Master's Thesis of Science in Agriculture

The Effect of Evening Primrose (*Oenothera odorata*) Extract on Growth Performance and Carcass Characteristics in Broiler Chickens

달맞이꽃 (*Oenothera odorata*) 추출물이 육계의 성장능력과 도체성적에 미치는 영향

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Abstract

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The present study was conducted to examine the effects of evening primrose (*Oenothera odorata*) extract (EPE) on growth performance and carcass characteristics in broiler chickens. One hundred twelve one-day-old commercial male broilers (Indian river) were randomly distributed to five experimental groups: Control (without administration), IV (Intravascular administration), IP (Intraperitoneal administration), IV(2x) (Intravascular administration with double dose) and IP(2x) (Intraperitoneal administration with double dose). The methanolic extract of whole plant (seed/flower/leaf/stem/root) of *Oenothera odorata* was administered to chickens by intravascular and intraperitoneal injection during 3-7 weeks of the experiment period.

There were significant increases in body weight and weight gain in all treatment groups compared to control group at 6-7 weeks of age ($p<0.05$). Also, significant higher feed intake at 5 and 7 weeks of age and lower feed conversion ratio at 7 weeks were observed in EPE treatment groups ($p<0.05$). In addition, the administration of EPE positively influenced the carcass yields such as breast muscle and drumstick ($p<0.05$).

The present study suggested that the extract derived from whole plant of evening primrose had a potential for improvement of growth performance and thereby could be

used as a potential growth promotor for productivity and quality of meat in broiler chickens.

Key words: Evening Primrose Extract (EPE), Phytogenic feed additives, Broiler, Growth Performance, Carcass Characteristics

***Student number**: 2016-26324*

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List of Abbreviations

AA: arachidonic acid

AGP: antibiotic growth promotor

CAGR: compound annual growth rate

DGLA: dihomo-gamma-linolenic acid

DMSO: dimethyl sulphoxide

EPE: evening primrose extract

EPO: evening primrose oil

FCR: feed conversion ratio

GLA: gamma-linolenic acid

I.P: intra-peritoneal

I.V: intra-vascular

LA: linoleic acid

MUFA: mono-unsaturated fatty acids

PFA: phytogenic feed additives

PGE1: prostaglandin E1

PMS: premenstrual syndrome

PUFA: poly-unsaturated fatty acids

SFA: saturated fatty acid

TC: total cholesterol

TG: triglyceride

15-HETrE: 15-hydroxyeicosatrienoic acid

Introduction

In the past decades, antibiotic growth promoters (AGP) have been widely used in livestock feed to improve the productivity and the quality of feed and food products as well as animal hygiene status.[1-5] However, European Union has banned its use as feed additives in 2006 because of the problems caused by antibiotic overuse and thereby non-antibiotic substances with growth promoting potential such as organic acids, probiotics and botanical products have received a lot of attention. It is known that botanical products including herbs, spices and their extracts and essential oils contain a large variety of chemical substances and have diverse effects on animal performance due to differences in origin of plants, processing and chemical composition.[6]

Evening primrose (*Oenothera odorata)* is a biennial herb that belongs to the Onagraceae family and native to South America and became naturalized in north-east China and Korea. It opens visibly fast in the evening, hence the name 'evening primrose.' All plant parts including roots, leaves, flowers and seeds are edible and medically applicable. Records showed that the whole plant and especially the leaves were boiled to tea by Native American tribes to treat laziness and fatness. They also used the roots externally to treat wounds and boils. Today, due to low-cost hand labor and climatic condition for growth of the crops, China is the world's largest producer of commercial evening primrose, accounting for 90% of the world supply.[7] According to a report by the MarketWatch (Sep 12, 2019), global evening primrose oil market is valued at 170 million US$ in 2017 and will reach 250 million US$ by the end of

2025, growing at a CAGR of 4.8% during 2018-2025. The oil derived from evening primrose seeds contains a high amount of linoleic acid (LA) (70-74%) and gamma-linolenic acid (GLA) (8-10%) which are high quality, essential polyunsaturated fatty acids (PUFA).[8] In recent years, various seed oils from herbal plants containing the high levels of GLA have been commercialized. The level of GLA in evening primrose oil (EPO) varies 7-10% of total fatty acids, whereas in borage oil it ranges 18-25%, and in black current oil it is 15-20%, and in hemp seed oil 1-6%.[9-11] Although evening primrose does not produce a high yield of seeds (thousand kernel weight: 0.3-0.7g) and thereby being the most expensive edible oil of commerce[12] compared with the other oil seeds, it is considered as the best source of GLA because of it's ease of production[13] and better absorption in the human body.[14] A study has shown that GLA from EPO has greater bio-activity than that from borage oil, which contains twice as much GLA content.[15]

GLA is an omega-6 PUFA found in human breast milk and several herbal seed oils and is commonly consumed as a dietary supplement, nutraceutical[9] and pharmaceutical drug.[16] GLA is an intermediate precursor of anti-inflammatory eicosanoids such as prostaglandins and leukotriens that are essential for proper functioning of body tissues.[8,10,16-17] GLA is produced in the body as an intermediate metabolite from LA in a reaction catalyzed by Δ6-desaturase. In turn, it is elongated to dihomo-gamma-linolenic acid (DGLA) by an elongase, and then DGLA converted to arachidonic acid (AA) by Δ 5-desaturase. DGLA is the precursor for the biosynthesis of prostaglandin E1 (PGE_1) and 15-hydroxyeicosatrienoic acid (15-HETrE) which alleviate inflammatory and proliferative processes.[9-10] The deficiency of GLA in the body may cause inflammatory,

autoimmune and neoplasmal disease. In contrast, the supplementation of GLA-rich oil has great potential in dampening inflammation and modulating immune function. The reported biological activities of evening primrose which is extremely high in GLA are anti-inflammatory, anti-oxidant, cytotoxic, antibacterial, antiviral, antihyperlipidaemic, thrombolytic and immunomodulation.[18] Therefore, EPO is widely used for attenuating several disorders such as atopic dermatitis, rheumatoid arthritis, obesity, diabetes mellitus, hyper-cholesterolemia, skin aging caused by using cosmetics, Alzheimer's disease, cardio-circulatory disease, multiple sclerosis and premenstrual syndrome (PMS) in woman.[17,19-23]

Several studies have been conducted to determine the effects of EPO for the capability as alternatives to AGP and the possibility as sources of functional products with feeding experiments in mono-gastric animals and poultry. However, previous studies have reported inconsistent results in broilers fed different levels of EPO, especially for growth performance and carcass traits. The bio-activity of evening primrose depends on the chemical composition of various parts of the evening primrose. Not only seeds but roots and leaves of this plant are used to make traditional medicine. The most interesting source of bio-active components in evening primrose is the GLA-rich seed oil, but it is likely that the other plant parts such as roots and aerial parts (flower, leaf and stem) also have biological activity similar to the seed, considering that they all contain the components of fatty acids, phenolic acids and flavonoids in them.[8] However, previous study on the bioactivity of whole plant extracts of evening primrose as a dietary supplement in livestock is scarce.

Thus, the aim of the present study was to evaluate the biological activity of evening

primrose extract (EPE) derived from the whole plant of *Oenothera odorata* and to explore the capability as alternatives to AGP when used as sources of dietary supplements in livestock. For this objective, the present study was conducted to determine the effects of EPE on growth performance and carcass characteristics in broiler chickens.

Materials and methods

1. Experimental animal care and treatment

The procedures used in the care of broiler chickens for experiments were approved by the Institutional Animal Care and Use Committee (SNU-190306-1), Seoul National University. All birds were maintained in accordance with the standard management program at the University Animal Research Farm, Pyeongchang Campus, Seoul National University, Korea. The procedures for animal management adhered to the standard operating protocols of our laboratory.

A total of 250 one-day-old commercial broilers (Indian river) were obtained from Join Hatchery (Gyeonggi, Korea). All birds were weighed at d 1 and their gender was identified through PCR sexing. Sexing PCR primers were designed to amplify 415bp product of W chromosome XhoI repeat sequence and 256bp product of ribosomal gene sequence, as reported in a previous study.[24] PCR was performed via initial incubation at 95℃ for 5 minutes, 35 cycles of 95℃ for 30 seconds, 60℃ for 30 seconds and 72℃ for 30 seconds. The only 112 male broilers were randomly distributed to five experimental groups: Control (without administration), IV (Intravascular administration), IP (Intraperitoneal administration), IV(2x) (Intravascular administration with double dose) and IP(2x) (Intraperitoneal administration with double dose). All birds were housed in 18 cages situated in an insulated room and room temperature, lighting regimes, relative

humidity and ventilation were followed according to the commercial recommendations. In all groups, the broiler chickens were fed the same commercial diets (Cargill Max series) throughout the experimental period and the feeding program consisted of a starter diet which was fed until d 11, a grower diet which was fed from d 12 to d 25 and a finisher diet which was fed from d 26 to d 49. Feed and water were provided *ad libitum* throughout the experimental period (Table 1).

Table 1. Composition of commercial feeds during experiment period.

Composition	Commercial feed		
	Starter	Grower	Finisher
Crude protein	> 22.00%	> 20.00%	> 18.50%
Crude fat	> 2.50%	> 2.50%	> 2.50%
Crude fiber	< 6.00%	< 6.00%	< 6.00%
Ash	< 8.00%	< 8.00%	< 8.00%
Calcium	> 0.80%	> 0.70%	> 0.80%
Phosphor	< 1.20%	< 1.20%	< 1.20%
Met + Cys	> 0.90%	> 0.80%	> 0.70%
AMEn	2,850 kcal/kg	2,950 kcal/kg	3,000 kcal/kg

2. Administration of Evening primrose extract

The methanolic extract of whole plant (seed/flower/leaf/stem/root) of *Oenothera odorata* was obtained from Korea Plant Extract Bank (Chungbuk, Korea). Evening primrose extract (EPE) was administered directly to all birds of treatment groups by intravascular and intraperitoneal injection, and dose of EPE was determined based on mean body weight of each treatment group on the same day. The standard dose was

400ul per body weight by kg and EPE was diluted with DMSO (dimethylsulphoxide) to administer to chickens. EPE was administered every week for the birds of group IV and IP, and twice a week for the group IV(2x) and IP(2x) during the 3-7 weeks of experiment, respectively (Table 2).

Table 2. Dose of evening primrose extract for broiler chickens during experiment period.

Age (wk)	3	3.5	4	4.5	5	5.5	6	6.5
Dose(ul/g)	210	210	420	420	580	580	810	810
Treatment group	IV, IP	IV(2x), IP(2x)	IV, IP	IV(2x), IP(2x)	IV, IP	IV(2x), IP(2x)	IV, IP	IV(2x), IP(2x)

3. Performance parameters

Parameters for productive performance (body weight, body weight gain, feed intake, and feed conversion ratio (FCR)) were measured on throughout the experimental period. All birds were weighed individually on d 7, 14, 21, 24, 28, 32, 35, 39, 42, 46 and 49 and feed intake values on a cage basis were determined by weighing the rest of feed at the same days. Weight gain and FCR were calculated on a cage basis at the end of 5th, 6th and 7th week of experiment period. Broilers of each group of control, IV and IP were divided equally into thirds and killed by a surgical blade for complete bleeding on d 35, 42 and 49 of the trial, and all birds of group IV(2x) and IP(2x) were sent to slaughtered at once on d 49 of the trial. The dressed weights of breast muscle and drumstick without skin as well as abdominal fat (from the proventriculus surrounding

the gizzard down to the cloaca) were weighed on the same day. The internal organs (liver, heart, spleen, gizzard) were also weighed.

4. Chemical blood analysis

Blood samples were collected from wing veins of the birds (5 birds per each treatment groups) using heparinized vacutainers. The blood samples were centrifuged for 10 min at 3,000 rpm to separate plasma. The values of triglyceride (TG), total cholesterol (TC) and glucose content in the plasma for the birds of 3-6 weeks of age were measured by using chemistry analyzer (IDEXX, Catalyst Dx, USA).

5. Statistical analysis

Statistical analysis was conducted using SAS, version9.4 (SAS Institute, Cary, NC, USA). The significance of differences was analyzed using a general linear model procedure and the differences among groups were considered statistically significant when $P < 0.05$.

Results

1. Growth performance

The effect of administration of EPE on growth performance of broilers during the study are summarized in Table 3.

1.1. Body weight and body weight gain

The average body weight (Figure 1) and body weight gain of the birds did not differ among groups at the age of 5 weeks, but they were significantly increased in the treatment groups IV, IP, IV(2x) and IP(2x) compared to group control at the age of 6-7 weeks ($p<0.05$). Among the treatment groups, the group IV showed obvious increases in body weight and weight gain from 6 weeks of age and continued until 7 weeks of age (Figure 2).

1.2. Feed intake and Feed conversion ratio

As shown in Figure 3 and 4, significantly higher ($P<0.05$) feed intake was observed in birds of the treatment groups IV and IP at the age of 5 weeks and the group IP(2x) at the age of 7 weeks, respectively. On the other hand, FCR was not significant among

groups at the age of 5-6 weeks, but it was lowered significantly (p<0.05) in the treatment groups IV and IV(2x) compared to group control at the age of 7 weeks.

Table 3. Effect of evening primrose extract on growth performance of broiler chickens at the age of 5-7 weeks.

Age (wk)	Treatment					*p*-value
	Control	IV	IP	IV(2x)	IP(2x)	
Body Weight (g)						
5	1489.1±81.9	1531.3±85.1	1561.8±70.2	1423.3±82.2	1675.0±101.8	N.S
6	1960.5±112.4^{a}	2217.6±97.2^{c}	2005.0±136.3^{b}	2106.0±142.2^{bc}	2181.3±62.7^{bc}	*
7	2212.5±38.5^{a}	2747.5±148.9^{b}	2635.0±129.1^{b}	2747.5±8.8^{b}	2625.0±152.3^{b}	*
Body Weight Gain (g)						
5	1442.4±82.6	1483.3±85.4	1513.5±70.4	1375.3±83.9	1625.7±98.7	N.S
6	1914.3±112.5^{a}	2169.6±96.8^{c}	1955.4±138.3^{b}	2058.0±143.0^{bc}	2132.0±58.9^{bc}	*
7	2163.0±37.8^{a}	2696.5±148.6^{b}	2583.7±133.2^{b}	2700.5±6.7^{b}	2575.7±151.4^{b}	*
Feed Intake (g)						
5	2504.2±98.1^{a}	2739.9±119.5^{b}	2742.0±123.2^{b}			*
6	3378.3±215.0	3978.1±466.4	3753.0±291.7			N.S
7	4951.8±89.4^{a}	5239.3±77.5^{ab}	5274.7±51.7^{ab}	5248.0±11.3^{ab}	5453.0±274.0^{b}	*
Feed Conversion Ratio						
5	1.78±0.14	1.94±0.15	1.78±0.05			N.S
6	1.71±0.11	1.92±0.21	2.03±0.26			N.S
7	2.29±0.04^{a}	1.97±0.11^{b}	2.08±0.13^{ab}	1.96±0.00	2.11±0.11^{ab}	*

$^{a-c}$ Values with different superscripts within a row differ significantly (*: $P < 0.05$, N.S: $P > 0.05$)

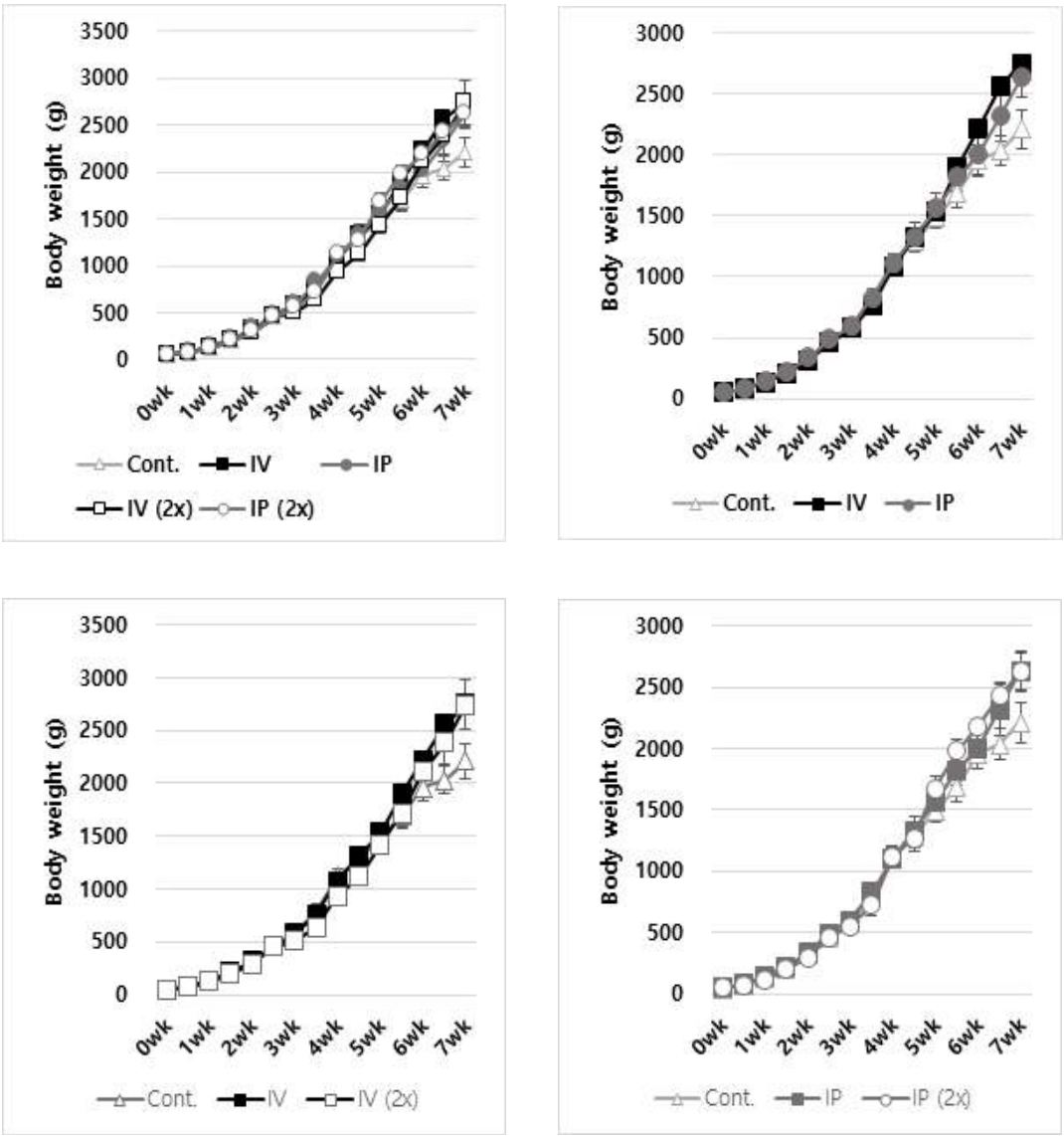
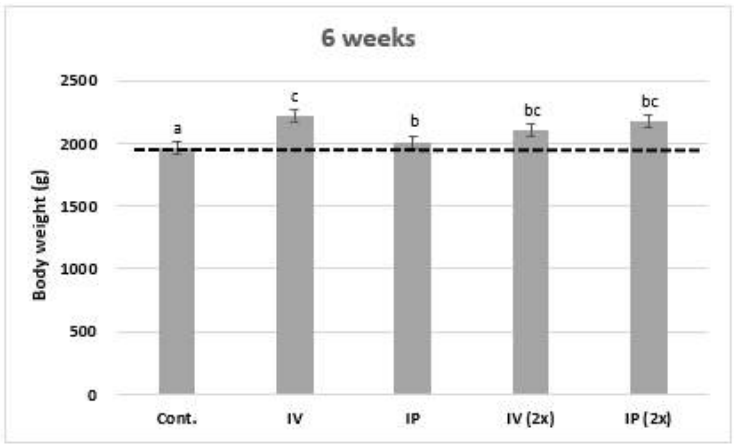


Figure 1. Effect of evening primrose extract on body weights of broiler chickens. There were significant increases in all treatment groups compared to control group at 6-7 weeks of age (P<0.05).

(A)



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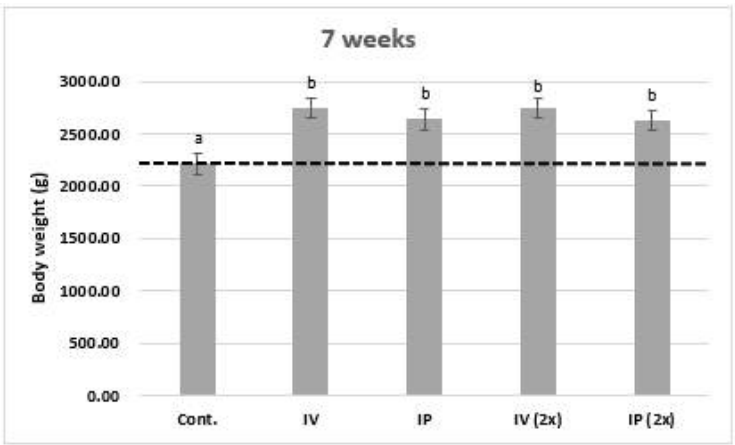


Figure 2. Effect of evening primrose extract on body weights of broiler chickens at the age of 6 weeks (A) and 7 weeks (B).

(A) (B)

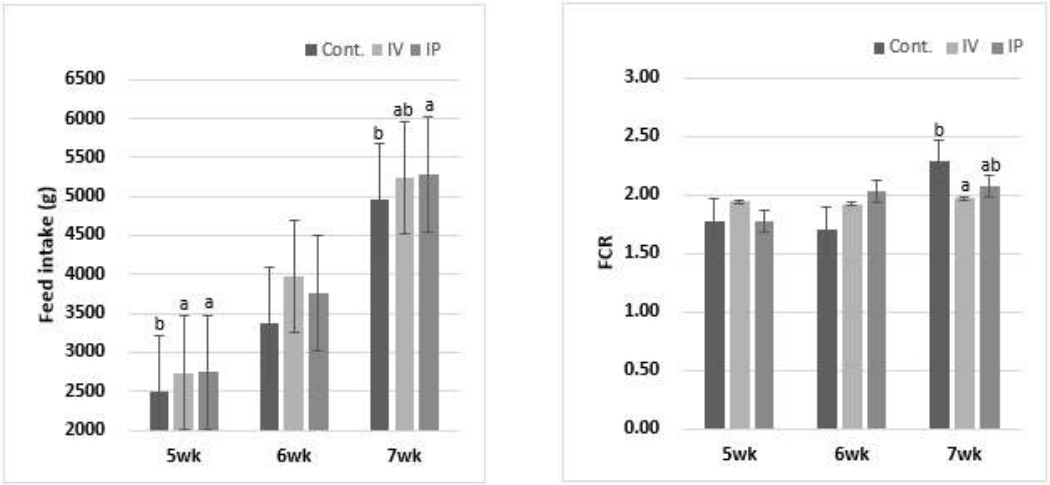
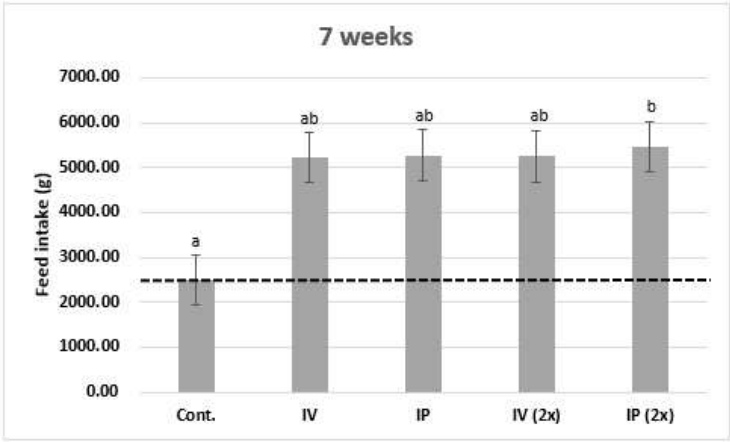


Figure 3. Effect of evening primrose extract on feed intake (A) and feed conversion ratio (B) of broiler chickens at the age of 5-7 weeks.

(A)



(B)

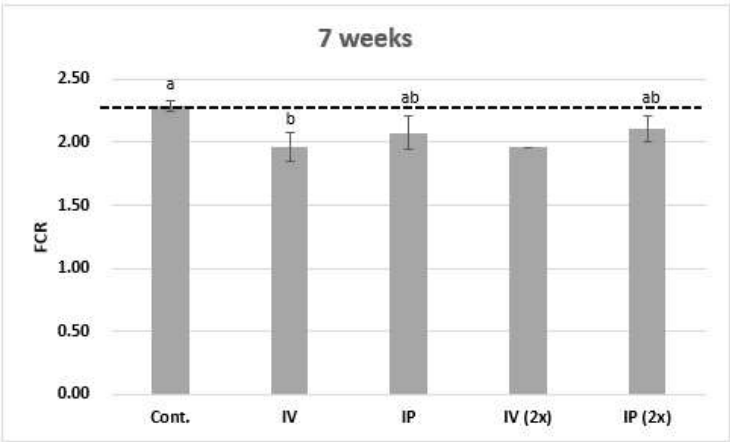


Figure 4. Effect of evening primrose extract on feed intake (A) and feed conversion ratio (B) of broiler chickens at the age of 7 weeks.

2. Carcass characteristics

The effect of administration of EPE on carcass characteristics of broilers during the study are summarized in Table 4. The dressed portional weights of breast muscle and drumstick and the weights of abdominal fats and internal organs of the birds were determined.

There were significant (P<0.05) increases of the weights of breast muscle in the treatment group IP at the age of 5 weeks and in the treatment groups IV and IV(2x) at the age of 7 weeks compared to group control, respectively. Similarly, the weights of drumstick did not differ significantly among groups at the age of 5-6 weeks, but they were also increased significantly (P<0.05) in the treatment groups IV and IV(2x) compared to group control at the age of 7 weeks (Figure 5 and 6).

However, as shown in Figure 6 and 7, no statistical differences in abdominal fat were observed between treatment groups and control group during the experiment period.

And there were no significant differences in weights of liver in all groups at the age of 5-6 weeks, but they were increased significantly (P<0.05) in the treatment group IV compared to group control at 7 weeks of age. For the weights of heart, no significant differences among groups were found at the age of 5 weeks, but they were also increased significantly (P<0.05) in the treatment group IP at the age of 6 weeks and in the treatment group IV at the age of 7 weeks compared to group control, respectively. However, the weights of spleen and gizzard did not significantly differ among groups throughout the experimental period (Figure 6).

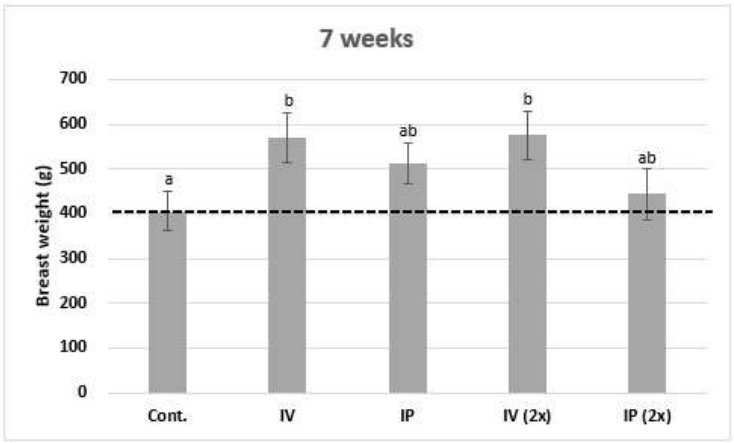
On the other hand, Table 5 shows the ratio of carcass yield to body weight and abdominal fat to carcass yield of broiler chickens at the age of 5-7 weeks. Results showed that there were no significant differences in the ratio of carcass yields (breast muscle, drumstick and abdominal fat)-to-body weight and abdominal fat-to-carcass yields (breast muscle and drumstick) of the birds among groups during the experiment period (Figure 8, 9 and 10).

Table 4. Effect of evening primrose extract on carcass characteristics of broiler chickens at the age of 5-7 weeks.

Parameter	Treatment					*p*-value
	Control	IV	IP	IV(2x)	IP(2x)	
Dressed weight (g)						
5wk (d 1-35)						
Liver	40.1±2.9	39.4±1.8	42.5±4.8			N.S
Heart	7.5±0.4	8.0±0.5	8.3±0.5			N.S
Gizzard	25.1±2.0	28.5±2.7	24.0±2.6			N.S
Spleen	1.9±0.3	2.2±0.4	2.1±0.3			N.S
Abd. Fat	13.2±3.1	13.3±2.0	14.0±3.0			N.S
Breast M.	260.4±23.1^{ab}	251.4±16.0^{a}	293.3±19.5^{b}			*
Drumstick	279.2±16.7	273.1±15.5	283.9±17.5			N.S
6wk (d 1-42)						
Liver	47.4±5.0	50.3±4.3	54.3±4.8			N.S
Heart	9.9±0.6^{a}	11.1±0.5^{ab}	11.6±0.8^{b}			*
Gizzard	28.9±3.3	26.4±2.7	28.3±3.0			N.S
Spleen	2.8±0.5	3.7±0.8	2.8±0.4			N.S
Abd. Fat	22.4±6.9	29.9±7.6	19.7±4.9			N.S
Breast M.	394.2±15.3^{b}	404.5±11.3^{b}	351.8±24.5^{a}			*
Drumstick	370.7±20.8	397.0±12.0	367.6±27.9			N.S
7wk (d 1-49)						
Liver	47.5±0.9^{a}	68.3±7.3^{b}	50.6±7.3^{ab}	42.1±0.4^{a}	45.8±2.4^{a}	*
Heart	10.1±0.9^{a}	13.2±0.6^{b}	10.6±0.7^{a}	10.8±0.5^{ab}	11.7±0.3^{ab}	*
Gizzard	26.7±2.7	28.8±1.9	25.5±1.8	29.8±2.1	29.3±1.0	N.S
Spleen	3.4±0.5	4.8±1.5	2.5±0.2	2.9±0.4	3.5±0.4	N.S
Abd. Fat	18.5±7.6	27.4±8.7	25.0±3.6	25.7±7.2	30.8±3.1	N.S
Breast M.	406.4±23.3^{a}	571.4±56.0^{b}	512.4±52.2^{ab}	575.6±16.0^{b}	444.2±57.6^{ab}	*
Drumstick	409.7±20.9^{a}	526.3±44.4^{b}	490.3±31.2^{ab}	536.3±6.6^{b}	480.7±29.9^{ab}	*

$^{a-b}$ Values with different superscripts within a row differ significantly (*: $P < 0.05$, N.S: $P > 0.05$)

(A)



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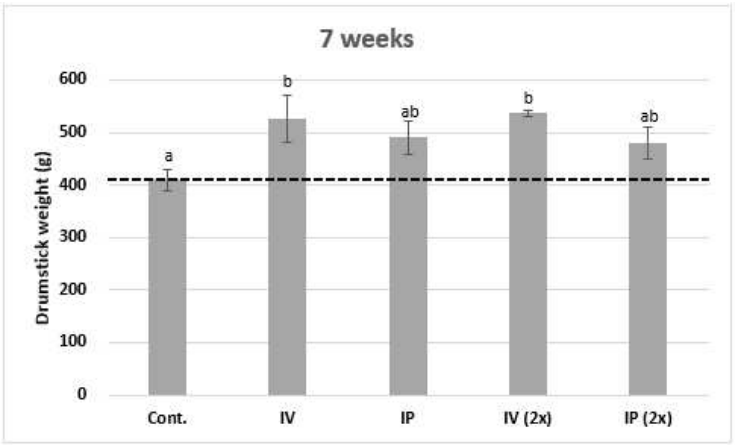
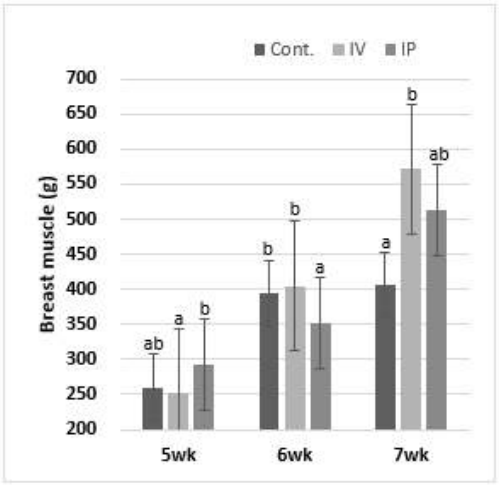
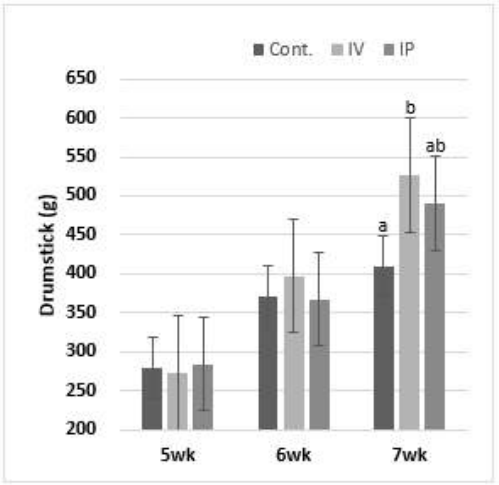
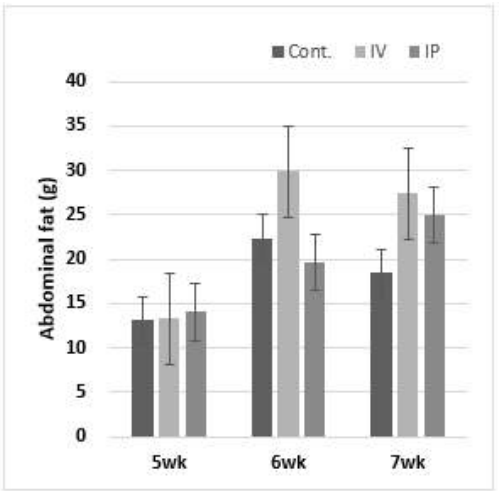
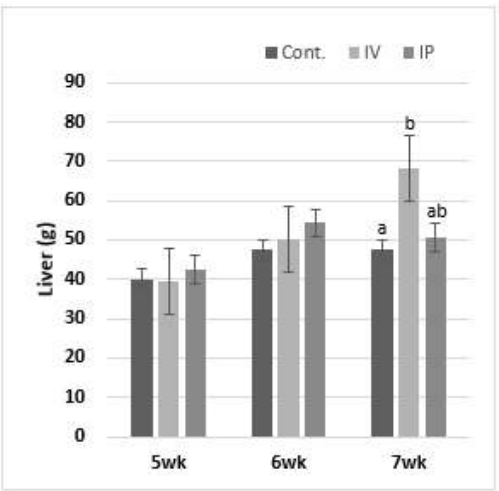


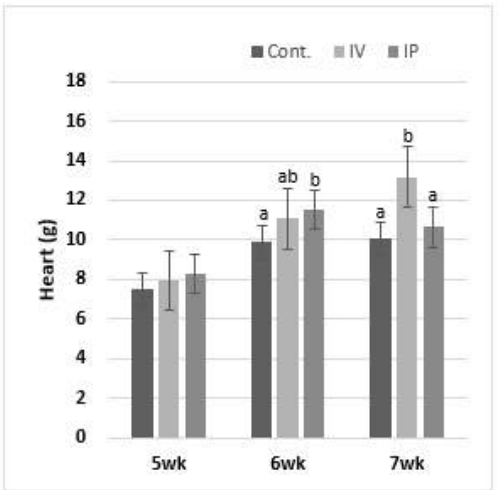
Figure 5. Effect of evening primrose extract on carcass yields of broiler chickens at the age of 7 weeks: dressed weight of breast muscle (A) and drumstick (B).

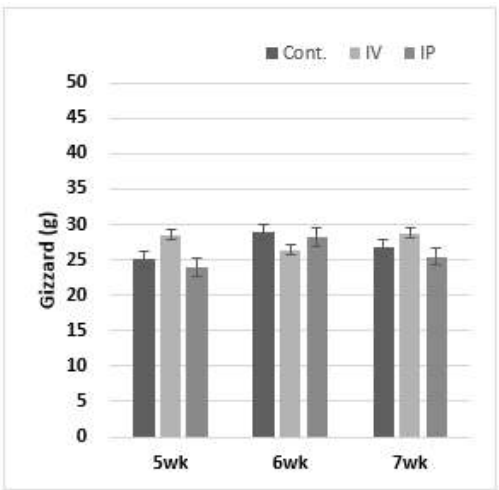

Cont. IV IP
Breast muscle (g)
700
650
600
550
500
450
400
350
300
250
200
ab a b b b a b ab
5wk 6wk 7wk


Cont. IV IP
Drumstick (g)
650
600
550
500
450
400
350
300
250
200
a b ab
5wk 6wk 7wk


Cont. IV IP
Abdominal fat (g)
40
35
30
25
20
15
10
5
0
5wk 6wk 7wk


Cont. IV IP
Liver (g)
90
80
70
60
50
40
30
20
10
0
a b ab
5wk 6wk 7wk


Cont. IV IP
Heart (g)
18
16
14
12
10
8
6
4
2
0
a ab b a b a
5wk 6wk 7wk


Cont. IV IP
Gizzard (g)
50
45
40
35
30
25
20
15
10
5
0
5wk 6wk 7wk

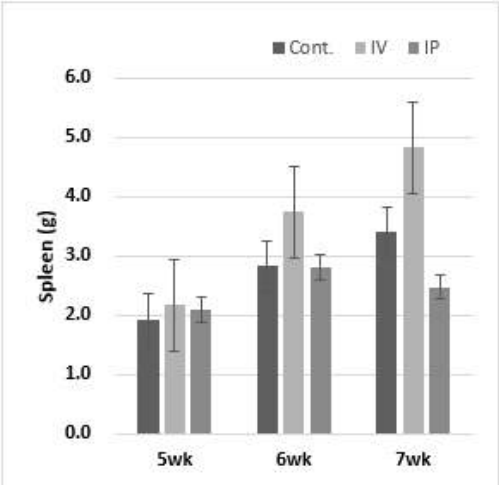
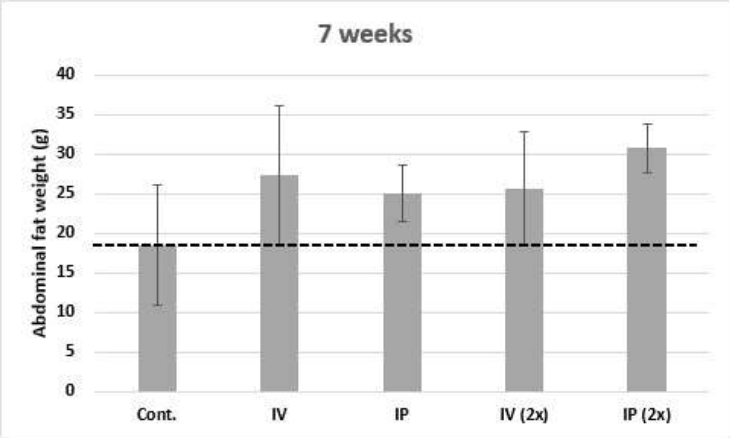
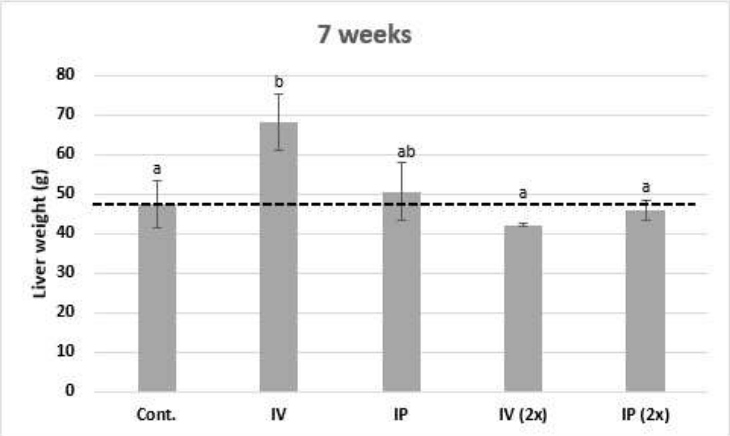


Figure 6. Effect of evening primrose extract on carcass yields of broiler chickens at the age of 5-7 weeks: dressed weight of breast muscle, drumstick, abdominal fat and internal organs.

(A)


7 weeks
Abdominal fat weight (g)
40
35
30
25
20
15
10
5
0
Cont.
IV
IP
IV (2x)
IP (2x)

(B)


7 weeks
Liver weight (g)
80
70
60
50
40
30
20
10
0
a
b
ab
a
a
Cont.
IV
IP
IV (2x)
IP (2x)

(C)

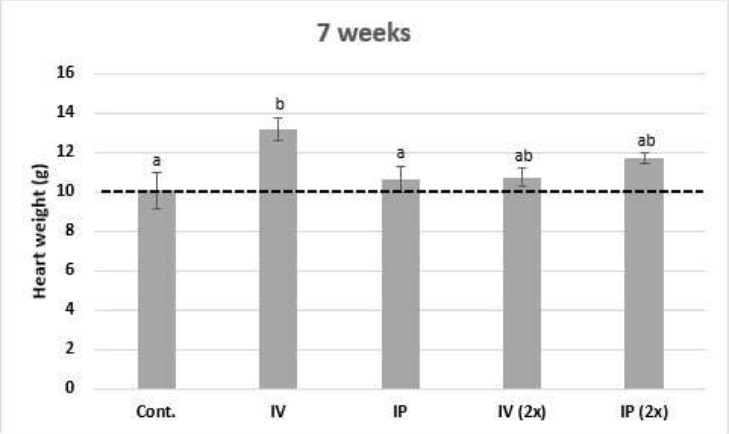

7 weeks
Heart weight (g)
16
14
12
10
8
6
4
2
0
a
b
a
ab
ab
Cont.
IV
IP
IV (2x)
IP (2x)

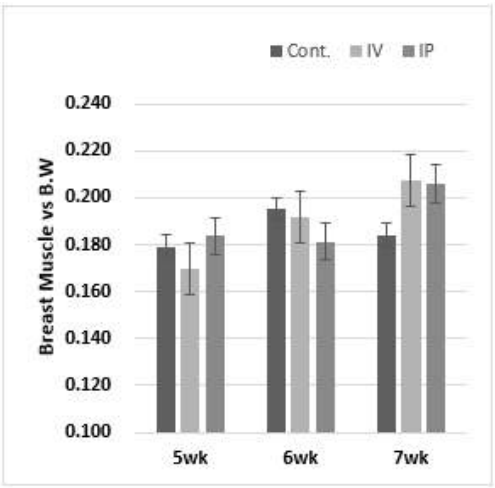
Figure 7. Effect of evening primrose extract on carcass yields of broiler chickens at the age of 7 weeks: dressed weight of abdominal fat (A), liver (B) and heart (C).

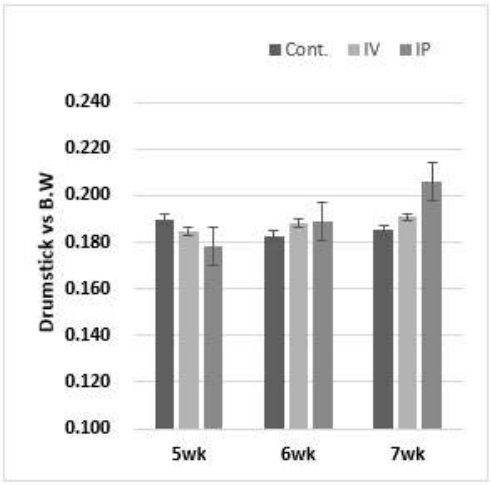
Table 5. Effect of evening primrose extract on carcass characteristics of broiler chickens at the age of 5-7 weeks: carcass yield-to-body weight ratio and abdominal fat-to-carcass yield ratio.

Parameter	Treatment					*P*-value
	Control	IV	IP	IV(2x)	IP(2x)	
Ratio of carcass yield to body weight						
5wk (d 1-35)						
Breast M.:BW	0.017±0.009	0.170±0.004	0.184±0.007			N.S
Drumstick:BW	0.190±0.008	0.185±0.006	0.178±0.006			N.S
Abd. Fat:BW	0.009±0.002	0.009±0.001	0.010±0.002			N.S
6wk (d 1-42)						
Breast M.:BW	0.195±0.010	0.192±0.007	0.181±0.006			N.S
Drumstick:BW	0.183±0.007	0.188±0.004	0.189±0.006			N.S
Abd. Fat:BW	0.011±0.003	0.014±0.004	0.010±0.002			N.S
7wk (d 1-49)						
Breast M.:BW	0.184±0.013	0.208±0.014	0.206±0.008	0.210±0.007	0.145±0.038	N.S
Drumstick:BW	0.185±0.009	0.191±0.008	0.188±0.005	0.195±0.003	0.183±0.001	N.S
Abd. Fat:BW	0.008±0.003	0.010±0.003	0.012±0.002	0.010±0.002	0.012±0.001	N.S
Ratio of abdominal fat to carcass yield						
5wk (d 1-35)						
Fat:Breast M.	0.048±0.009	0.053±0.0098	0.053±0.012			N.S
Fat:Drumstick	0.045±0.010	0.049±0.007	0.055±0.012			N.S
6wk (d 1-42)						
Fat:Breast M.	0.056±0.017	0.0763±0.022	0.055±0.013			N.S
Fat:Drumstick	0.058±0.015	0.076±0.021	0.053±0.012			N.S
7wk (d 1-49)						
Fat:Breast M.	0.048±0.022	0.051±0.019	0.053±0.014	0.046±0.014	0.048±0.014	N.S
Fat:Drumstick	0.046±0.041	0.054±0.018	0.052±0.010	0.048±0.014	0.065±0.007	N.S

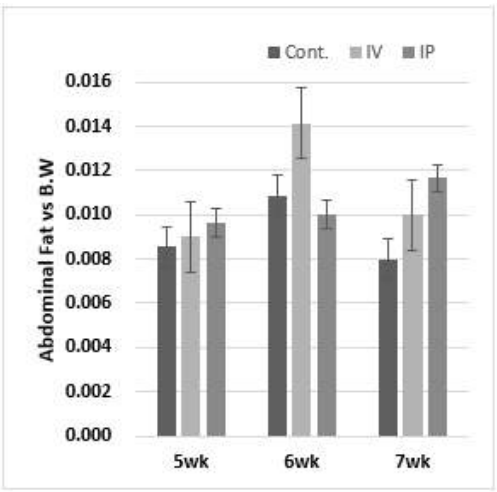
N.S: $P > 0.05$

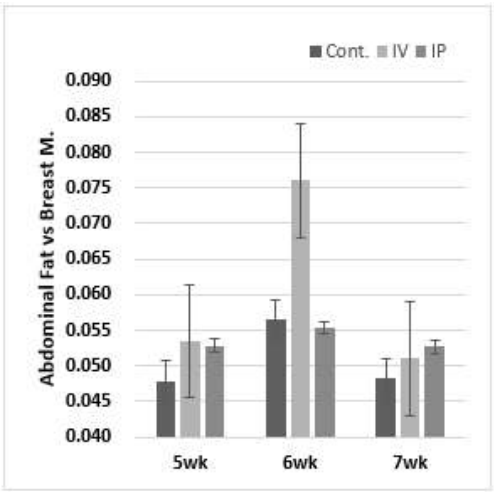
(A)


Cont. IV IP
Breast Muscle vs B.W
0.240
0.220
0.200
0.180
0.160
0.140
0.120
0.100
5wk
6wk
7wk


Cont. IV IP
Drumstick vs B.W
0.240
0.220
0.200
0.180
0.160
0.140
0.120
0.100
5wk
6wk
7wk

(B)


Cont. IV IP
Abdominal Fat vs B.W
0.016
0.014
0.012
0.010
0.008
0.006
0.004
0.002
0.000
5wk
6wk
7wk


Cont. IV IP
Abdominal Fat vs Breast M.
0.090
0.085
0.080
0.075
0.070
0.065
0.060
0.055
0.050
0.045
0.040
5wk
6wk
7wk

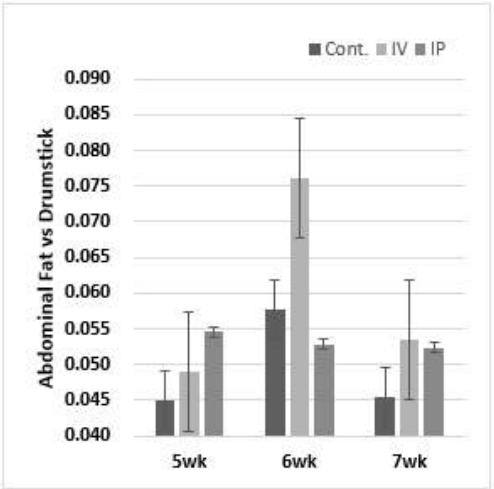
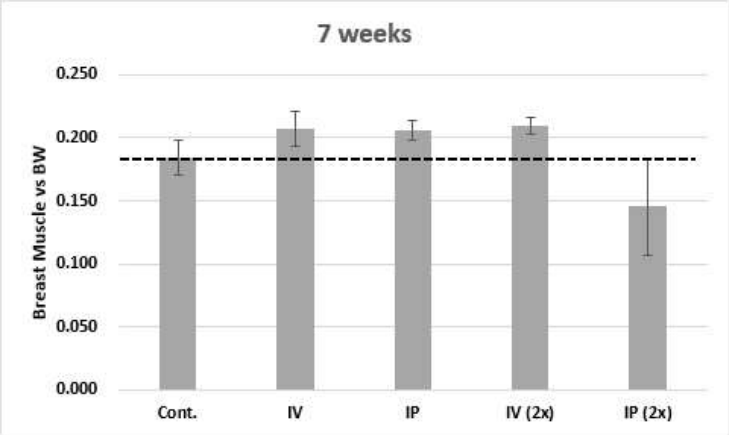
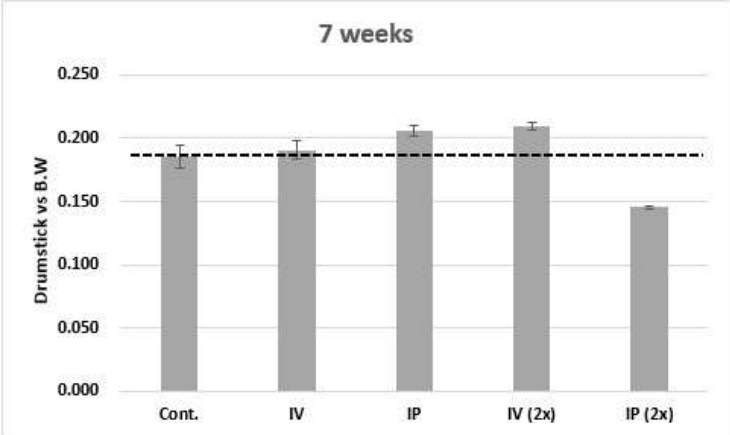

Cont. IV IP
Abdominal Fat vs Drumstick
0.090
0.085
0.080
0.075
0.070
0.065
0.060
0.055
0.050
0.045
0.040
5wk
6wk
7wk

Figure 8. Effect of evening primrose extract on carcass yields of broiler chickens at the age of 5-7 weeks: carcass yield (breast muscle, drumstick and abdominal fat)-to-body weight ratio (A), abdominal fat-to-carcass yield (breast muscle and drumstick) ratio (B).

(A)


7 weeks
Breast Muscle vs BW
0.250
0.200
0.150
0.100
0.050
0.000
Cont.
IV
IP
IV (2x)
IP (2x)

(B)


7 weeks
Drumstick vs B.W
0.250
0.200
0.150
0.100
0.050
0.000
Cont.
IV
IP
IV (2x)
IP (2x)

(C)

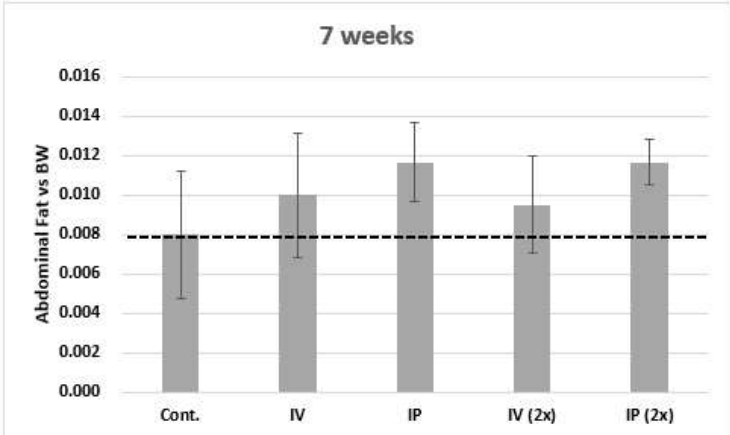
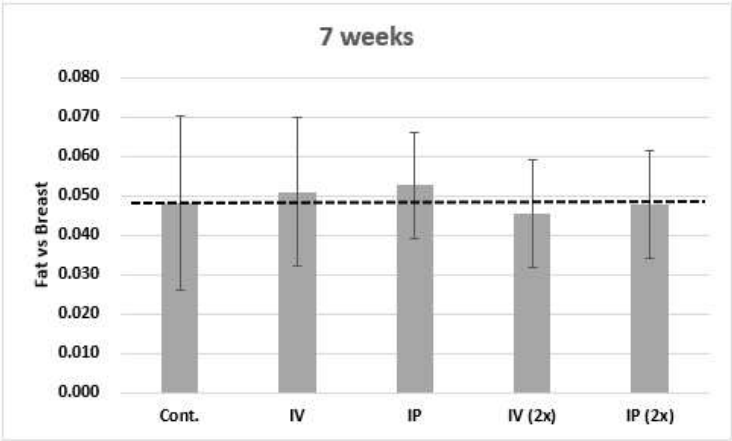

7 weeks
Abdominal Fat vs BW
0.016
0.014
0.012
0.010
0.008
0.006
0.004
0.002
0.000
Cont.
IV
IP
IV (2x)
IP (2x)

Figure 9. Effect of evening primrose extract on carcass yields of broiler chickens at the age of 7 weeks: breast muscle-to-body weight ratio (A), drumstick-to-body weight ratio (B) and abdominal fat-to-body weight ratio (C).

(A)



(B)

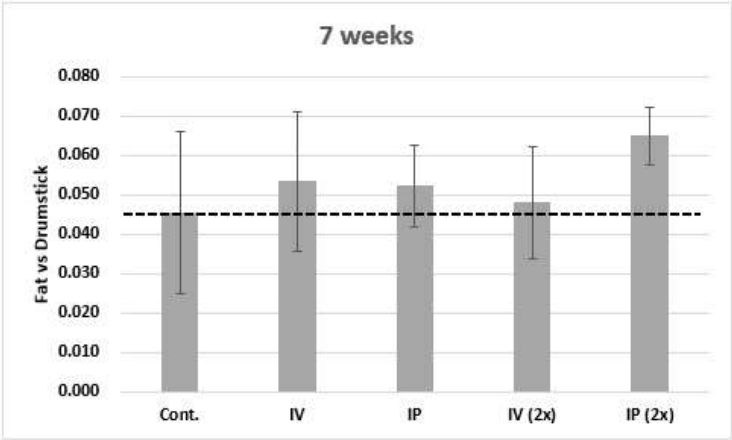


Figure 10. Effect of evening primrose extract on carcass yields of broiler chickens at the age of 7 weeks: abdominal fat-to-breast muscle ratio (A) and abdominal fat-to-drumstick ratio (B).

3. Blood plasma analysis

The results of blood plasma analysis of the birds at the age of 3 (before EPE administration), 4 and 6 weeks (after EPE administration) are presented in Table 6. Results showed decreasing tendency of TG content in all groups at 4 weeks of age, but TG content was strangely increased at 6 weeks in all experiment groups except group IV. Only group IV indicated a linear diminished TG content during the experiment period, the other groups were not. In addition, TG of group IV(2x) was significantly higher than that of group control at 4 and 6 weeks of age.

The results also showed that there was significant higher plasma content of TC in the treatment groups IV(2x) and IP(2x) compared to group control at the age of 4 weeks, but no significant difference was observed among groups at 6 weeks of age.

For glucose content of the birds, it did not differ significantly between treatment groups and control group during the experiment (Figure 11).

Table 6. Results of blood plasma analysis in broiler chickens at the age of 3 weeks (before EPE administration), 4 and 6 weeks (after EPE administration).

Parameter	Treatment					*p*-value
	Control	IV	IP	IV(2x)	IP(2x)	
Triglycerides (mg/dl)						
3wk (d 0)	129.0±30.0	164.8±26.9	133.0±4.8	145.0±7.9	132.0±9.2	N.S
4wk (d 1-28)	42.0±14.1[a]	78.3±19.2[ab]	47.7±16.5[a]	114.0±25.1[b]	72.0±12.7[ab]	*
6wk (d 1-42)	78.5±13.1[b]	49.0±8.5[a]	81.0±3.5[b]	174.5±5.3[c]	87.5±35.0[bc]	*
Total cholesterol (mg/dl)						
3wk (d 0)	49.3±14.2	80.3±6.9	36.7±8.3	62.0±13.8	62.0±6.4	N.S
4wk (d 1-28)	91.3±8.0[a]	107.3±4.4[ab]	87.3±2.8[a]	126.3±9.4[c]	115.0±2.1[b]	*
6wk (d 1-42)	100.5±36.4	101.0±17.7	103.5±2.5	102.0±13.4	110.5±11.7	N.S
Glucose (mg/dl)						
3wk (d 0)	257.8±3.8	247.3±17.4	228.3±7.4	242.0±3.0	244.5±9.5	N.S
4wk (d 1-28)	246.5±5.0	255.5±9.9	230.3±2.8	239.7±8.9	245.5±1.8	N.S
6wk (d 1-42)	244.0±14.1	229.5±10.3	212.5±1.8	242.5±6.7	231.0±8.5	N.S

[a-c] Values with different superscripts within a row differ significantly (*: $P < 0.05$, N.S: $P > 0.05$)

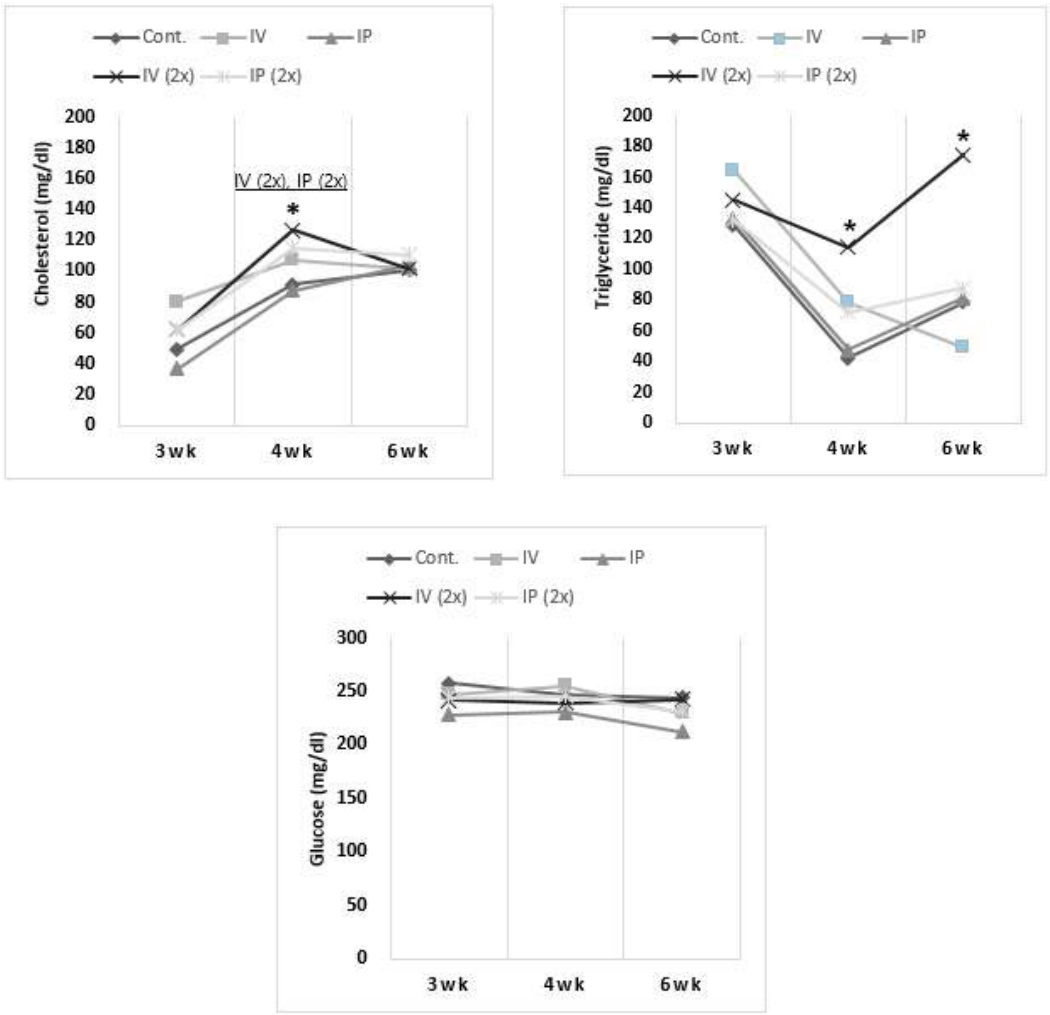


Figure 11. Plasma contents of triglyceride, total cholesterol and glucose of broiler chickens at the age of 3 (before EPE administration), 4 and 6 weeks (after EPE adminstration).

Discussion

The aim of this study was to examine the effect of administration of EPE on growth performance and carcass characteristics in broiler chickens. The determined parameters were body weight, body weight gain, feed intake, FCR, dressed portional weight of breast muscle and drumstick and weight of abdominal fat and internal organs (liver, heart, spleen, gizzard).

1. Growth performance

Results of the present study clearly showed that the administration of EPE had positive effects on growth performance in broiler chickens. According to the results, there were significant increases in body weight and body weight gain in all treatment groups compared to control group at 6-7 weeks of age (Table 3). While the final body weight of the birds in control group was 2,212g, those of the birds in treatment groups were between 2,625g and 2,748g at the age of 7 weeks. These results showed a similarity to previous study which reported that body weight gain was significantly increased at 5 weeks of age when broilers were fed 1.5% and 3% EPO.[25] On the other hand, another study showed that body weight was significantly increased at 4weeks of age when broilers were fed 1% EPO, but found no significant difference in body weight

gain.[26] However, the conflicting result has been reported in the study with male rats where administration of EPO (72.8% linoleic acid and 9.16% gamma-linolenic acid) for 30 days lowered body weight due to reduction of carcass fat.[27]

Feed intake was also increased significantly in all treatment groups compared to group control at 5 and 7 weeks of age. This could be related to the improvement of body weight and weight gain. Several studies suggested that the plant additives added into feedstuff such as herbs, spices, their extracts and essential oils can improve the taste and smell of the feed and stimulate appetite, and thus increase feed intake and growth performance in mono-gastric animals[28-29] and broilers.[30] However, the mechanism of how EPE worked to improve feed intake was not clear in this study.

FCR was calculated by using the following formula:

FCR = cumulative feed intake (g) / total weight gain (g)

Lower FCR values indicate a better feed efficiency. Results showed that FCR did not differ between treatment groups and control group during 5-6 weeks of age, whereas it was lowered and the feed conversion was improved at the final 7 weeks of experiment. These results contradicted the previous studies which showed no difference[25] or significant increase[26] in broilers fed different levels of EPO.

2. Carcass characteristics

Results obtained in the present study showed that the administration of EPE had significant effect on the carcass yields such as breast muscle and drumstick in broiler chickens. The weight of breast muscle was increased significantly in the treatment

groups at 5 and 7 weeks of age. The breast weight of control group was 406.4g and those of treatment groups IV and IV(2x) varied between 571.4 and 575.6g at the end of 7 weeks. Similarly, the drumstick weight was also significantly increased in the treatment groups IV and IV(2x) at 7 weeks of age (Figure 5 and 6). The improvement of body weight and weight gain seems to be a consequence of increased weight of breast muscle and drumstick. These results were similar to the previous study which reported that there was significant increase in the weight of breast muscle and no difference in carcass drumstick at 5 weeks of age when broilers were fed 1.5% and 3% EPO.[25] However, the results contradicted the previous study that there were no significant differences in the weight of breast muscle and drumstick at 4 weeks of age when broilers were fed 1% EPO.[26]

Fat deposition in the body often happens when energy-to-protein ratio of the feed is increased. When there is an excess of energy needed for growth, this energy will be stored as a body fat. A large part of body fat is deposited in the form of abdominal fat, amounting to about 20% of total body fat in broiler chickens.[31] Several previous studies indicated that PUFA inhibit lipid synthesis and increase fatty acid oxidation in both birds and mammals,[32-34] and abdominal fat was reduced with PUFAs compared to saturated (SFA) or mono-unsaturated fatty acids (MUFA).[35-36] Similar findings have been reported that abdominal fat was decreased when broilers were fed 1.5% and 3% EPO,[25] and total body fat was reduced when EPO (72.8% LA and 9.16% GLA) was fed to male rats.[27] Similar effect of fat reduction was expected in the present study where EPE was administered to broiler chickens as a source of GLA which is a kind of PUFA, but there was no significant reducing effect of abdominal fat among treatment groups

(Figure 6 and 7).

Liver is a main organ plays an vital role in synthesis and oxidation of fatty acids.[37] Previous study suggested that plant extracts enhanced hepatic metabolism and increased relative liver weight in rats.[4] Results of this study indicated that the administration of EPE affected significantly on liver weight (Figure 6 and 7). The weight of liver was increased significantly in the treatment group IV compared to group control at 7 weeks of age, and these results showed a similarity to earlier studies that liver weight was increased significantly in broilers fed 0.5% and 1% EPO,[26] and in genetically hyperlipidemic mice fed diets containing GLA oil dose-dependently.[38] The values of heart weight also showed a increasing tendency in the treatment group IV compared to group control at 7 weeks of age (Figure 6 and 7), and these results were not consistent with several findings reported no difference for heart weight in broilers fed 0.5% and 1% EPO at 4 weeks of age[26] and significant decrease in broilers fed 4 gram of Roselle (*Hibiscus sabdariffa*) calyx extract at 6 weeks of age.[39] On the other hand, no differences were found among groups for the weight of gizzard and spleen throughout the experiment period.

The ratios of carcass weights of breast, drumstick and abdominal fat to body weight were also determined, but no statistical differences were observed among groups (Figure 8 and 9). Likewise, the ratio of abdominal fat to carcass weights of breast and drumstick did not differed significantly among groups during the experiment period (Figure 8 and 10).

3. Blood plasma analysis

The plasma content of TG showed a decreasing tendency in all treatment groups a week later after EPE administration (4th week) and then two weeks later (6th week) they were increased in all groups except group IV. Unlike the other treatment groups, TG content of group IV was decreased in a linear way after EPE administration. However, TC content was increased after EPE administration (4th and 6th week) and showed a significant increase in high-dosed groups IV(2x) and IP(2x) compared to group control. On the other hand, no statistical differences in glucose content were observed among groups during the experiment period (Figure 11). These results did not agree with the studies that inclusion of EPO lowered TG and TC levels significantly in laying hens[11] and hyperlipidemia-induced mice[40] and fasting serum glucose was highly reduced after 3 months of EPO administration in type 2 diabetic patients.[41]

Prior to blood sample collection, in general, fasting is required. Thus, blood gathering is usually carried out in the morning and on empty stomach. But we could't stick to it for maintaining the feeding condition of *ad libitum* throughout the experiment period. Therefore, the figures obtained in the blood analysis do not mean anything in and of themselves and seem to be inappropriate for evaluating the effect of EPE before and after adminstration in this study.

Conclusion

The aim of the present study was to examine the effects of administration of EPE on growth performance and carcass characteristics in broiler chickens.

The results clearly showed positive effects of EPE on body weight, weight gain and feed intake in growing broiler chickens. There were significant increases in body weight and weight gain in all treatment groups compared to control group at 6-7 weeks of age. Moreover, significant increases in feed intake and carcass yields such as breast muscle and drumstick were found in EPE treatment birds at 5 and 7 weeks of age. The improvements in body weight and weight gain seem to be a consequence of increased weight of breast muscle and drumstick, but the actual mechanism underlying increased feed intake is not clear. For FCR, it did not differ among groups during the first 5-6 weeks of age, however, it was lowered and FCR was improved at the final 7 weeks of age. On the other hand, there was no significant reducing effect of abdominal fat in treatment groups compared to control group.

The results of this study suggested that the supplementation of EPE, which is extracted from whole plant (seed/flower/stem/root) of evening primrose has improved the productive performance and specific carcass characteristics of broiler chickens. Therefore, EPE could be used as a potential growth promotor that can improve the growth performance and the quality of food products in the poultry industry.

To make effective use of evening primrose extract (*Oenothera odorata)* as a

phytogenic growth promotor, further research for exploring its detailed bio-active constituents and the exact modes of action and determining optimum dietary inclusion level of this plant extracts to achieve optimal productivity in chicken meat production is required.

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Abstract in Korean

달맞이꽃 추출물이 육계의 성장능력과 도체성적에 미치는 영향을 조사하기 위하여 본 연구를 수행하였다. 112수의 1일령 상용 (인디안 리버 종) 수컷 육계를 5개의 실험군으로 나누어 임의 배치하였다: 대조 (투여 없음), IV (정맥 내 투여), IP (복강 내 투여), IV(2x) (정맥 내 2배 투여), IP(2x) (복강 내 2배 투여). 달맞이꽃 (*Oenothera odorata)*의 전초 (종자/꽃/잎/줄기/뿌리)의 메탄올 추출액을 3-7 주의 시험 기간 동안 달맞이꽃 추출물 처치군의 육계에 정맥 내 주사와 복강 내 주사의 방법으로 투여하였다.

6-7주령의 모든 달맞이꽃 추출물 처치군에서 대조군에 비하여 체중과 증체량에 유의한 증가가 있었다 (p<0.05). 또한 달맞이꽃 추출물 처치군에서 사료섭취량이 5주와 7주령에 유의하게 증가하였고, 사료 전환율은 7주령에 유의하게 감소하였다 (p<0.05). 뿐만 아니라, 달맞이꽃 추출물의 투여는 가슴육과 앞다리의 도체성적에도 긍정적인 영향을 주었다 (p<0.05).

본 연구는 달맞이꽃의 전초에서 얻어진 추출물이 육계의 성장능력을 개선하는데 잠재력이 있으며, 따라서 고기의 생산성과 품질을 위한 식물성 성장촉진제로서 이용될 수 있음을 보여 주었다.

주제어: 달맞이꽃 추출액, 식물성 사료첨가제, 육계, 성장능력, 도체성적