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# Soya lecithin and season affect the productive performance, nutrient digestibility and blood constituents of growing rabbits

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**ABSTRACT.** This study was performed to determine the effect of different levels of soya lecithin (SL) added to the diets for growing V-line rabbits in the winter and summer seasons. One hundred sixty 35-day-old rabbits were used in two experiments, one was conducted in the winter and the other in the summer (each for 49 days). Animals were randomly assigned to 4 experimental groups and fed diet supplemented with 0, 0.5, 1.0 and 1.5% of SL. The addition of SL to the diet improved weight gain, feed intake and feed conversion ratio in both seasons. Body weight gain and carcass traits were improved by the inclusion of SL in the summer ($P < 0.05$). Dietary SL increased ($P < 0.05$) ether extract apparent faecal digestibility, levels of triglycerides, total lipids, phospholipids, high-density lipoprotein cholesterol (HDL), and the enzymatic activity of acid phosphatase, whereas decreased ($P < 0.05$) the levels of total cholesterol and low-density lipoprotein cholesterol (LDL), and the activities of aspartate amino transferase and alanine amino transferase in the blood. In the winter, lower nutrient digestibility coefficients and lower relative weights of the heart and spleen were found. In the summer season the elevated ($P < 0.05$) blood levels of glucose, HDL and LDL were observed in comparison to the winter season. Supplementation of feed with 1% or 1.5% SL improved rabbit growth performance, fat digestibility and HDL blood level in both seasons. So, the soya lecithin can be a useful feed additive also in the heat stress conditions.

## Introduction

In the summer in Egypt and in many other countries, the rabbit production declines pronouncedly causing a drop in productive and economic benefits. Animal performance may be influenced by the heat stress and consequently the depression of feed intake (Marai et al., 2005).

It is known that the higher temperature, the smaller number of solid meals eaten and the more water drunk (Gidenne et al., 2010). In the study of Zeferino et al. (2011) on straightbred and crossbred Botucatu rabbits maintained at 30 °C from 5 to 10 weeks of age, the feed intake decreased by 21% and growth rate by 18% in comparison to the animals kept at 18 °C. Moreover, high temperature in the summer season is the most important factor that influences the post-weaning mortality. According to Habeeb et al. (1997) and Shehata et al. (1998), mortality rate may be even 18% during the summer.

The mean temperature in Egypt is about 34 and 22 °C in the summer and winter, respectively. In the summer, the temperature much higher than the comfort temperature for rabbits (18–21 °C) causes a heat stress condition. In order to improve the productive and physiological performance of rabbits during the summer season in Egypt, several feed supplements have been studied (Attia et al., 2011). Among them is soya lecithin (SL) – a mixture of natural phospholipids, phosphatidylcholine (PC), phosphatidylethanolamine and phosphatidylinositol. On average PC, phosphatidylethanolamine and inositol phosphatides in SL constitute 19–21%, 8–20% and 20–21%, respectively (Scholfield, 1981), and phosphatidylserine 0.2–6.3% (Liu and Ma, 2011).

SL improves the productive and reproductive performance of laying hens and rabbit bucks and is a good source of unsaturated fatty acids, antioxidants and energy (Attia et al., 2009; Attia and Kamel, 2012). PC from biliary sources increased lymphatic triglyceride absorption in Wistar rats which might be connected with the packaging and secretion of chylomicrons (Nishimukai et al., 2003).

In Egypt rabbit breeding season normally begins in October and ends in April with the oncoming summer season. Heat stress occurs in these animals when they are not able to regulate their heat homeostasis passively, and the reduction in white and red blood cells counts and the increase in blood cholesterol content may be observed (Ondruska et al., 2011).

Feed additive supplements, such as SL, can improve nutrient utilization, blood parameters and productive performance during the summer season due to its antioxidant properties. Thus, the aim of the study was to determine the effect of different levels of SL in the diet during the winter and summer season on growth performance, ability to digest nutrients and blood parameters of V-line growing rabbits raised from 35 to 84 days of age.

## Material and methods

The present study was carried out at El-Sabahiea Poultry Research Station, Alexandria Governorate, Animal Production Research Institute, Agriculture Research Centre (Egipt). The experiment design was approved by the Animal Production Research Institute Scientific and Ethics Committee (Protocol No. 04-05-03-37).

### Experimental design and diets

In total, 160 35-day-old V-line growing rabbits with the average initial body weight of 748 ± 148 g were used in two experiments, with 40 males and 40 females in each. The experiments were run from January to February (winter) and from July to August (summer), each for 49 days. The rabbits were randomly assigned to 4 experimental groups with 20 animals per group, in each season. Animals were housed separately in galvanized wire cages (dimensions 50×45×40 cm) and fed 4 different diets: control (without SL addition) and experimental with 0.5, 1.0 and 1.5% SL inclusion levels to pelleted feed. Animals had *ad libitum* access to pelleted feed and water throughout the experiment (from 35 to 84 days of age).

The determination of the SL fatty acid profile in the diets (Table 1) was performed with the use of Shimadzu Gas Chromatograph GC-4CM (Shimadzu Corp., Kyoto, Japan) with a field-effect mobility (pFE) connected to a glass column (3 m × 3.1 mm ID; cat no. 221-14368-31, Shimadzu Corp., Kyoto, Japan) packed with 5% diethylene glycol succinate (DEGS) and equipped with a flame ionization detector (FID) according to Radwan (1978). Fat was extracted prior to GC analysis according to Folch et al. (1957).

### Measurements

Rabbits were weighed at day 35 (initial body weight) and 84 of age (final body weight) and the body weight gain (BWG) was calculated. The amount of consumed feed was also monitored to determine the feed intake (FI) and the feed conversion ratio (FCR). Survival rate was also determined.

At day 65 of age, five male rabbits from each treatment were moved to metabolic cages to estimate the apparent digestibility. The animals were housed individually for 5 days of adaptation and 5 days of collection period. During the collection period, daily faeces were collected and the amount of consumed feed was measured. The collected faeces were collected, and faecal samples were dried in the oven at 60 °C for 72 h, finely ground, and kept under room temperature until further chemical analysis.

Samples of commercial pelleted feed and faeces were analysed for dry matter (DM), crude protein (CP), ether extract (EE), crude fibre (CF) and ash content according to the AOAC (2007) methods. Organic matter (OM) and nitrogen-free extract (NFE) were also determined. The nutrients digestibility coefficient was calculated using balance method.

**Table 1.** Ingredients and chemical composition of diets fed to V-line rabbits

| Indices | Dietary soyabean lecithin, g · kg⁻¹ | | | |
|---|---|---|---|---|
| | 0 | 5 | 10 | 15 |
| Ingredients | | | | |
| clover hay | 400 | 400 | 400 | 400 |
| yellow maize | 100 | 87 | 70 | 55 |
| barley | 130 | 140 | 140 | 140 |
| wheat bran | 150 | 163 | 180 | 200 |
| soyabean meal | 175 | 170 | 170 | 165 |
| soyabean lecithin | 0 | 5 | 10 | 15 |
| molasses | 30 | 20 | 15 | 10 |
| dicalcium phosphate | 8 | 8 | 8 | 8 |
| sodium chloride | 3 | 3 | 3 | 3 |
| vitamin and mineral premix[1] | 3 | 3 | 3 | 3 |
| DL-methionine | 1 | 1 | 1 | 1 |
| Analysed and calculated composition, $g \cdot kg^{-1}$ | | | | |
| dry matter[2] | 897 | 898 | 897 | 898 |
| crude protein[2] | 172 | 172 | 174 | 175 |
| crude fibre[3] | 143 | 144 | 145 | 147 |
| ether extract[2] | 34 | 39 | 44 | 49 |
| nitrogen free extract[3] | 560 | 553 | 544 | 545 |
| digestible energy[3], $MJ \cdot kg^{-1}$ | 11.69 | 11.62 | 11.53 | 11.42 |
| Ca[3] | 13.0 | 13.0 | 13.0 | 13.0 |
| available P[3] | 3.6 | 3.6 | 3.6 | 3.6 |
| total methionine[3] | 3.6 | 3.6 | 3.6 | 3.6 |
| total sulphur amino acid[3] | 6.8 | 6.8 | 6.8 | 6.8 |
| total lysine[3] | 9.3 | 9.3 | 9.3 | 9.3 |
| Analysed fatty acid composition, $g \cdot kg^{-1}$ of total fatty acids | | | | |
| capric acid (C10:0)[4] | 62.7 | 36.1 | 70.7 | 46.2 |
| lauric acid (C12:0)[4] | 61.0 | 51.0 | 3.60 | 4.70 |
| myristic acid (C14:0)[4] | 47.8 | 10.4 | 47.1 | 56.6 |
| palmitic acid (C16:0)[4] | 224.8 | 191.8 | 130.6 | 95.9 |
| palmitoleic acid (C16:1n-7)[4] | 0.00 | 25.9 | 30.2 | 34.2 |
| stearic acid (C18:0)[4] | 81.7 | 42.5 | 35.2 | 28.9 |
| oleic acid (C18:1n-9)[4] | 300.1 | 291.2 | 263.5 | 246.5 |
| linoleic acid (C18:2n-6)[4] | 180.1 | 283.2 | 388.7 | 458.2 |
| arachidic acid (C20:0)[4] | 41.8 | 67.9 | 30.4 | 28.9 |
| saturated fatty acid (SFA) | 519.9 | 399.7 | 317.6 | 260.8 |
| unsaturated fatty acid (UFA) | 480.1 | 600.3 | 682.4 | 738.9 |
| polyunsaturated fatty acid (PUFA) | 180.1 | 283.2 | 388.7 | 458.2 |
| monounsaturated fatty acid (MUFA) | 300.1 | 317.1 | 293.7 | 280.7 |
| SFA:UFA | 1.08 | 0.67 | 4.70 | 3.50 |
| MUFA:UFA | 0.62 | 0.53 | 0.43 | 0.38 |
| MUFA:PUFA | 1.67 | 1.12 | 0.76 | 0.61 |
| PUFA:UFA | 0.38 | 0.47 | 0.57 | 0.62 |

[1] per kg: IU: vit A 6000, vit $D_3$ 450; mg: vit E 40, vit $K_3$ 1, vit $B_1$ 1, vit $B_2$ 3, vit $B_3$ 180, vit $B_6$ 39, vit $B_{12}$ 2.5, pantothenic acid 10; biotin 10, folic acid 2.5, choline chloride 1200, Mg 15, Zn 35, Fe 38, Cu 5, Co 0.1, I 0.2 and Se 0.05; [2] analysed values according to AOAC International (2007) methods (dry matter – 925.09; crude protein – 999.04D; ether extract – 55-1976; ash – 923.03); [3] calculated values according to Sauvant et al. (2004), Gaafar et al. (2010) and Khalel et al. (2014); [4] analysed values according to Radwan et al. (1978)

Before slaughter on the last day of experiment (84 day of rabbit age) blood samples (5 ml) were collected from 6 rabbits (randomly chosen 3 females and 3 males) per treatment per season. Blood was taken from the marginal ear vein under vacuum into the heparinized tubes. Plasma samples were obtained by centrifugation of the blood at 1750 *g* for 20 min, and stored at −20 °C until analysis of the biochemical parameters.

The plasma levels of glucose, total protein, albumin, urea, creatinine, total lipids, phospholipids, triglycerides, total cholesterol, low-density lipoprotein cholesterol (LDL) and high-density lipoprotein cholesterol (HDL), and the activities of the acid phosphatase (ACP), alkaline phosphatase (ALP), lactate dehydrogenase (LDH), aspartate aminotransferase (AST) and alanine aminotransferase (ALT) were determined using commercial kits produced by Diamond Diagnostics Company (Giza, Egypt). Globulin was calculated by determining the difference between total protein and albumin.

At the end of experiment rabbits were fasted with free water supply for 18 h before slaughter by Islamic method (sharp knife is used to cut the windpipe (throat), food-tract (oesophagus) and the two jugular veins) (Attia et al., 2016). The dressing percentages of carcass with head and proportions of the organs were determined according to Blasco and Ouhayoun (1993).

### Statistical analyses

The data were analysed by a two-way ANOVA using the software SISVAR® (Ferreira, 2011) that considered the main effects of SL and season, and their interactions. Tukey´s test was used to detect significant differences among the groups means.

## Results

### Climate conditions

The range from minimal to maximal and average environmental temperature and relative humidity were 16.6–29.6 °C, 22.3 °C, 39.6–78.8% and 57.4% in the winter and 25.3–38.4 °C, 32.0 °C, 31.3–78.9% and 54% in the summer. Since the thermoneutral zone for rabbits is from 18 to 21 °C (Habeeb et al., 1998) the average temperatures in the summer and winter indicated that pronounced heat stress conditions were more often observed in the summer (average temperature 11 °C higher than neutral one for rabbits).

### Nutrient utilization

In animals fed diets with 1.0 and 1.5% addition of SL the EE apparent digestibility increased ($P < 0.05$) progressively without significant effect on the other nutrients. The coefficients of apparent

**Table 2.** Effect of soya lecithin (SL) supplementation and season on nutrient apparent digestibility coefficients and ash retention in V-line rabbits between 65 and 70 day of age

| Treatments | DM | OM | CP | EE | CF | Ash | NFE |
|---|---|---|---|---|---|---|---|
| Effect of SL supplementation, % | | | | | | | |
| 0.0 | 79 | 60 | 63 | 56$^{c}$ | 58 | 56 | 60 |
| 0.5 | 79 | 60 | 64 | 61$^{bc}$ | 59 | 56 | 60 |
| 1.0 | 79 | 60 | 64 | 66$^{ab}$ | 58 | 56 | 61 |
| 1.5 | 79 | 61 | 64 | 68$^{a}$ | 59 | 56 | 61 |
| Effect of the season | | | | | | | |
| winter | 79 | 57$^{b}$ | 60$^{b}$ | 50$^{b}$ | 54$^{b}$ | 52$^{b}$ | 58$^{b}$ |
| summer | 79 | 63$^{a}$ | 67$^{a}$ | 66$^{a}$ | 63$^{a}$ | 60$^{a}$ | 62$^{a}$ |
| SEM | 1 | 1 | 1 | 1 | 1 | 2 | 1 |
| *P*-values | | | | | | | |
| SL | 0.907 | 0.983 | 0.851 | 0.001 | 0.852 | 0.985 | 0.926 |
| season | 0.585 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 |
| SL × season | 0.768 | 0.917 | 0.924 | 0.922 | 0.974 | 0.991 | 0.929 |

n = 5 per treatment per season; DM – dry matter; OM – organic matter; CP – crude protein; EE – ether extract; CF – crude fibre; NFE – nitrogen-free extract; $^{abc}$ – means with different superscripts within each column are significantly different at $P < 0.05$

digestibility of CP, EE, CF, NFE, OM, and ash were lower during the winter than in the summer season. There was no effect ($P > 0.05$) of the SL supplementation × season interactions on nutrient digestibility (Table 2).

## Growth performance

Survival rate was not affected ($P > 0.05$) by the treatments. The SL × season interaction affected ($P < 0.05$) FBW, BWG, FI and FCR. The FI of rabbits fed control diet was the same in both seasons, but the FCR was lower and FBW and BWG were higher in the winter. When SL was added to the diets, FBW and BWG were improved and FI was reduced and FCR was improved in both seasons, however, the values of FBW, BWG and FI were higher and FCR was better during the winter (Table 3).

## Carcass traits and inner organs

In winter in rabbits fed diets supplemented with 1.5% of SL the relative heart weight was reduced, whereas in control rabbits relative spleen weight

**Table 3.** Effect of soya lecithin (SL) supplementation and season on productive performance[1] and carcass traits[2] (%) of V-line rabbits at 84 day of age (the end of experiment)

| Treatments | FBW, g | BWG | FI | FCR, g feed · g$^{-1}$ BWG | SR | Carcass | Liver | Heart | Kidney | Spleen |
|---|---|---|---|---|---|---|---|---|---|---|
| | | g · d$^{-1}$ | | | % | | | | | |
| SL supplementation, % | | | | | | | | | | |
| 0.0 | 1588$^{c}$ | 18.69$^{b}$ | 98.84$^{a}$ | 5.28$^{a}$ | 93.75 | 48.87$^{b}$ | 3.44$^{a}$ | 0.32$^{a}$ | 0.71 | 0.06$^{c}$ |
| 0.5 | 1659$^{b}$ | 19.61$^{b}$ | 89.45$^{b}$ | 4.56$^{b}$ | 96.25 | 51.81$^{a}$ | 3.10$^{b}$ | 0.33$^{a}$ | 0.65 | 0.07$^{ab}$ |
| 1.0 | 1820$^{a}$ | 21.73$^{a}$ | 89.67$^{b}$ | 4.12$^{c}$ | 97.50 | 53.64$^{a}$ | 3.43$^{a}$ | 0.31$^{a}$ | 0.66 | 0.08$^{a}$ |
| 1.5 | 1792$^{a}$ | 21.33$^{a}$ | 90.22$^{b}$ | 4.23$^{c}$ | 100.00 | 51.87$^{a}$ | 3.41$^{a}$ | 0.27$^{b}$ | 0.67 | 0.07$^{ab}$ |
| Season | | | | | | | | | | |
| winter | 1720 | 24.90$^{a}$ | 95.20$^{a}$ | 3.83$^{b}$ | 98.12 | 50.60 | 3.86$^{a}$ | 0.28$^{b}$ | 0.68 | 0.05$^{b}$ |
| summer | 1704 | 18.06$^{b}$ | 90.47$^{b}$ | 5.00$^{a}$ | 95.62 | 52.02 | 3.09$^{b}$ | 0.32$^{a}$ | 0.67 | 0.08$^{a}$ |
| Effect of the SL supplementation (%) × season interaction | | | | | | | | | | |
| 0.0 × winter | 1639$^{c}$ | 22.76$^{c}$ | 99.16$^{a}$ | 4.36$^{c}$ | 95.00 | 45.30$^{c}$ | 3.63$^{bc}$ | 0.33 | 0.68$^{ab}$ | 0.04 |
| 0.5 × winter | 1638$^{c}$ | 25.35$^{b}$ | 94.14$^{b}$ | 3.71$^{d}$ | 97.50 | 53.43$^{b}$ | 3.25$^{c}$ | 0.29 | 0.67$^{ab}$ | 0.05 |
| 1.0 × winter | 1814$^{ab}$ | 26.10$^{a}$ | 92.86$^{b}$ | 3.55$^{d}$ | 100.00 | 51.01$^{b}$ | 4.50$^{a}$ | 0.26 | 0.75$^{a}$ | 0.06 |
| 1.5 × winter | 1789$^{b}$ | 25.43$^{ab}$ | 94.67$^{b}$ | 3.72$^{d}$ | 100.00 | 52.67$^{b}$ | 4.05$^{a}$ | 0.25 | 0.65$^{b}$ | 0.05 |
| 0.0 × summer | 1486$^{d}$ | 16.65$^{d}$ | 98.65$^{a}$ | 5.92$^{a}$ | 92.50 | 50.65$^{b}$ | 3.34$^{c}$ | 0.31 | 0.73$^{a}$ | 0.07 |
| 0.5 × summer | 1698$^{b}$ | 16.76$^{d}$ | 87.10$^{c}$ | 5.19$^{b}$ | 95.00 | 50.99$^{b}$ | 3.03$^{cd}$ | 0.34 | 0.65$^{b}$ | 0.08 |
| 1.0 × summer | 1909$^{a}$ | 19.57$^{c}$ | 88.08$^{c}$ | 4.50$^{c}$ | 95.00 | 54.96$^{a}$ | 2.90$^{d}$ | 0.34 | 0.62$^{b}$ | 0.08 |
| 1.5 × summer | 1805$^{a}$ | 19.29$^{c}$ | 88.00$^{c}$ | 4.56$^{c}$ | 100.00 | 51.46$^{b}$ | 3.09$^{cd}$ | 0.28 | 0.68$^{ab}$ | 0.07 |
| SEM | 15.35 | 0.01 | 0.86 | 0.09 | 2.33 | 0.77 | 0.14 | 0.02 | 0.02 | 0.004 |
| *P*-values | | | | | | | | | | |
| SL | 0.001 | 0.001 | 0.001 | 0.001 | 0.317 | 0.001 | 0.037 | 0.028 | 0.072 | 0.001 |
| season | 0.314 | 0.001 | 0.001 | 0.001 | 0.295 | 0.081 | 0.001 | 0.013 | 0.317 | 0.001 |
| SL × season | 0.001 | 0.008 | 0.045 | 0.015 | 0.901 | 0.002 | 0.001 | 0.099 | 0.001 | 0.127 |

[1] n = 20 per treatment per season; [2] n = 6 per treatment per season; FBW – final body weight; BWG – body weight gain; FI – feed intake; FCR – feed conversion ratio; SR – survival rate; $^{a–d}$ – means with different superscripts within each column are significantly different at $P < 0.05$

was lower. In the summer higher relative weights of the heart and spleen were observed (Table 3).

SL supplementation × season interaction influenced ($P < 0.05$) the carcass yield, and liver and kidney relative weights. In the winter, SL supplementation increased the carcass yield regardless of dose and liver relative weight but only when 1 and 1.5% of SL was added. The relative weight of kidney was higher in group supplemented with 1.5% SL in comparison to group with 1% SL but both these groups did not differ from control group. In the summer, SL at 1% increased the carcass yield, but reduced the liver and kidney relative weights in comparison to the control diet (Table 3).

## Blood parameters

SL inclusion at 1 and/or 1.5% resulted in higher ($P < 0.05$) levels of triglycerides, total lipids, phospholipids, and HDL and decreased ($P < 0.05$) levels of total cholesterol and LDL, and the LDL:HDL ratio in the blood. Higher ($P < 0.05$) levels of glucose, HDL:LDL, and LDL:HDL ratios were found in the summer than in the winter (Table 4). The SL supplementation also reduced ($P < 0.05$) the blood urea level by 7.8% when added at 1.5%. The enzymatic activities of AST and ALT were lower ($P < 0.05$) in all supplemented groups and the activities of ACP and LDH were increased ($P < 0.05$) when SL was added in the amount of 1 and 1.5% (Table 5).

**Table 4**. Effect of soya lecithin (SL) supplementation and season on blood biochemical profile of V-Line rabbits at 84 day of age

| Treatments | Glucose | TG | TP | Alb | Glb | TL | PL | TCH | HDL | LDL | LDL : HDL |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | mg · dl$^{-1}$ | | g · dl$^{-1}$ | | | mg · dl$^{-1}$ | | | | | |
| SL supplementation, % | | | | | | | | | | | |
| 0.0 | 111 | 39.59$^{c}$ | 6.68 | 3.25 | 3.42 | 457$^{c}$ | 185$^{b}$ | 128$^{a}$ | 43.91$^{c}$ | 62.45$^{a}$ | 0.229$^{a}$ |
| 0.5 | 111 | 46.09$^{b}$ | 6.55 | 3.22 | 3.33 | 496$^{b}$ | 200$^{ab}$ | 121$^{b}$ | 50.33$^{b}$ | 57.37$^{b}$ | 0.200$^{b}$ |
| 1.0 | 109 | 49.20$^{a}$ | 6.65 | 3.26 | 3.38 | 512$^{b}$ | 214$^{ab}$ | 116$^{c}$ | 57.83$^{a}$ | 53.29$^{c}$ | 0.167$^{b}$ |
| 1.5 | 112 | 50.87$^{a}$ | 6.70 | 3.27 | 3.43 | 537$^{a}$ | 228$^{a}$ | 117$^{c}$ | 57.12$^{a}$ | 53.16$^{c}$ | 0.154$^{b}$ |
| Season | | | | | | | | | | | |
| winter | 109$^{b}$ | 46.17 | 6.61 | 3.27 | 3.33 | 500 | 208 | 120 | 50.70$^{b}$ | 54.66$^{b}$ | 0.178$^{b}$ |
| summer | 113$^{a}$ | 46.70 | 6.69 | 3.23 | 3.45 | 501 | 206 | 121 | 53.89$^{a}$ | 58.47$^{a}$ | 0.197$^{a}$ |
| SEM | 3 | 1.25 | 0.08 | 0.05 | 0.11 | 11 | 12 | 2 | 1.91 | 1.56 | 0.01 |
| *P*-values | | | | | | | | | | | |
| SL | 0.749 | 0.001 | 0.331 | 0.829 | 0.802 | 0.001 | 0.008 | 0.001 | 0.001 | 0.001 | 0.001 |
| season | 0.027 | 0.547 | 0.199 | 0.263 | 0.136 | 0.931 | 0.821 | 0.211 | 0.002 | 0.001 | 0.027 |
| SL × season | 0.069 | 0.963 | 0.613 | 0.671 | 0.855 | 0.768 | 0.899 | 0.795 | 0.618 | 0.926 | 0.930 |

n = 6 per treatment per season; TG – triglycerides; TP – total proteins; Alb – albumin; Glb – globulin; TL – total lipids; PL – phospholipids; TCH – cholesterol; HDL – high-density lipoprotein cholesterol; LDL – low-density lipoprotein cholesterol; $^{abc}$ – means with different superscripts within each column are significantly different at $P < 0.05$

**Table 5.** Effect of soya lecithin (SL) supplementation and season on renal and hepatic functions in V-Line rabbits at 84 day of age

| Treatments | Urea | Creatinine | Urea : Creatinine | ALP | ACP | AST | ALT | AST : ALT | LDH |
|---|---|---|---|---|---|---|---|---|---|
| | mg · dl$^{-1}$ | | | U · l$^{-1}$ | | | | | U · l$^{-1}$ |
| SL supplementation, % | | | | | | | | | |
| 0.0 | 45.91$^{a}$ | 1.32 | 34.75 | 176 | 48.20$^{c}$ | 53.75$^{a}$ | 29.75$^{a}$ | 1.81 | 279$^{b}$ |
| 0.5 | 44.17$^{ab}$ | 1.29 | 34.21 | 170 | 51.25$^{b}$ | 48.00$^{b}$ | 26.41$^{b}$ | 1.84 | 290$^{b}$ |
| 1.0 | 44.37$^{ab}$ | 1.30 | 33.98 | 169 | 53.83$^{ab}$ | 46.53$^{b}$ | 23.91$^{c}$ | 1.95 | 320$^{a}$ |
| 1.5 | 42.33$^{b}$ | 1.29 | 32.67 | 175 | 55.08$^{a}$ | 44.75$^{b}$ | 22.58$^{c}$ | 1.99 | 349$^{a}$ |
| Season | | | | | | | | | |
| winter | 44.56 | 1.31 | 33.91 | 172 | 52.10 | 48.20 | 25.33 | 1.92 | 313 |
| summer | 43.83 | 1.29 | 33.90 | 173 | 52.08 | 48.33 | 26.00 | 1.88 | 306 |
| SEM | 1.07 | 0.02 | 1.04 | 4 | 1.32 | 1.68 | 1.11 | 0.11 | 14 |
| *P*-values | | | | | | | | | |
| SL | 0.018 | 0.497 | 0.250 | 0.175 | 0.001 | 0.001 | 0.001 | 0.274 | 0.001 |
| season | 0.342 | 0.236 | 0.993 | 0.741 | 0.982 | 0.917 | 0.402 | 0.568 | 0.517 |
| SL × season | 0.585 | 0.802 | 0.438 | 0.368 | 0.888 | 0.916 | 0.920 | 0.973 | 0.977 |

n = 6 per treatment per season; ALP – alkaline phosphatase; ACP – acid phosphatase; AST – aspartate aminotransferase; ALT – alanine aminotransferase; LDH – lactate dehydrogenase; $^{abc}$ – means with different superscripts within each column are significantly different at $P < 0.05$

## Discussion

SL as an emulsifier may promote the incorporation of fatty acids in micelles, which increases fat absorption in the intestine and could explain the better EE digestibility. In animals fed diet with 1.5% SL PUFA content was increased up to 154% in comparison to the control group, and so confirms the fact that digestibility of dietary fats is influenced by the fatty acid profile with a positive relationship between degree of unsaturation of fats and their digestibility (Maertens et al., 1986). The higher digestibility coefficients of most nutrients during the summer season resulted from the high ambient temperature that causes lower feed intake and decreased digesta passage rate (Arca et al., 1999), and so extend the time of nutrient digestion and absorption. In addition, heat stress may lead to an increase in the activity of the amylase (Routman et al., 2003) and lipase (Hao et al., 2012), which could increase NFE and EE digestibility. However, the values of nutrient digestibility observed herein are lower than those reported by Ondruška et al. (2010), Strychalski et al. (2014) and Zwoliński et al. (2017) and could be attributed to rabbit age and breed, season of the year, environmental conditions and analytical procedure. Strychalski et al. (2014) also mentioned that nutrient digestibility may differ by more than 10% and is related to the animal age, health, diet and genetic line. Our results, however, are close to the values obtained by Al-Dobaib (2010) in V-line rabbits.

**Animal performance.** The reduction in FI due to the SL supplementation is caused by the lower gastric emptying rate – phosphatidylcholine enhances the lymphatic output of chylomicron, which are important stimuli of cholecystokinin (CCK) secretion by dietary lipids, and CCK suppresses gastric emptying (Nishimukai et al., 2003). Reduced BWG during summer season in comparison to the winter is connected with declination of energy intake during heat conditions. FBW and BWG were higher in rabbits fed diets with 1 or 1.5% than in control group and in rabbits raised during the winter season (+37.9%). Since BWG values were higher in rabbits raised during the winter, FCR was also better in comparison to the summer, mainly due to SL supplementation. Survival rate was not influenced by the treatments and varied from 92.50 to 100%.

**Carcass traits.** PUFA present in SL may exert a protective effect on the heart by improving the energy efficiency in this muscle (Abdukeyum et al., 2008). Diets enriched with PUFA increase antioxidant enzyme expression and decrease mitochondrial reactive oxygen species (Anderson et al., 2014) which may protect the spleen and increase its proportion. Higher energy availability for protein deposition and so better carcass yield may be due to SL supplementation improving lipid metabolism in the body. In the diets with 1 or 1.5% addition of SL, the higher PUFA content than SFA content leads to higher metabolizable energy (Celebi and Utlu, 2004). In addition, under heat stress conditions, metabolizable energy is inadequate to sustain the processes of protein synthesis and diverts energy and protein away from growth (Attia et al., 2003). Also, the liver relative weight can be improved by SL inclusion to the diet since lipogenesis occurs primarily in the liver, and this effect may be correlated with enhanced lipid metabolism in this organ. In addition, PUFA present in the diets containing SL can protect hepatocytes by inhibiting liver cell peroxidation as shown by Qiu et al. (2012). In the summer, lower liver relative weight was noted since during the hot season the FI was lower and so the capillary blood flow decreased in the internal organs.

**Blood parameters.** Higher levels of triglycerides, total lipids and phospholipids in the blood were found in animals fed diets with SL addition which as an emulsifier increases fat absorption in the gut (Attia et al., 2009; Attia and Kamel, 2012). In addition, triglyceride levels were also dependent on the level of hepatic lipogenesis. Huang et al. (2008) noted that SL affected the expression of hepatic genes involved in lipid metabolism, particularly those genes regulating lipogenesis, which also explains the higher triglycerides in the blood. Also, dietary lecithin could modify the cholesterol homeostasis in the liver; lecithin reduces excess LDL and promotes the synthesis of great amount of HDL in the liver (Lin et al., 2004). Le Blanc et al. (2003) reported that the effect of SL was associated with cholesterol that was rapidly directed for elimination in the bile or converted to bile acids. The high content of PUFA in the experimental diets might also reduce plasma cholesterol, since PUFA can increase the activity of the LDL receptor, decrease LDL apoB pool size and increase LDL fractional catabolic rate (Ramprasath et al., 2012).

During the summer blood glucose levels were higher because of the lower energy metabolism during heat stress associated with lower plasma levels of insulin and thyroxin (Habeeb et al., 1996). The hot season also increased the levels of HDL and LDL cholesterol and the LDL : HDL ratio. This might be due to an increased activity of 3-hydroxy-3-methylglutaryl-coenzyme A reductase, which is the limiting enzyme in cholesterol synthesis (Endo, 1992). In the study of Ondruska et al. (2011) conducted on rabbits raised at 18 or 36 °C the higher blood cholesterol levels were stated in heat-stressed rabbits. Higher levels of HDL and LDL cholesterol could be attributed to higher cholesterol synthesis, as HDL and LDL cholesterol are involved in the transportation of cholesterol in the body, as reported by Kalmath et al. (2013).

**Enzyme activity.** PUFA can regulate the expression of enzymes involved in carbohydrate and lipid metabolism. According to Cavaliere et al. (2016), n-3 PUFA decreases mitochondrial efficiently, particularly in the skeletal muscles, which may result in higher lactate production and consequently higher conversion of lactate to pyruvate by LDH.

ALT and AST are important liver markers, and the results of the presented study suggest a protective effect of SL on liver cells. As SL increases the activity of the antioxidant enzymes, it may protect cells against the oxidative stress and from the presence of elevated levels of AST and ALT in the serum. Dewi (2016) also reported a reduction in AST and ALT in rats fed diets with lecithin and $CCl_4$, indicating a protective effect of SL against liver injury. This effect was attributed to the antioxidant properties of SL.

## Conclusions

Supplementing V-line rabbit diets with soya lecithin at the amount of 1 and 1.5% improves growth performance, fat digestibility and increases the level of high-density lipoprotein cholesterol in the blood during both summer and winter seasons. So, the soya lecithin can be a useful feed additive also in the heat stress conditions.

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