to the diet significantly decreased the liver fat content of laying hens (P<0.05). The lowest numerically value was for HE+artichoke 10 g/kg group (18.83 %) (Table 6).

DISCUSSION

Productive performance

High energy diet negatively affected performance values. This result is confirmed by previous studies showing lower feed intake in a HE diet (Rozenboim et al., 2016). Several types of research showed that hens fed a high energy diet consumed less feed and than hens fed a control diet (Kang et al., 2018; Rozenboim et al., 2016). As dietary energy level increases, so egg production is limited by decreased feed intake.

In this study, FCR and egg production were improved by HE+ artichoke 10 g/kg groups (Table 2). Hence, the addition of artichoke to a high energy diet was beneficial for the egg production and FCR of the laying hens. Abadjieva et al., (2020) showed that similarly Rouzmehr et al., (2014) and Yıldız et al., (2006) found that the supplementation of the artichoke to laying hen diet improved FCR. This may be due to the improvement of microbial ecology in layers intestine by using artichoke. Contrary to the present results, Abdo et al., (2007) reported that the supplementation 2, 4 and 6 % Cynara scolymus leaf powder increased FCR.

Egg weight was not influenced by any of the treatments but the highest numerically value was for HE+artichoke 15 g/kg group (63.45 gr), (Table 2). Abadjieva et al., (2021) and Wen et al., (2021) also found that artichoke supplementation of laying hens was not influenced egg weight between the groups.

Egg quality (albumen weight, yolk weight, haugh unit, shell breaking strenght, shell weight, shape index, shell thickness)

The addition of artichoke to the feeds positively affected egg quality criteria such as shell breaking strength, shell weight, egg yolk color, shape index and shell thickness (Table 3). These results agree with the reports of Klementavičiūtė et al. (2018). Several types of research showed that dietary artichoke in laying hens improved shell breaking strength and shell weight of egg (Klementavičiūtė et al. 2018; Torki et al. 2018). Eggshell breaking strength and egg shape index is an important index off egg quality that is a vital role for the transport and storage of eggs. The improvement in shell breaking strength due to artichoke, is a rich source of inulin and oligofructose which results in increasing mineral absorption, especially of calcium. Also, the egg yolk color parameter was affected by treatments. Radwan et al., (2007) found that the addition of 12 % artichoke significantly increased yolk color. It has been determined in many studies that aromatic additives have a positive effect on egg yolk color (Garcia et al., 2019; Gostin 2019).

Blood serum constituents

Serum triglyceride, LDL and VLDL concentration for hens fed artichoke was lower than hens fed high energy diet (Table 4). Some components in plants decrease blood fat (Westendarp, 2005). Artichoke (Cynara scolymus) is a pharmacological plant with hypolipidemic potentials (Suarez et al., 2019). Fallah et al., (2013) were found that serum cholesterol and triglyceride was decreased significantly by 1.5% Cynara scolymus powder as compared the control. Consistent with our findings, Yıldız et al., (2008) reported that artichoke decreased serum triglyceride levels in laying hens. Smilarly, Abdulkhaleq et al., (2019) found that artichoke extract treatment decreased the triglyceride level when compared to HFD (high feed diet) group. Suarez et al., (2019) reported that high-fat diets supplemented with 20% of artichoke significantly reduced plasma triglyceride levels (34%), plasma LDL and VLDL (29%) and total (24%) cholesterol. These results was supported in this article. Reduction of blood LDL, VLDL and triglycerides were observed using artichoke. This result suggested that artichokes contain luteolin, an antioxidant which prevents cholesterol formation. Luteolin inhibited cholesterol absorption.

In contrast to; Mirderikvandi et al., (2016) found that the supplementation of Cynara scolymus extract in drinking water of broilers had no statistically significant effect on blood parameters. Also, similar research Mohammadzadeh et al., (2014) found that 500 mg/l artichoke extract did not affect blood parameters. The researchers attribute the lack of effect of Cynara scolymus extract on blood parameters to the low dose of the extract.

MDA has been widely used as an indicator of lipid peroxidation. The addition of 5 g/kg of artichoke to the diet significantly decreased the serum MDA level. SOD value was not affected by treatments. The GSH, CAT and GPx values which are enzymatic antioxidants in serum were increased HE+ artichoke 5 g/kg groups. The highest concentration of GSH, CAT and GPx was obtained with HE+artichoke 5 g/kg groups (Table 5). This finding was similar to the study carried out by Salem et al., (2017). Smilarly Abdulkhaleq et al., (2019) examined the effect of using low and high doses of water extract of artichoke leaves that given to rats observed a significant reduction in serum MDA level, and increased GSH level. Also Kaymaz et al. (2017) reported that supplementation with aqueous extract of artichoke leaf of rat diet caused significant decrease of MDA level and significant increase of activity of SOD, GPx, and CAT in treatment group compared with control group. Several researchers have shown that artichoke significant decrease of serum MDA levels (Jaleel et al., 2016; Kaymaz et al., 2017; Tang et al., 2017). Considering that artichoke is rich in flavonoids and vitamin C, the artichoke might increase the concentration of enzymatic antioxidants (GSH, CAT and GPx) in the serum.

Estrogen receptors play a key role in the regulation of metabolic diseases such as NAFLD (Nonalcoholic fatty liver disease), obesity and insulin resistance (Palmisano et al., 2017). Estrogen stimulates liver fatty acid metabolism and suppresses hepatic glucose production (Ezhilarasan 2020). Estrogen prevents glucose-dependent lipid peroxidation by inhibiting intestinal glucose uptake and inhibiting the sodium-bound glucose transporter. The effect of artichoke leaf powder on estrogen hormone level was found to be statistically insignificant due to the dose increase ($P>0.05$).

Weight and fat ratio of liver

The supplementation of the diet with artichoke by product resulted in a significant reduction ($P<0.05$) of the liver fat content and a lower liver weight (Table 6). It was found that the addition of 5 g/kg artichoke to the diet significantly decreased the fresh and dry weight of the liver (Table 6). The liver fat content was dramatically lower ($P<0.05$) in laying hens fed on artichoke diets compared with those fed on the high energy diet (48.26 %). HE+artichoke 10 g/kg group (18.83 %) had the lowest fat content value. The results of the articles showed that artichoke has protective activity in the liver. It has been reported that the lipid-lowering effect of Artichoke is due to the relationship of luteolin with hydroxy-methyl-glutaryl-enzyme A reductase, liver sterol regulatory element-binding proteins and acetyl-CoA C-acetyltransferase (Gebhardt, 2002; Oppedisano et al., 2020). In experimental animal studies, liquid and dry extracts of artichoke have demonstrated an ability to protect the liver (EbrahimiMameghani et al., 2018; Rezazadeh et al., 2018; Suarez et al., 2019). Several researchers reported decreased liver fat content when artichoke, bergamot, rosemary, choline, flaxseed or flax oil were added to the diet (Musolino et al., 2020; Oppedisano et al., 2020; Urusan 2021). Although there are several studies with artichoke, none of the researchers have been conducted to evaluate the influence of the hepatoprotective effect of artichoke in laying hens.

Zhuang et al., (2019) suggested that the liver fat and abdominal fat in the high energy low protein diet were increased at the end of the study. Several studies releated that the level of energy intake increased liver fat and fatty liver hemorrhagic syndrome (Peng et al., 2018; Urusan 2021; Rozenboim et al., 2016). At present, hepatoprotectors are used in the integrated therapy of liver diseases. A reduction in relative liver fat in laying hens fed artichoke 5, 10, 15 g/kg high energy diets was in line.

In conclusion, the effects of artichoke supplementation in the high energy diet of laying hens on egg quality, performance, some antioxidant enzymes and liver fat ratio were measured. The result indicates that the use of artichoke in the high energy feed of laying hens improved the FCR, egg production and egg quality traits (shell weight, shell breaking strength, shell thickness and yolk color). Also artichoke are useful for reducing the serum triglyceride, LDL and VLDL concentration and increasing the serum antioxidant enzymes (GSH, CAT and GPx). Overall the use of artichoke for laying hens exerted benefits by decreasing liver fat ratio, which indicated artichoke has the potential to protective activity in the liver.

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