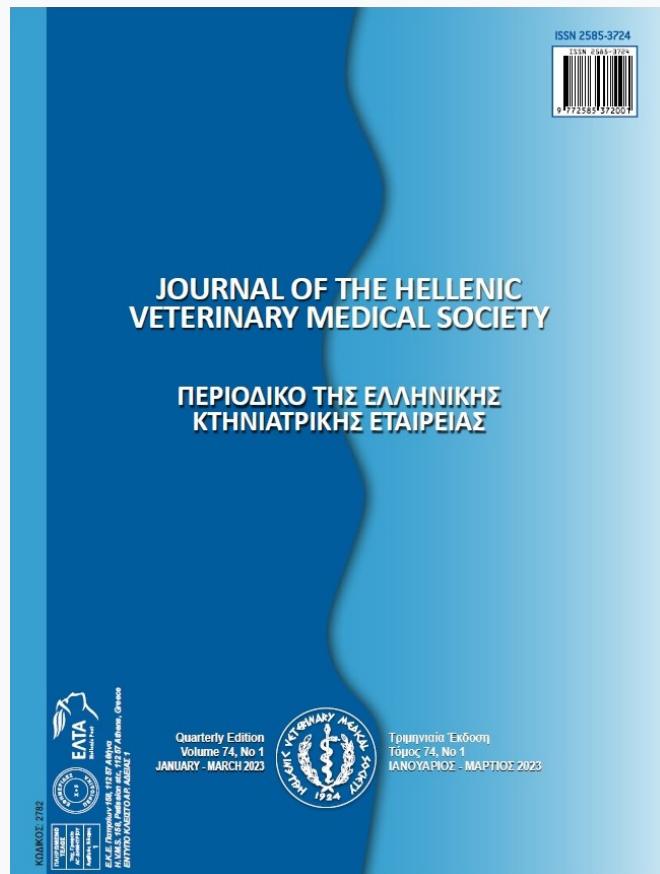


Journal of the Hellenic Veterinary Medical Society

Vol 74, No 1 (2023)



Hepatoprotective effect of Artichoke (Cynara scolymus) in laying hens

H Ürüşan

doi: [10.12681/jhvms.28954](https://doi.org/10.12681/jhvms.28954)

Copyright © 2023, Hilal Ürüşan



This work is licensed under a [Creative Commons Attribution-NonCommercial 4.0](https://creativecommons.org/licenses/by-nc/4.0/).

To cite this article:

Ürüşan, H. (2023). Hepatoprotective effect of Artichoke (Cynara scolymus) in laying hens. *Journal of the Hellenic Veterinary Medical Society*, 74(1), 5249–5258. <https://doi.org/10.12681/jhvms.28954> (Original work published 11 avril 2023)

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

H. Urusan^{*} 

Department of Plant and Animal Production, Technical Science Vocational School, Ataturk University,
Erzurum, 25240, Turkey

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 a 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

Corresponding Author:

H. Urusan, Department of Plant and Animal Production, Technical Science Vocational School, Ataturk University, Erzurum, 25240, Turkey.
E-mail address: hilalurusan@atauni.edu.tr

Date of initial submission: 17-12-2021
Date of acceptance: 15-03-2022

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 hepatopro-

tective 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 Ataturk 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 analyses (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 (Yoshiko 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 Bioteck Elisa Reader (Bio Single μ Quant 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 mul-

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 strength, 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)	Triglycerit (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 5 g/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	2.62 ^a	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 in-

cluding 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 strength, 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 released 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.

REFERENCES

Abadjieva D, Ankova1 D, Grigorova S, Kistanova E (2021) The effect of Artichoke (*Cynara scolymus* L.) on the expression of calcium-binding proteins in the eggshell gland of laying hens. Polish J Vet Sci 24(1):127-133. doi: 10.24425/pjvs.2021.136801

Abadjieva D, Ankova D, Grigorova S (2020) Effect of feeding artichoke (*Cynara scolymus* L.) on reproductive performance of laying hens. J Ento Zoo Studies 8(6):11-14.

Abdel-Moneim A, Ahmed OM, Abd El-Twab SM, Zaky MY, Bakry LN (2021) Prophylactic effects of *Cynara scolymus* L. leaf and flower hydroethanolic extracts against diethylnitrosamine/acetylaminofluorene-induced lung cancer in Wistar rats. Environ Sci Pollut Res Int 28:43515-27. doi: 10.1007/s11356-021-13391-x]

Abdo MA, Radwan NL, Selim NA (2007) The effect of artichoke leaves meal on the utilization of dietary energy for broiler chickens. Int J Poult Sci 12:973-982.

Abdulkhaleq RH, Hussein RH, Alnahdi HS (2019) Artichoke leaves water extract attenuate oxidative stress and regulates lipid profile in rats fed high fat diet. Int J Pharm Res Allied Sci 8: 138-145.

AOAC (Association of official analytical chemists) (2005) Official methods of analysis of AOAC international, 18th ed. AOAC Int., Washington, DC.

Bayraktar B, Tekce E (2018) Investigation of the effect of some herbal extracts used in different ratios on serum iron level in experimentally heat stress created in broiler. J Tradit Med Complement 1(2):50-55 doi: <https://doi.org/10.5336/jtracom.2018-61570>

Ben Salem M, Ksouda K, Dhouibi R, Charfi S, Turki M, Hammami S (2019) LC-MS/MS Analysis and Hepatoprotective Activity of Artichoke (*Cynara Scolymus* L.) Leaves Extract against High Fat Diet-Induced Obesity in Rats. Biomed Res Int 4851279. doi:10.1155/2019/4851279

Bolukbasi SC, Urusan H, Erhan MK (2018) Effects of *mentha pulegium* extract and vitamin E supplementation on laying hens performance, egg quality, antioxidant enzyme activity in serum. Fresenius Environ Bull 27(12):8014-8020.

Duman F (2016) The effects of using of dried artichoke leaves on growth performance and some carcass parameters in japanese quails. Ordu University master's thesis 2016, 27.

Ebrahimi-Mameghani M, Asghari-Jafarabadi M, Rezazadeh K (2018) TC-F7L2-rs7903146 polymorphism modulates the effect of artichoke leaf extract supplementation on insulin resistance in metabolic syndrome: a randomized, double-blind, placebo-controlled trial, J Integrative Med 16(5):329-334 <https://doi.org/10.1016/j.joim.2018.05.006>.

Ezhilarasan D (2020) Critical role of estrogen in the progression of chronic liver diseases. Hepatobiliary Pancreatic Diseases Int 19(5):429-434 ISSN 1499-3872, <https://doi.org/10.1016/j.hbpd.2020.03.011>.

Fallah R, Kiani A, Azarfar A (2013) Effect of artichoke leaves meal and mentha extract (*mentha piperita*) on immune cells and blood biochemical parameters of broilers. Global Vet 10(1):99-102. doi: 10.5829/idosi.gv.2013.10.1.71206

Farhan MM, Hassawi DS, Ibraheem NK (2018) Polyphenols compounds investigation of leaves and callus artichoke (*Cynara scolymus* L.). Plant Archives 18:2629-2635

Folch J, Lees M, Stanley GHS (1957) A simple method for the isolation and purification of total lipides from animal tissues. J Biol Chem 226:497-509 doi: [https://doi.org/10.1016/S0021-9258\(18\)64849-5](https://doi.org/10.1016/S0021-9258(18)64849-5)

Gao X, Liu P, Wu C, Wang T, Liu G, Cao H (2019) Effects of fatty liver hemorrhagic syndrome on the AMP-activated protein kinase signaling pathway in laying hens. Poult Sci 98:2201-2210 doi: 10.3382/ps/pey586

Garcia ERDM, Chaves NRB, Oliveira CALD, Kiefer C, Melo EPD (2019) Performance and egg quality of laying hens fed with mineral sources and rosemary oil. Academia Brasileira De Ciencias 91(2):1678-2690.

Gebhardt R (2002) Inhibition of cholesterol biosynthesis in HepG2 cells- by artichoke extracts is reinforced by glucosidase pretreatment. Phytotherapy Res 16(4):368-372.

Gostin AI, Waisundara VY (2019) Edible flowers as functional food: A review on artichoke (*Cynara cardunculus* L.). Trends Food Sci Technol 86:381-391.

Goth L (1991) A simple method for determination of serum catalase activity and revision of reference range. Clinica Chimica Acta 196: 143-

151. doi: 10.1016/0009-8981(91)90067-m.

Jaleel GA, Saleh DO, El-Awdan SA (2016) Beneficial effect of artichoke leaf extract on ethylene glycol-induced urolithiasis in rats. *Int J Pharma Phytochem Res* 8: 960-967.

Kang HK, Park SB, Jeon JJ, Kim HS, Park KT, Kim SH, Hong EC, Kim CH (2018) Effect of increasing levels of apparent metabolizable energy on laying hens in barn system. *Asian-Australasian J Anim Sci* 31(11):1766-1772 https://doi.org/10.5713/ajas.17.0846

Kaymaz MB, Kandemir MF, Pamukçu E, Erökşüz Y, Özdemir N (2017) Effects of aqueous artichoke (*Cynara scolymus*) leaf extract on hepatic damage generated by alpha-amanitine. *J Faculty of Vet Med, Kafkas University* 23:155-160 doi: 10.9775/kvfd.2016.16094

Klementavičiūtė JR, Gružauskas A, Racevičiūtė-Stupelienė A, Miežlienė G, Alenčikienė V, Buckiūnienė A, Daukšienė L, Kudlinskienė J, Lionikienė G, Stanytė V, Šastyte Valaitienė V (2018) Jerusalem artichoke (*Helianthus tuberosus* L.) influence on laying hen's eggs' quality characteristics. *Vet Med Zoot* 76:46-50.

Krepkova LV, Babenko AN, Saybel OL (2021) Valuable Hepatoprotective Plants-How Can We Optimize Waste Free Uses of Such Highly Versatile Resources? *Frontiers Pharma* 12:738504 doi: 10.3389/fphar.2021.738504.

Liu Y, Lin X, Zhou X, Wan D, Wang Z (2017) Effects of dynamic feeding low and high methionine diets on egg quality traits in laying hens. *Poult Sci* 96:1459-1465 doi: 10.3382/ps/pew398

Matkovics B, Laszio A, Varga SZI (1988) Changes and correlations of antioxidant enzymes, lipid peroxidation and serum neutral lipids due to hemodialysis treatment in chronic uraemic patients. *Int Urol Nephrol* 20:559-564 doi: 10.1007/BF02550619.

Michalak M (2022) Plant-Derived Antioxidants: Significance in Skin Health and the Ageing Process. *Int J Mol Sci* 23:585 doi: https://doi.org/10.3390/ijms23020585

Mirderikvandi M, Kiani A, Khaldari M, Alirezaei M (2016) Effects of artichoke (*Cynara scolymus* L.) extract on antioxidant status in chicken thigh meat. *Iran J Vet Med* 10(1):73-81.

Mohammadzadeh S, Brumandnia Z, Khaldari M (2014) Investigations on the effects of artichoke (*Cynara cardunculus* var. *scolymus*) extract on 35 - 42 days blood lipid parameters of broiler chickens. *Anim Res Int* 11:2091-2096.

Moradi M, Sohrabi G, Golbidi M, Yarmohammadi S, Hemati N, Campbell SM, Moradi S, Kermani MAH, Farzaei MH (2021) Effects of artichoke on blood pressure: A systematic review and meta-analysis. *Complement Therapy Med* 57: 102668, ISSN 0965-2299, https://doi.org/10.1016/j.ctim.2021.102668.

Musolino V, Micaela G, Bombardelli E, Nucera S, Carresi C, Maiuolo J, Mollace R, Paone S, Bosco F, Scarano F, Scicchitano M, Macri R, Ruga S, Zito MC, Palma E, Gratteri S, Ragusa M, Volterrani V, Fini M, Mollace V (2020) The synergistic effect of *Citrus bergamia* and *Cynara cardunculus* extracts on vascular inflammation and oxidative stress in non-alcoholic fatty liver disease. *J Trad Compl Med* 10(3):268-274 https://doi.org/10.1016/j.jtcme.2020.02.004.

Olarotimi OJ (2020) Serum electrolyte balance and antioxidant status of broiler chickens fed diets containing varied levels of monosodium glutamate (MSG). *Bull Natl Res Cent* 44:(1)1-7 doi: https://doi.org/10.1186/s42269-020-00360-6

Oppedisano F, Muscoli C, Musolino V, Carresi C, Macri R, Giancotta C, Bosco F, Maiuolo J, Scarano F, Paone S, Nucera S, Zito MC, Scicchitano M, Ruga S, Ragusa M, Palma E, Tavernese A, Mollace R, Bombardelli E, Mollace V (2020) The Protective Effect of *Cynara Cardunculus* Extract in Diet-Induced NAFLD: Involvement of OCTN1 and OCTN2 Transporter Subfamily. *Nutrients* 12(5):1435. https://doi.org/10.3390/nu12051435

Palmisano BT, Zhu L, Stafford JM (2017) Role of Estrogens in the Regulation of Liver Lipid Metabolism. In: Mauvais-Jarvis F. (eds) Sex and Gender Factors Affecting Metabolic Homeostasis, Diabetes and Obesity. *Adv Exp Med Biol* 1043 https://doi.org/10.1007/978-3-319-70178-3_12

Pandino G, Mauromicale G (2020) Globe artichoke and cardoon forms between traditional and modern uses. *Acta Hort* 1(18):1284.

Peng G, Huang E, Ruan J, Huang L, Liang H, Wei Q, Xie X, Zeng Q, Huang J (2019) Effects of a high energy and low protein diet on hepatic and plasma characteristics and Cidea and Cidec mRNA expression in liver and adipose tissue of laying hens with fatty liver hemorrhagic syndrome. *Anim Sci J* 90:247- 254. https://doi.org/10.1111/asj.13140

Radwan NL, Abdo ZMA, Hassan RA (2007) Effect of feeding artichoke leaves meal on productive and reproductive performance of mandarin hens. *Int J Poult Sci* 6(11):826-834.

Rahim MA, Saeed F, Khalid W, Hussain M, Anjum MF (2021) Functional and nutraceutical properties of fructo-oligosaccharides derivatives: a review. *Int J Food Prop* 24(1):1588-1602, doi: 10.1080/10942912.2021.1986520

Rezazadeh K, Rezazadeh F, Ebrahimi-Mameghani M (2018) The effect of artichoke leaf extract supplementation on lipid and CETP response in metabolic syndrome with respect to Taq 1B CETP polymorphism: A randomized placebo-controlled clinical trial, *European J Integrative Med* 17:112-118 https://doi.org/10.1016/j.eujim.2017.12.008.

Rouzbeh F, Mohit A, KoshSekeh M, Hassanzade M (2014) The effect of the additive containing artichoke extract (APC) on growth, blood cholesterol level, carcass characteristics and immune system of broiler chickens. *Iranian J Vet Clin Pathol* 8:357-366.

Rozenboim I, Mahato J, Cohen NA, Tirosh O (2016) Low protein and high-energy diet: a possible natural cause of fatty liver hemorrhagic syndrome in caged white leghorn laying hens. *Poult Sci* 95:612-621. doi: 10.3382/ps/pev367

Salata A, Nurzyńska-Wierdak R, Kalisz A, Kunicki E, Ibáñez-Asensio S, Moreno-Ramón H (2022) Effects of Organic Cropping on Phenolic Compounds and Antioxidant Capacity of Globe Artichoke Herbs. *Agronomy* 12(1):192 https://doi.org/10.3390/agronomy12010192

Salem MB, Kolsi RB, Dhouib R, Ksouda K, Charfi S (2017) Protective effects of *Cynara scolymus* leaves extract on metabolic disorders and oxidative stress in alloxan-diabetic rats. *BMC Comp Altern Med* 17(1):328. doi: 10.1186/s12906-017-1835-8

SPSS 23.0 Package Software

Suarez MJV, Aparicio IM, Pérez-Cózar ML, Yokoyama W, Redondo-Cuencina A (2019). Hypolipidemic effects of dietary fibre from an artichoke by-product in Syrian hamsters. *J Funct Foods* 56:156-162 ISSN 1756-4646 https://doi.org/10.1016/j.jff.2019.03.013.

Sun Y, Oberley LW, Li Y (1988) A simple method for clinical assay of superoxide dismutase. *Clin Chem* 34:497-500. doi: https://doi.org/10.1093/CLINCHEM%2F34.3.497

Tajodini M, Samadi F, Hasani S, Hashemi SR, Samadi S (2015) Influence of artichoke (*Cynara scolymus*) leaf powder on growth performance, carcass traits and blood parameters in broiler chickens. *Iran J Appl Anim* 5(1):141-146.

Tang X, Wei R, Deng A, Lei T (2017) Protective Effects of Ethanolic Extracts from Artichoke, an Edible Herbal Medicine, against Acute Alcohol-Induced Liver Injury in Mice. *Nutrients* 9(9):1000 doi: 10.3390/nu9091000. PMID: 28891983; PMCID: PMC5622760.

Targher G, Byrne CD, Tilg H (2020) NAFLD and increased risk of cardiovascular disease: clinical associations, pathophysiological mechanisms and pharmacological implications. *Gut* 69:1691-1705.

Tietze F (1969) Enzymic method for the quantitative determination of nanogram amounts of total and oxidized glutathione: applications to mammalian blood and other tissues. *Anal Biochem* 27:502-522 doi: https://doi.org/10.1016/0003-2697(69)90064-5

Torki M, Sedgh-Gooya S., Mohammadi H (2018) Effects of adding essential oils of rosemary, dill and chicory extract to diets on performance, egg quality and some blood parameters of laying hens subjected to heat stress. *J App Anim Res* 46(1):1118-1126 doi: 10.1080/09712119.2018.1473254

Urusan H (2021) The Effect of Rosemary Leaves (*Rosmarinus officinalis*) Addition to Diets with High Energy on Laying Hen Performance, Egg Quality Parameters, Serum Lipid Profile and Liver Fat Rate. *J Tekirdağ Agri Faculty* 18(1):115-124.

Wen J, Zhe Z, QianWen W, Wei L (2021) Effect of homologous traditional chinese medicine feed additives on production performance of laying hens and egg quality and economic benefits. *Turk J Field Crops* 26(1):285-298 doi: 10.17557/tjfc.834527

Westendarp H (2005) Essential oils for the nutrition of poultry, swine and ruminants. *Deutsche Tierärztliche Wochenschrifte* 112: 375-380.

Yıldız G, Sacaklı P, Gungor T (2006) The effect of dietary jerusalem artichoke (*helianthus tuberosus* L.) on performance, egg quality characteristics and egg cholesterol content in laying hens. *Czech J Anim Sci*

51:349-354 doi: <https://doi.org/10.17221/3950-CJAS>

Yıldız G, Sacaklı P, Gungor T, Uysal H (2008) The effect of jerusalem artichoke (*helianthus tuberosus* L.) on blood parameters, liver enzymes and intestinal ph in laying hen. *J Anim Vet Adv* 7:1297-1300 <https://hdl.handle.net/20.500.12587/4071>

Yoshiko T, Kawada K, Shimada T (1979) Lipid peroxidation in maternal and cord blood and protective mechanism against activated-oxygen toxicity in the blood. *Am J Obstet* 135:372-376. doi: 10.1016/0002-9378(79)90708-7.

Zhuang Y, Xing C, Cao H, Zhang C, Luo J (2019) Insulin resistance and metabonomics analysis of fatty liver haemorrhagic syndrome in laying hens induced by a highenergy low-protein diet. *Sci Reports* 9:10141 doi:<https://doi.org/10.1038/s41598-019-46183-y>