



## Article

# Effects of Rocket Seed Oil, Wheat Germ Oil, and Their Mixture on Growth Performance, Feed Utilization, Digestibility, Redox Status, and Meat Fatty Acid Profile of Growing Rabbits

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**Abstract:** Vegetable oils are a source of natural antioxidants, including tocopherols, sterols, phenolic compounds, coenzymes, and polyunsaturated fatty acids that provide nutritional value, organoleptic properties, and significantly delay or prevent lipid oxidation. Eighty-four V-line rabbits at 5 weeks of age with an initial body weight (BW) of  $535.60 \pm 13.48$  g were assigned randomly to four experimental groups (seven replicates in each group with three rabbits each). The first group served as a control and received 0.3 mL/kg BW of distilled water (CON), while the second and third groups received 0.3 mL/kg BW of rocket seed oil (RSO) and wheat germ oil (WGO), respectively. The fourth group received a mixture of oils consisting of 0.15 mL of RSO and 0.15 mL of WGO/kg BW (MOs). The experiment lasted 7 weeks. The study investigated the effects of RSO, WGO, and their mixture on growth performance, feed utilization, antioxidant status, and immune response of growing rabbits. The results indicated that the rabbits that were administered orally with RSO and WGO or their mixture had higher ( $p \leq 0.05$ ) final BW, weight gain, and average daily gain when compared to the control group. In addition, the feed conversion ratio improved significantly with RSO, WGO, and MOs treatments. Different oil treatments improved nutrient digestibility, nutritive value, and nitrogen balance. Moreover, the rabbits that received RSO, WGO, and their mixture had an improvement the meat fatty acid composition compared to the control rabbits. Oral administration of RSO, WGO, and their mixture significantly improved serum protein fractions, decreased blood urea nitrogen, and had a positive effect on serum total lipids, HDL-c, and LDL-c. Furthermore, the treatments of RSO, WGO, and MOs had a significant improvement in the antioxidative status and immune response.

**Keywords:** rocket seed oil; wheat germ oil; growing rabbits; growth performance; antioxidant status; digestibility

## 1. Introduction

Phytogenic feed additives have been recognized as antimicrobials, antioxidants, anti-toxigenic, anti-coccidiosis, and antiparasitic [1–3]. In addition, phyto-feed additives improve the palatability and digestibility of feed, enhance the absorption of nutrients, as well as manipulate the microbial habitat and gut functions of domestic animals [4,5]. Moreover, they protect the feed lipids from oxidative damage and improve the antioxidant and immune status of the animal. Furthermore, phyto-feed supplementations are natural additives, less poisonous, residue-free, with more integrity and perfect as feed additives for poultry when compared to antibiotics [1]. Consequently, they can be considered as an important tool in poultry nutrition for enhancing growth performance, feed efficiency and reproductive performance, and reducing the incidence of diseases and the house emissions

of poultry [1,4]. The inclusion of phytogetic feed additives in the diet can improve the nutritional value of meat and tissue composition [6].

As one of the phytogetic feed additives, vegetable oils, such as olive oil, rice bran oil, corn germ oil, and wheat germ oil are commonly used as food supplements in the human diet [7]. Vegetable oils are natural, healthy, and nutritious due to their high content of unsaturated fatty acids and functional molecules, and their high energy value [8].

Rocket (*Eruca sativa* Mill.) belongs to the large family of Brassicaceae (also called Cruciferae or the mustard family). The rocket is an annual or biannual herb that originated in the Mediterranean region and has spread through the world [9]. *E. sativa* species are widely used in folklore and traditional medicine for their therapeutic properties as digestive, astringent, laxative, emollient, depurative, diuretic, rubefacient, stimulant, and tonic [10]. The composition of rocket seeds has shown the presence of many active compounds, such as glucosinolates (glucoerucin and glucoraphanin), flavonoids (quercetin, kaempferol, and isohamnetin), carotenoids, and vitamin C, which are ascribed to antioxidant activity [10]. Rocket seeds contain up to 25–35% of oil [11] and rocket seed oil (RSO) has about 18% of the total saturated fatty acids and 82% of the total unsaturated fatty acids. Rocket seed oil prompts the regeneration of hepatic tissue, decreases hepatic lipid levels, and possesses potent free radical scavenging [12], as well as inhibits melanoma tumor growth in mice [13].

Additionally, rocket seed oil inhibits the growth of some Gram-positive and Gram-negative bacteria and has approximately the same efficiency as the broad-spectrum antibiotic Gentamicine [14]. Moreover, RSO ameliorated the harmful effect of aflatoxin on rabbit blood, semen, and pathological changes in the liver, kidney, and testes [15]. Furthermore, *E. sativa* improved significantly the final body weight, average daily gain, feed intake, and feed conversion ratio of rabbits [16]. The dietary supplementation of 1 g RSO/kg diet alone or with 1 g onion seed oil/kg diet in the growing rabbit's diet for 12 weeks under heat stress improved growth performance, carcass weight, and nutrient digestibility as well as enhanced immunity [17]. In this vein, Alagawany et al. [18] found that dietary supplementation with 0.5–2 g/kg diet of watercress oil alone or in combination with coconut oil for 8 weeks in intensive rabbit production improved growth performance, feed utilization, antioxidant status, and immunity, as well as reduced pathogenic cecal bacteria. On the other hand, the addition of high levels of RSO (1–3 mL/kg body weight) to the rabbits for 2 weeks resulted in a reduction of the body weight with an increasing RSO oil dose [19].

Wheat (*Triticum aestivum* L.) germ is produced during wheat milling and is used worldwide as a diet supplement in the feed formulation of farm animals [20]. Wheat germ oil (WGO) represents about 10–15% of the whole wheat germ [21]. In addition, it contains tocopherol derivatives and tocotrienols [22],  $n - 3$  fatty acids, especially alpha-linolenic acid [23], fat-soluble carotenoids [24], phytosterols, especially D5-avenasterol [25] and phenolic compounds [26]. Moreover, wheat germ oil has an anti-inflammatory effect and strong antioxidant effects [21,26]. Whereas, it reduces  $O_2$ -production and NADPH oxidase activity, and thereby, decreases oxidative stress [23]. WGO manages the serum lipid profile and prevents hypercholesterolemia and atherosclerosis in male albino rabbits fed high cholesterol diet [27]. Other benefits of wheat germ and its derivatives are lowering cholesterol absorption, retarding platelet aggregation, delaying ageing, improving physical endurance, enhancing fertility [25], as well as preventing and curing carcinogenesis [28]. Furthermore, dietary WGO supplementation increased the body weight of male broilers [29].

Taking previous knowledge into account, the present study aimed to investigate the effects of RSO, WGO, and their mixture on growth performance, feed utilization, nutrient digestibility, carcass characteristics, meat fatty acid profile, and redox and immune status of growing rabbits.

## 2. Materials and Methods

### 2.1. Animal Management and Feeding

Eighty-four V-line rabbits at 5 weeks of age (after weaning) with an initial BW of  $535.60 \pm 13.48$  g were assigned randomly into four experimental groups (seven replicates in each group, three rabbits in each replicate). The first group served as the control and received 0.3 mL/kg BW of distilled water (CON), the second group received 0.3 mL/kg BW of rocket seed oil (RSO), the third group received 0.3 mL/kg BW of wheat germ oil (WGO), and the fourth group received a mixture of oils consisting of 0.15 mL of RSO and 0.15 mL of WGO/kg BW (MOs). The oils of wheat germ and rocket seeds were obtained from El Madina Factory for natural seed extract in Borg El Arab, Alexandria, Egypt.

Rabbits were given oils once daily via gavage (oral administration) for 7 weeks from 28 May to 15 July. The basal ration was formulated and pelleted to meet the nutrient requirements of rabbits, according to the NRC [30]. The rations were offered to rabbits *ad libitum*. The ingredients and chemical composition of the pelleted rations are shown in Table 1. The rabbits were offered free access to freshwater.

**Table 1.** The ingredients and chemical analysis of the experimental ration.

Ingredients	(g/kg)
Berseem hay	280.00
Barley	173.00
Corn yellow	179.00
Wheat bran	120.00
Soybean meal 44%	200.00
Molasses	30.00
Di-Ca-Ph	10.00
Salt	3.00
Vitamin premix <sup>1</sup>	3.00
Lysine	1.00
Methionine	1.00
Chemical analysis	(g/kg dry matter)
Organic matter	912.50
Ash	87.50
Crude protein	174.04
Ether extract	84.09
Crude fiber	127.49
Nitrogen-free extract	526.88
Neutral detergent fiber	373.00
acid detergent fiber	210.59
Hemicellulose	162.41
Energy value	
Gross energy (kcal/kg)	3940.87
Digestible energy (kcal/kg)	2528.56

<sup>1</sup> It provides the following nutrients (unit/kg diet): Vitamin A, 12,000 IU; vitamin D3, 2000 IU; vitamin E, 11 IU; vitamin K, 2 mg; pantothenic acid (d-Ca pantothenate), 10 mg; folic acid, 1 mg; choline (choline chloride), 250 mg; Mn (manganous oxide), 60 mg; Fe (ferrous sulfate), 30 mg; Zn (zinc oxide), 50; Cu (copper sulfate), 10 mg; iodine (ethylenediamine dihydroiodide), 1 mg; cobalt (cobalt sulphate heptahydrated), 0.1 mg; and Se (sodium selenite), 0.1 mg.

All the rabbits were kept under similar management, as well as hygienic and environmental conditions. Freshwater was automatically available all the time through stainless steel nipples that were fixed in each cage. The rabbits were housed in galvanized wire cages (dimensions: 40 × 50 × 65 cm) located in a well-ventilated building. The daily photoperiod is a 16:8 h light-dark cycle. This study was conducted at the Rabbit Research Laboratory, Department of Animal and Fish Production, Faculty of Agriculture (Saba Basha), Alexandria University. All the protocols applied in the present experiment have been approved by the Alexandria University, Animal Care and Use Committee with approval no. AU: 19/21/03/25/3/16.

## 2.2. Body Weight and Feed Intake

The rations were removed at night before the days of rabbit weight. The growing rabbits were weighed weekly in the morning before being given a feed. The average daily gain (ADG) and weight gain percentage were calculated. The feed intake was recorded biweekly, then daily feed consumption was calculated by dividing the weekly feed intake by 14 days. The feed conversion ratio (FCR) was calculated by dividing the daily feed intake by the average daily gain.

## 2.3. Digestibility Trial

At 10 weeks of age, sixteen male rabbits were randomly taken to determine the nutrient digestion coefficients of the experimental diets. The rabbits were allocated to four different treatments (four rabbits in each group). The rabbits within each treatment were housed individually in metabolic cages that enabled the separation of urine and feces. The preliminary period was 2 days to adapt rabbits to the new cages and then followed by 5 days as a collection period for feces and urine. During the collection period, the total excreted feces and urine of each rabbit are collected daily in buckets before offering a morning meal and weighing them.

Representative samples (10%) of the total quantity of feces from each rabbit were oven-dried daily at 70 °C for 48 h to determine the total dry matter (DM) of the feces and to calculate the quantity of feces on a DM basis. At the end of the collection period, the faecal samples from each rabbit were mixed thoroughly, and representative samples (10%) of the mixtures were ground through a 1-mm screen on a Wiley mill grinder and then stored frozen at −20 °C prior to the chemical analysis.

Nutritive values in terms of total digestible nutrients (TDN) and digestible crude protein (DCP) were calculated according to the classic formula [31] as follows:

$$\text{TDN}\% = \text{DCP}\% + \text{DCF}\% + \text{DNFE}\% + (\text{DEE}\% \times 2.25) \quad (1)$$

where DCP is the digestible crude protein, DCF is the digestible crude fiber, DNFE is the digestible nitrogen-free extract, and DEE is the digestible ether extract.

$$\text{NR: Nutritive value} = (\text{TDN} (\%) / \text{DCP} (\%)) - 1 \quad (2)$$

Digestible energy (DE) was calculated using the equation according to [32], as follows:

$$\text{DE (kcal/kg diet)} = 44.3 \times \text{TDN}\% \quad (3)$$

## 2.4. Lipid Content and Fatty Acid Profile of Rabbit Meat

The lipid content and fatty acid profile of rabbit meat were determined in the musculus semitendinosus of three slaughtered rabbits per group. Total lipids were extracted with chloroform:methanol (2:1 v/v) from 0.8 g of meat, according to the procedure of Folch et al. [33].

Lipid extraction from the meat samples was performed according to the procedure of Pearson [34]. About 10 g of the sample was weighed in a 250 mL centrifuge bottle. The total volume was completed to 16 mL with distilled water, then 40 mL of methanol and

20 mL of chloroform were added and macerated for 2 min. After that, 20 mL of chloroform was added and macerated for 30 s, then 20 mL of water was added and macerated again for 30 s. The mixture was centrifuged for 10 min at 2000–2500 rpm. The bottom layer of chloroform was removed and filtered through a coarse filter paper into a dry-weight flask or beaker. Then, the chloroform was evaporated to dryness.

Preparation of fatty acid methyl esters from the total lipids of the sample was performed according to the procedure of Radwan [35]. A sample of total lipids (50 mg) was transferred into a Screw-Cap flask, then 2 mL of benzene and 5 mL of methanolic sulphuric acid (1 mL of conc sulphuric acid and 100 mL of methanol) were added. The vial was covered under a stream of nitrogen gas, then placed in a water bath at 90 °C for 90 min. The flask was cooled, then 10 mL of distilled water was added and the methyl esters in each flask were extracted with 5 mL of petroleum ether three times. The petroleum ether extracts were combined and concentrated to their minimum volume using a stream of nitrogen. The analysis of fatty acids was carried out by gas-liquid chromatography (HP, Hewlett Packard 6890 GC model) equipped with a flame ionization detector (FID). Separation was achieved in a column HP-INWAX (cross linked polyethylene glycol, 60 m, 0.25 mm ID, 0.25 µm film thickness) under the following conditions: Detector temperature, 250 °C; injector temperature, 220 °C; injection volume, 3 µL; split ratio, 50:1; carrier gas, nitrogen; gas flow, 1.5 mL/min. Before running the samples, a standard mixture of methyl esters was analyzed under identical conditions. The retention times of the unknown sample of methyl esters were compared with the standard. The proportions of methyl esters were calculated by the triangulation method.

## 2.5. Serum Biochemical Parameters

Before slaughter, 4 mL of blood sample was taken with a sterile syringe from the ear vein of five growing rabbits from each group. The blood sample was placed into a sterile vacutainer tube without an anticoagulant for the serum biochemical analysis.

The serum total protein, lipid profile, and urea were estimated colorimetrically using commercial kits produced by Bio Diagnostic Co., Giza, Egypt. The serum total protein and albumin were determined according to Doumas et al. [36]. The serum globulin concentration was calculated by the difference between the total protein and albumin [37].

Total lipids were estimated by the reaction with sulphuric and phosphoric acids and vanillin to form a pink chromophore [38]. Triglycerides were measured colorimetrically using the quadruple enzymatic reaction [39]. Cholesterol was determined after enzymatic hydrolysis and oxidation as described by Allain et al. [40]. High-density lipoprotein-cholesterol (HDL-c) was determined according to the methods of Grove [41]. Low-density lipoprotein-cholesterol (LDL-c) was determined using the following calculation according to Warnick et al. [42] using the following equation:

$$\text{LDL-c} = \text{cholesterol} - (\text{HDL-c} + \text{vLDL-c}). \quad (4)$$

The very low-density lipoprotein-cholesterol (vLDL-c) was calculated by dividing the value of TG by a factor of 5 according to the method of Warnick, Benderson, and Albers [42]. Serum urea was assayed according to Chaney and Marbach [43].

The triiodothyronine (T3) and thyroxine (T4) hormones were determined in the serum by a direct radioimmunoassay technique. Kits from the Diagnostic Products Corporation (Los Angeles, CA, USA) with ready, antibody-coated tubes were used based on the manufacturer's instructions, according to Kubasik et al. [44].

## 2.6. Antioxidant Assays

Thiobarbituric acid reactive substances (TBARs) were measured colorimetrically according to Tappel and Zalkin [45]. The catalase activity (U/mL serum; EC 1.11.1.6, CAT) was measured according to Luck [46]. The superoxide dismutase activity (U/mL serum; EC 1.15.1.1, SOD) was evaluated according to Misra and Fridovich [47]. The total antioxidant



capacity (TAC) was estimated colorimetrically using commercial kits produced by Bio Diagnostic, Egypt according to the method of [48].

### 2.7. Antibody Titers against SRBCs

The primary and secondary immune response was assayed by measuring antibody titer against sheep red blood cell counts (SRBCs), as the agglutination titer described by Wegmann and Smithies [49]. The agglutination titer was calculated as the log of the reciprocal of the highest serum dilution for the whole agglutination [50].

### 2.8. Chemical Analysis

Chemical analyses of the experimental rations and feces samples were carried out according to AOAC [51] for crude protein (CP, method 968.06), ether extract (EE, method 920.39), crude fiber (CF, method 932.09), and ash (method 967.05). The nitrogen-free extract (NFE) was calculated according to the next equation:

$$\text{NFE (\%)} = 100 - (\text{CP\%} + \text{EE\%} + \text{CF\%} + \text{Ash\%}). \quad (5)$$

Organic matter (OM) was calculated as the difference between 100% DM and ash. Gross energy (GE, kcal/kg) of the experimental diets was calculated based on 5.64, 4.11, and 9.44 kcal GE/g CP, NFE, and EE, respectively NRC [52].

Digestible energy (DE) of the experimental diets was calculated according to the equation described by Cheeke [53], as follows:

$$\text{DE (kcal/kg)} = 4.36 - 0.0491 \times \text{NDF\%} \quad (6)$$

$$\text{whereas, NDF\%} = 28.924 + (0.657 \times \text{CF\%}) \text{ and } \text{ADF\%} = 9.432 + 0.912 (\text{CF\%}) \quad (7)$$

The concentration of hemicellulose was estimated as the difference between NDF and ADF. Nitrogen in urine was determined by the micro-Kjeldahl method [51].

### 2.9. Statistical Analysis

Data of the experiment were analyzed statistically using the one-way analysis of variance (ANOVA) with the SPSS 11.0 statistical software [54]. Differences among means were determined using the Duncan test [55]. Data were analyzed using the following model:

$$Y_{ij} = U + A_i + E_{ij} \quad (8)$$

where U is the overall mean,  $A_i$  is the effect of wheat germ oil, rocket seed oil, and their mixture treatments; and  $E_{ij}$  is the random error.

## 3. Results

### 3.1. Body Weight, Feed Intake, and Feed Conversion Ratio

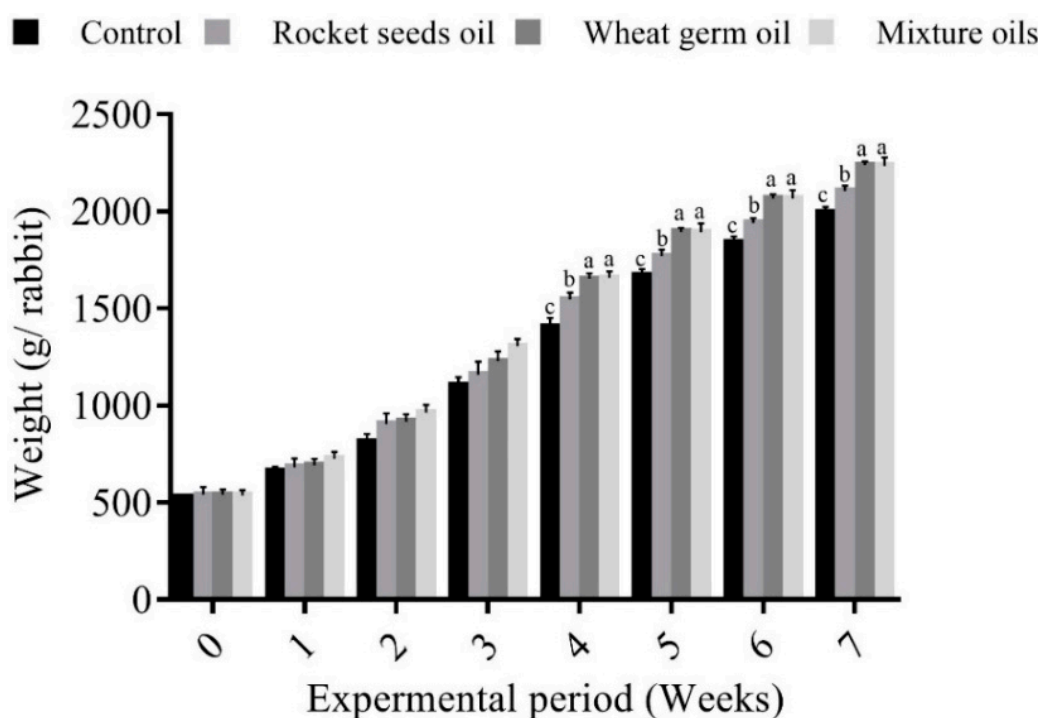
The feed intake of rabbits that were administered orally with RSO and WGO or their mixture is presented in Table 2. The final BW increased significantly ( $p = 0.001$ ) when rabbits were administered orally with RSO and WGO or their mixture compared to the control group. Weight gain and ADG increased significantly ( $p = 0.001$ ) with WGO and MOs treatments compared to the control group. The highest value of final BW, weight gain, and ADG was recorded in the MOs treatment. However, vegetable oil treatments did not affect the average weight gain percentage, total feed intake, and daily feed intake. Meanwhile, FCR improved significantly with RSO and WGO or their mixture treatments compared to the control group.

**Table 2.** Growth performance, feed intake, and feed conversion ratio of V-line growing rabbits (5–12 weeks of age) that were administered orally with rocket seed oil, wheat germ oil, and their mixture.

Items	Control	Rocket Seed Oil	Wheat Germ Oil	Mixture Oils	<i>p</i> -Value
Initial body weight (g/rabbit)	525.12 ± 10.17	540.43 ± 38.96	541.05 ± 26.33	535.81 ± 30.52	0.977
Final body weight (g/rabbit)	1995.71 ± 28.86 <sup>c</sup>	2104.29 ± 27.42 <sup>b</sup>	2237.57 ± 19.98 <sup>a</sup>	2233.81 ± 43.72 <sup>a</sup>	0.001
Weight gain (g/rabbit)	1470.60 ± 31.80 <sup>c</sup>	1563.86 ± 30.76 <sup>b</sup>	1696.52 ± 24.33 <sup>a</sup>	1698.00 ± 32.43 <sup>a</sup>	0.001
Average daily gain (g/day)	30.01 ± 0.65 <sup>c</sup>	31.91 ± 0.63 <sup>b</sup>	34.62 ± 0.50 <sup>a</sup>	34.65 ± 0.66 <sup>a</sup>	0.001
Weight gain percent (%)	280.99 ± 9.72	300.02 ± 24.83	318.15 ± 16.21	322.97 ± 19.10	0.372
Feed intake (g/experimental period)	5541.45 ± 25.16	5531.86 ± 14.09	5516.33 ± 11.23	5568.77 ± 21.40	0.275
Daily feed intake (g/day)	113.09 ± 0.51	112.89 ± 0.29	112.58 ± 0.23	113.65 ± 0.44	0.277
Feed conversion ratio	3.78 ± 0.08 <sup>a</sup>	3.55 ± 0.07 <sup>b</sup>	3.26 ± 0.04 <sup>c</sup>	3.29 ± 0.07 <sup>c</sup>	0.001

<sup>a,b,c</sup> Means with a different superscript in the same row are significantly different ( $p \leq 0.05$ ).

Results in Figure 1 indicate that there was no significant difference between the treatments in body weights in the first 3 weeks of the present study. However, body weights increased ( $p \leq 0.05$ ) with RSO and WGO or their mixture treatments from the 4th week to the 7th week of the experiment compared to the control group.

**Figure 1.** Body weight of V-line growing rabbits (5–12 weeks of age) that were administered orally with rocket seed oil, wheat germ oil, and their mixture. Columns marked with different superscripts are significantly different at  $p \leq 0.05$ .

### 3.2. Digestion Coefficients of Nutrient, Nutritive Values, and Nitrogen Balance

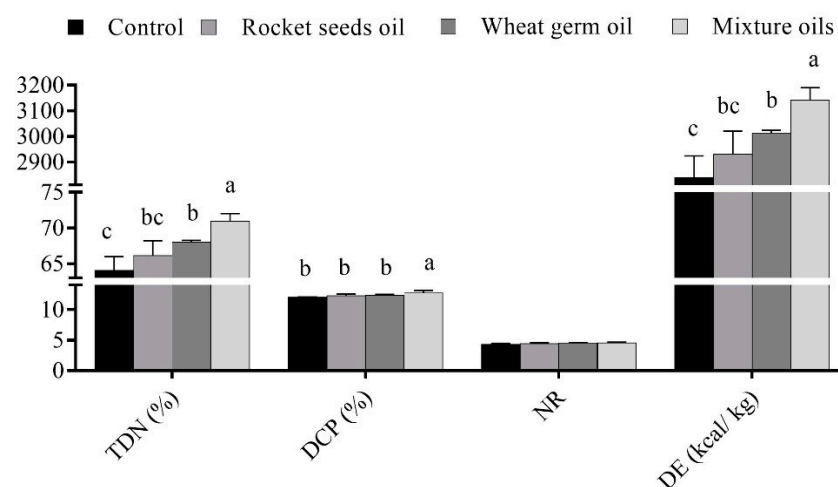
The different experimental treatments with oils had a significant ( $p \leq 0.05$ ) improvement in the digestibility of dry matter, organic matter, crude protein, ether extract, and fiber fraction compared to the control group (Table 3). The results illustrated in Figure 2 show that the oral administration of RSO, WGO, and their mixture had a significant effect on the total TDN, DCP, and DE. The data presented in Table 3 showed that there was a significant ( $p \leq 0.05$ ) improvement in nitrogen intake, absorbed nitrogen, NB, NB as % of N-intake, and NB as % of absorbed-N in rabbits that received Mos, followed by those of rabbits that received RSO and WGO compared to the control group. The results showed

that there were no significant differences in fecal nitrogen and urinary nitrogen among the experimental diets.

**Table 3.** Digestion coefficients of nutrient and nitrogen balance of experimental diets of V-line growing rabbits (5–12 weeks of age) that were administered orally with rocket seed oil, wheat germ oil, and their mixture.

Items	Control	Rocket Seed Oil	Wheat Germ Oil	Mixture Oils	<i>p</i> -Value
<b>Digestion coefficient (%)</b>					
Dry matter	59.80 ± 1.09 <sup>c</sup>	62.28 ± 0.91 <sup>b</sup>	64.46 ± 0.04 <sup>b</sup>	67.79 ± 0.45 <sup>a</sup>	0.001
Organic matter	63.58 ± 1.10 <sup>c</sup>	65.72 ± 0.86 <sup>bc</sup>	67.64 ± 0.18 <sup>b</sup>	70.57 ± 0.40 <sup>a</sup>	0.001
Crude protein	69.01 ± 0.13 <sup>b</sup>	70.39 ± 0.77 <sup>b</sup>	70.84 ± 0.47 <sup>b</sup>	73.21 ± 1.05 <sup>a</sup>	0.008
Ether extract	52.16 ± 1.26 <sup>d</sup>	58.77 ± 0.77 <sup>c</sup>	62.47 ± 1.02 <sup>b</sup>	67.11 ± 0.44 <sup>a</sup>	0.001
Crude fiber	57.60 ± 0.64	58.69 ± 2.63	59.78 ± 0.53	62.12 ± 1.77	0.293
NDF	54.17 ± 0.84 <sup>d</sup>	57.93 ± 0.87 <sup>c</sup>	60.89 ± 0.21 <sup>b</sup>	64.97 ± 0.45 <sup>a</sup>	0.001
ADF	53.32 ± 0.91 <sup>d</sup>	58.29 ± 0.82 <sup>c</sup>	61.56 ± 0.55 <sup>b</sup>	65.88 ± 0.39 <sup>a</sup>	0.001
Hemicellulose	55.27 ± 1.04 <sup>c</sup>	57.47 ± 0.95 <sup>c</sup>	60.02 ± 0.28 <sup>b</sup>	63.80 ± 0.59 <sup>a</sup>	0.002
Nitrogen free extract	65.50 ± 2.00 <sup>b</sup>	66.98 ± 1.02 <sup>b</sup>	69.09 ± 0.48 <sup>ab</sup>	71.89 ± 0.40 <sup>a</sup>	0.012
<b>Nitrogen balance, NB</b>					
N intake (g/day)	2.97 ± 0.03 <sup>c</sup>	3.15 ± 0.03 <sup>b</sup>	3.20 ± 0.03 <sup>b</sup>	3.35 ± 0.03 <sup>a</sup>	0.001
Feces N (g/day)	0.92 ± 0.01	0.93 ± 0.02	0.94 ± 0.02	0.90 ± 0.03	0.670
Absorbed N (g/day)	2.05 ± 0.02 <sup>c</sup>	2.21 ± 0.03 <sup>b</sup>	2.27 ± 0.02 <sup>b</sup>	2.46 ± 0.04 <sup>a</sup>	0.001
Urine N (g/day)	0.53 ± 0.02	0.46 ± 0.02	0.48 ± 0.02	0.48 ± 0.04	0.315
N balance (g/day)	1.52 ± 0.02 <sup>c</sup>	1.76 ± 0.02 <sup>b</sup>	1.79 ± 0.03 <sup>b</sup>	1.98 ± 0.07 <sup>a</sup>	0.001
NB intake (%)	51.17 ± 0.46 <sup>b</sup>	55.86 ± 0.74 <sup>a</sup>	55.90 ± 0.81 <sup>a</sup>	58.95 ± 2.13 <sup>a</sup>	0.006
NB absorption (%)	74.15 ± 0.78 <sup>b</sup>	79.37 ± 0.92 <sup>a</sup>	78.90 ± 0.86 <sup>a</sup>	80.45 ± 1.83 <sup>a</sup>	0.012

<sup>a,b,c,d</sup> Means with a different superscript in the same row are significantly different ( $p \leq 0.05$ ). NDF: Neutral detergent fiber; ADF: Acid detergent fiber; NB: Nitrogen balance.



**Figure 2.** Nutritive value and digestible energy of experimental diets of V-line growing rabbits (5–12 weeks of age) that were administered orally with rocket seed oil, wheat germ oil, and their mixture. Columns marked with different superscripts are significantly different at  $p \leq 0.05$ . TDN: Total digestible nutrients; DCP: Digestible crude protein; NR: Nutritive value; DE: Digestible energy.



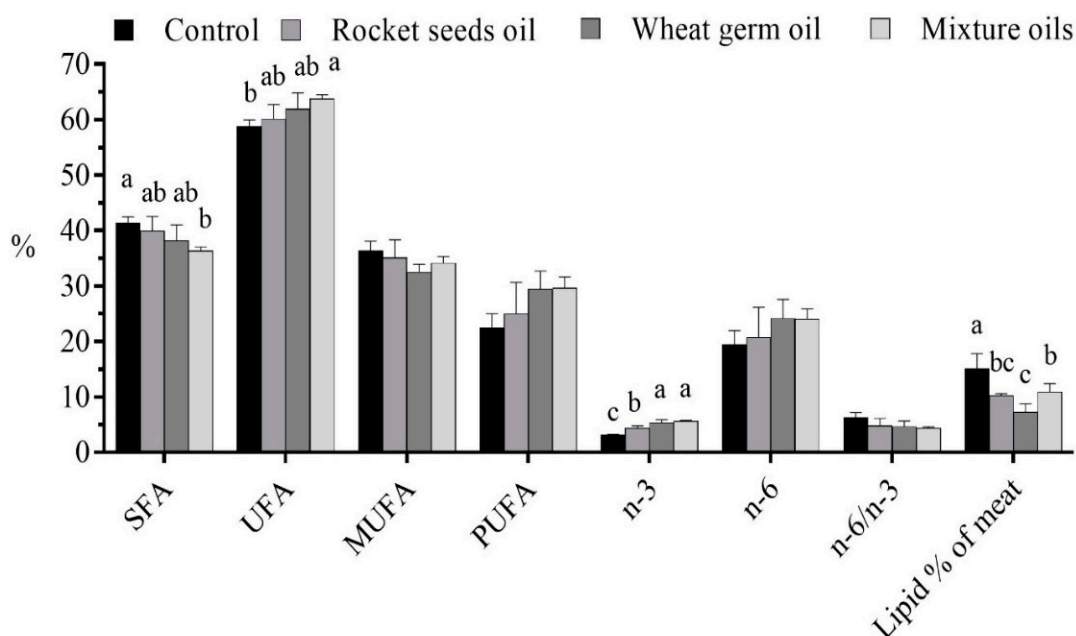
### 3.3. Lipid Content and Fatty Acids Profile of Rabbit Meat

The results of the lipid content and the fatty acid composition of the rabbit meat were influenced by the oil administration (Table 4 and Figure 3). It was observed that rabbits that received RSO, WGO, and MOs had a significant ( $p = 0.001$ ) decrease in the meat content of lipids compared to the control rabbits. In addition, rabbits that received RSO and WGO had a significant ( $p = 0.001$ ) increase in the meat content of linolenic c18:3 n-3 compared to the control rabbits. Moreover, TUFA in meat increased significantly ( $p = 0.050$ ) with MOs treatment and insignificantly with RSO and WGO treatments compared to the control group. There was a significant ( $p = 0.050$ ) reduction in the palmitic c16:0 and oleic c18:1 concentration in the muscles of rabbits that received a mixture of oils and WGO compared to the control rabbits. Furthermore, there was a significant ( $p = 0.050$ ) reduction in SFA concentration in the muscle of rabbits that received a mixture of oils compared to the control rabbits. On the other hand, oral administration of RSO, WGO, and their mixture had no effect on the meat content of linoleic c18:2, PUFA, and omega-6.

**Table 4.** Meat fatty acid profile of V-line growing rabbits (5–12 weeks of age) that were administered orally with rocket seed oil, wheat germ oil, and their mixture.

Items	Control	Rocket Seed Oil	Wheat Germ Oil	Mixture Oils	<i>p</i> -Value
Palmitic (c16:0,%)	33.54 ± 0.56 <sup>a</sup>	32.45 ± 1.74 <sup>ab</sup>	30.79 ± 1.04 <sup>ab</sup>	27.03 ± 2.47 <sup>b</sup>	0.050
Stearic (c18:0,%)	6.78 ± 0.20	6.45 ± 0.15	6.49 ± 1.12	7.19 ± 1.08	0.902
Palmitoleic (c16:1,%)	4.42 ± 0.56	4.43 ± 0.83	3.18 ± 0.64	4.65 ± 0.29	0.372
Oleic (c18:1,%)	31.35 ± 0.43 <sup>a</sup>	30.21 ± 0.96 <sup>ab</sup>	28.30 ± 0.42 <sup>b</sup>	28.64 ± 0.85 <sup>b</sup>	0.050
Linoleic (c18:2; n-6,%)	19.31 ± 1.52	20.65 ± 3.20	24.13 ± 1.99	24.03 ± 1.08	0.330
Linolenic (c18:3; n-3,%)	3.12 ± 0.07 <sup>c</sup>	4.32 ± 0.25 <sup>b</sup>	5.29 ± 0.35 <sup>a</sup>	5.59 ± 0.12 <sup>a</sup>	0.001

<sup>a,b,c</sup> Means with a different superscript in the same row are significantly different ( $p \leq 0.05$ ).



**Figure 3.** Meat fatty acid profile and lipids content of V-line growing rabbits (5–12 weeks of age) that were administered orally with rocket seed oil, wheat germ oil, and their mixture. Columns marked with different superscripts are significantly different at  $p \leq 0.05$ . SFA: Saturated fatty acids; UFA: Unsaturated fatty acids; MUFA: Monounsaturated fatty acids; PUFA: Polyunsaturated fatty acids; n-3: Omega-3; n-6: Omega-6.

### 3.4. Serum Biochemical Parameters

The changes in the serum biochemical parameters due to the oral administration of growing rabbits with RSO and WGO or their mixture are presented in Table 5. The serum total protein increased significantly ( $p = 0.019$ ) by oral administration of MOs compared with the control group. However, serum albumin tended to increase in groups that received RSO and MOs than in the control group. As well as serum globulin tended to increase in the rabbits that received WGO and MOs than in the control group. In comparison with the control group, oral administration of RSO and WGO or a mixture of them caused ( $p = 0.050$ ) a decrease in serum blood urea nitrogen.

**Table 5.** Serum biochemical constituents of V-line growing rabbits (5–12 weeks of age) that were administered orally with rocket seed oil, wheat germ oil, and their mixture.

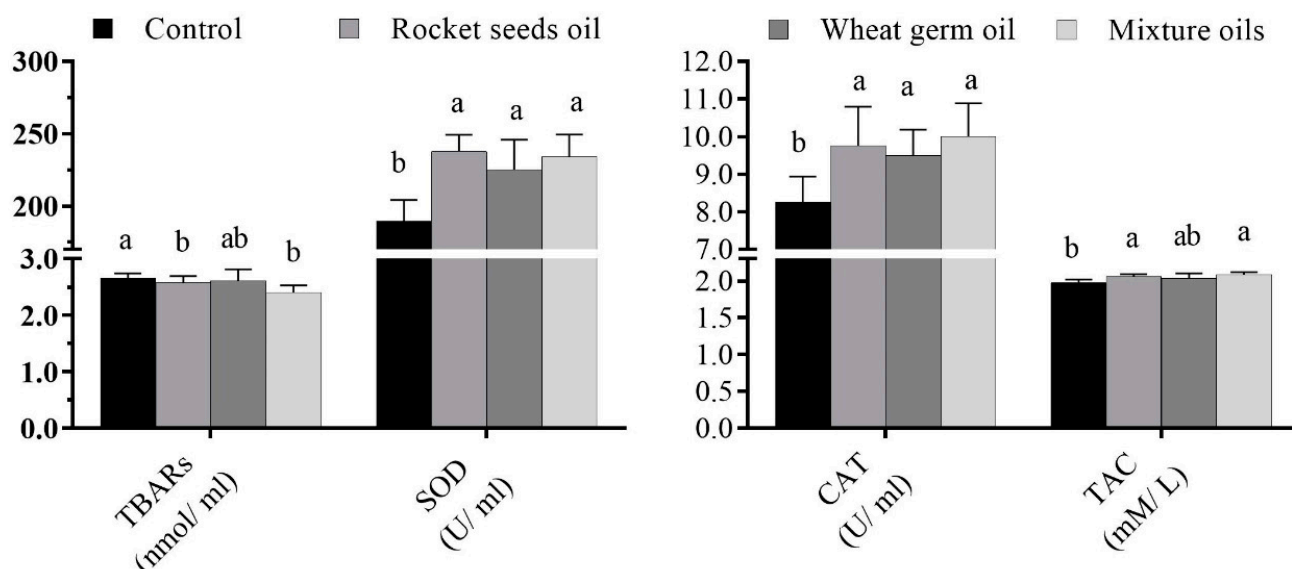
Items	Control	Rocket Seed Oil	Wheat Germ Oil	Mixture Oils	<i>p</i> -Value
<b>Protein profile</b>					
Protein (g/dL)	5.37 ± 0.09 <sup>b</sup>	5.39 ± 0.15 <sup>b</sup>	5.70 ± 0.20 <sup>ab</sup>	5.97 ± 0.05 <sup>a</sup>	0.019
Albumin (g/dL)	3.06 ± 0.14 <sup>ab</sup>	3.36 ± 0.09 <sup>a</sup>	3.01 ± 0.06 <sup>b</sup>	3.38 ± 0.12 <sup>a</sup>	0.041
Globulin (g/dL)	2.31 ± 0.22 <sup>ab</sup>	2.03 ± 0.21 <sup>b</sup>	2.69 ± 0.19 <sup>a</sup>	2.59 ± 0.16 <sup>a</sup>	0.050
A/G ratio	1.41 ± 0.22	1.56 ± 0.20	1.15 ± 0.10	1.34 ± 0.13	0.215
<b>Kidney function</b>					
Urea (mg/dL)	49.50 ± 1.70 <sup>a</sup>	44.30 ± 1.22 <sup>b</sup>	45.70 ± 0.89 <sup>ab</sup>	45.40 ± 1.12 <sup>b</sup>	0.050
<b>Lipid profile</b>					
Total lipid (mg/dL)	433.00 ± 11.45 <sup>b</sup>	470.00 ± 3.85 <sup>a</sup>	424.70 ± 6.55 <sup>b</sup>	424.50 ± 4.26 <sup>b</sup>	0.001
TG (mg/dL)	61.60 ± 2.93	65.10 ± 4.89	69.10 ± 2.41	71.10 ± 5.67	0.411
Cholesterol (mg/dL)	63.00 ± 3.74	61.40 ± 4.48	62.00 ± 2.02	60.40 ± 1.89	0.955
HDL-c (mg/dL)	29.40 ± 1.29 <sup>b</sup>	32.50 ± 0.92 <sup>ab</sup>	34.00 ± 0.71 <sup>a</sup>	33.20 ± 1.16 <sup>a</sup>	0.033
LDL-c (mg/dL)	21.28 ± 3.40 <sup>a</sup>	15.88 ± 3.74 <sup>b</sup>	14.18 ± 1.97 <sup>b</sup>	12.98 ± 2.00 <sup>c</sup>	0.001
vLDL-c (mg/dL)	12.32 ± 0.59	13.02 ± 0.98	13.82 ± 0.48	14.22 ± 1.13	0.412
HDL-c/LDL-c ratio	1.61 ± 0.39	2.50 ± 0.53	2.56 ± 0.30	2.78 ± 0.40	0.238
<b>Hormone assay</b>					
T4 (ng/mL)	2.83 ± 0.10	3.48 ± 0.10	3.15 ± 0.15	3.46 ± 0.30	0.070
T3 (ng/mL)	1.04 ± 0.07 <sup>b</sup>	1.34 ± 0.02 <sup>a</sup>	1.36 ± 0.04 <sup>a</sup>	1.42 ± 0.16 <sup>a</sup>	0.035

<sup>a,b,c</sup> Means with a different superscript in the same row are significantly different ( $p \leq 0.05$ ). A/G ratio: Albumin/globulin ratio; HDL-c: High-density lipoprotein-cholesterol; LDL-c: Low-density lipoprotein-cholesterol; vLDL-c: Very low-density lipoprotein-cholesterol; T3: Thyroxine; T4: Triiodothyronine.

In terms of lipid profile, it has been observed that oral administration of RSO ( $p = 0.001$ ) increased total lipids compared to other groups. Serum blood HDL-c was higher ( $p = 0.033$ ) in the WGO and MOs groups than in the RSO and the control groups. Whereas, all the treated rabbits with vegetable oils had ( $p = 0.001$ ) a decrease in serum LDL-c compared to the control group. Moreover, there is no significant ( $p > 0.05$ ) effect between oil treatments and the control group in serum blood TG, cholesterol, and vLDL-c and HDL-c/LDL-c ratio. The treatments of RSO, WGO, and a mixture of them had a positive effect on thyroid hormone secretion.

### 3.5. Antioxidant Status

Oral administration of RSO and MOs resulted in a significant ( $p = 0.050$ ) decrease in blood serum lipid peroxidation (i.e., TBARS) (Figure 4). Rocket seed oil and MOs reduced serum TBARS concentration by about 9.43% of the control group. However, there is a significant increase in serum antioxidant activities as measured by CAT ( $p = 0.021$ ) and SOD ( $p = 0.001$ ) by oral administration of RSO and WGO or their mixture when compared to the control group, while serum TAC activity increased significantly ( $p = 0.017$ ) by oral administration of RSO and MOs when compared to the control group.



**Figure 4.** Serum thiobarbituric acid reactive substances and antioxidants status of V-line growing rabbits (5–12 weeks of age) that were administered orally with rocket seed oil, wheat germ oil, and their mixture. Columns marked with different superscripts are significantly different at  $p \leq 0.05$ . CAT: Catalase; SOD: Superoxide dismutase; TAC: Total antioxidant capacity; TBARS: Thiobarbituric acid reactive substances.

### 3.6. Antibody Titers against SRBCs

The humoral immune response includes the response of natural antibodies to SRBCs, which were measured at 9, 10, and 11 weeks of age, as shown in Table 6. Oral administration of RSO, WGO, and their mixture caused an improvement ( $p = 0.010$ ) in the antibody titers against SRBCs of growing rabbits at 9 weeks of the rabbit age compared to the control group. However, the antibody titers against SRBCs of growing rabbits at 10 weeks of rabbit age significantly increased ( $p = 0.044$ ) in the group that orally received WGO compared to the control.

**Table 6.** Antibody titers against SRBCs of V-line growing rabbits (5–12 weeks of age) that were administered orally with rocket seed oil, wheat germ oil, and their mixture.

Items	Control	Rocket Seed Oil	Wheat Germ Oil	Mixture Oils	<i>p</i> -Value
SRBCs at 9 weeks of age	0.74 ± 0.04 <sup>b</sup>	0.84 ± 0.02 <sup>a</sup>	0.87 ± 0.02 <sup>a</sup>	0.84 ± 0.02 <sup>a</sup>	0.010
SRBCs at 10 weeks of age	0.76 ± 0.03 <sup>b</sup>	0.84 ± 0.03 <sup>ab</sup>	0.85 ± 0.02 <sup>a</sup>	0.76 ± 0.03 <sup>b</sup>	0.044
SRBCs at 11 weeks of age	0.71 ± 0.04	0.76 ± 0.11	0.88 ± 0.02	0.71 ± 0.03	0.201

<sup>a,b</sup> Means with a different superscript in the same row are significantly different ( $p \leq 0.05$ ). SRBCs: Sheep red blood cell counts.

## 4. Discussion

### 4.1. Growth Performance and Feed Utilization

Vegetable oils, such as olive oil, rice bran oil, corn germ oil, rocket seed oil, and wheat germ oil have been used as a source of energy, essential polyunsaturated fatty acids and fat-soluble vitamins with great nutritional and health benefits [56]. Rocket, *E. sativa* is considered an important leafy vegetable crop that is high in antioxidant molecules, and its seeds contain oil up to 25–35% [11]. Wheat has been called the staff of life, and people who have many health concerns have used wheat germ oil [57]. Wheat germ oil represents about 10–15% of the whole wheat germ, which is reported to be one of the potential resources for beneficial molecules [21].

In the current study, the final BW, weight gain, and ADG increased significantly in rabbits that were administered orally with RSO and WGO or their mixture compared to the control group. In the same vein, the RSO treatment significantly increased the final BW and daily gain of rabbits [16]. Moreover, the final BW, ADG, and total gain of growing rabbits were higher significantly with the supplementation of RSO, and the mixture of RSO and onion oil [17] or with the supplementation of watercress oil and the mixture of watercress oil and coconut oil [18]. Furthermore, dietary supplementation of WGO increased the BW of male broilers [29]. In conflict with our results, the addition of RSO (1–3 mL/kg BW) in rabbit's diet for 2 weeks tended to decrease BW as the dependent dose [19].

In the current study, all the groups were fed the same diet (isocaloric), but the groups receiving the supplemental oils (0.3 mL/kg BW) had more caloric value by  $\approx 3$  kcal/kg BW as an energy intake, representing a 0.7% increase in the daily gross energy intake. This increase is not significant, and it could not affect the obtained results of growth, feed utilization, physiological performance, and digestibility. Previous studies revealed that ADG, slaughter live BW, and carcass weight were not affected either by the fat source or fat level [58]. In this study, the difference in gross energy was 3.44%, which was obtained using different fat sources (linseed and black soldier fly). In addition, the increase in fat levels by 3% did not affect the growth rate of rabbits due to the decreased feed intake, but it increased energy digestibility and feed efficiency [59,60]. Moreover, rabbits fed three diets with different energy levels (2707, 2436, and 2276 kcal DE/kg) did not affect live BW, weight gain, FCR [61]. However, the increase in gross energy by 8.79% could affect the rabbit BW [62].

Accordingly, the improvement in BW and BWG with vegetable oil supplementation in the present study could be attributed to the content of active molecules in rocket seeds, such as carotenoids, vitamin C, glucoerucin, and flavonoids, which are health-promoting agents [63]. In addition, the volatile oil of rocket seeds contains isothiocyanates, which have antimicrobial, antioxidant, and anticarcinogenic activities [64]. Moreover, WGO is a natural source of  $\alpha$ -tocopherol, which increases ( $p \leq 0.05$ ) the BW and BWG of growing rabbits [65]. Mustacich et al. [66] supported these findings by stating that the natural  $\alpha$ -tocopherol has higher natural activity than synthetic  $\alpha$ -tocopherol. Furthermore, linoleic acid found in WGO operates as the precursor of cell membrane phospholipids [67], which could also participate in the growth improvement in the current study.

The oral administration of vegetable oils had no effect on daily feed intake and total feed intake during the whole experimental period in the present study. The route of administration in the present study was gavage, which could not affect the diet palatability and therefore maintained the normal feed intake. Meanwhile, FCR improved significantly with RSO and WGO or their mixture treatments compared to the control group. In accordance, the feed intake did not affect the 12-weeks aged rabbits that were given orally different levels of watercress oil plus coconut oil compared to the control group. However, the FCR of rabbits was improved with watercress oil or watercress oil plus coconut oil [18]. The improvement in the FCR of growing rabbits may be attributed to the properties of these oils that act as antibacterial, antiprotozoal, antifungal, and antioxidants [18,68,69]. Moreover, rocket seed cakes increased the FCR of male rabbits, which may be due to their beneficial effect on stimulating and activating the digestive system [16].

#### 4.2. Digestion Coefficients of Nutrient, Nutritive Values, and Nitrogen Balance

The different experimental oil treatments had a significant ( $p \leq 0.05$ ) improvement in nutrient digestibility compared to the control group. This improvement in nutrient digestion coefficients resulted in a significant increase in body weight gain and an improvement in the FCR (Table 2). Whereas, rocket seed cakes have a beneficial effect on stimulating and activating the digestive system [16]. In parallel to our results, using onion or moringa oils or a mixture of them significantly ( $p \leq 0.05$ ) improved digestibility coefficients of CP and EE compared to the control group. Meanwhile, the digestibility of DM, OM, CF, and NFE was not affected significantly by the addition of different oils [70,71]. In this line, the addition of 1 g RSO/kg diet or 1 g onion seed oil/kg diet and their combination in the growing rabbit's diet increased ( $p \leq 0.05$ ) the digestion coefficients of CP and EE compared to the control group [17]. In this regard, the addition of fennel seeds, oregano leaves only or the mixture to the rabbit's diet had a significant ( $p \leq 0.05$ ) improvement in DM, OM, and CF digestibility [72].

Concerning the nutritive values and digestible energy of the experimental diets, the results showed that TDN, DCP, and DE increased significantly in RSO, WGO, and their mixture groups. In accordance with the current results, the fat-containing rabbit diets with or without a herbal mixture formulation containing fennel seeds and oregano leaves improved both TDN and DCP values [72]. Moreover, there was a significant ( $p \leq 0.05$ ) improvement in nitrogen intake, absorbed nitrogen, and NB in rabbits that received Mos, followed by rabbits that received RSO and WGO compared to the control group. The improvement in N absorbed and NB of the experimental diets of rabbits that received vegetable oils resulted in a significant ( $p = 0.050$ ) decrease in serum blood urea nitrogen in the current study (Table 5).

#### 4.3. Lipid Content and Fatty Acid Profile of Rabbit Meat

Currently, consumers are increasingly praising foods that contain not only macro-nutrients, but also beneficial compounds for health and welfare [73]. Rabbit meat is a good source of protein with a low fat and cholesterol content, and it has a lower energetic value than red meat [74]. Moreover, the fatty acid composition of rabbit meat consists of a high polyunsaturated fatty acid content [74]. Several studies have suggested that n-3 fatty acids play an important role in human nutrition since they help reduce the incidence of lifestyle diseases such as coronary artery diseases, atherosclerotic diseases, hypertension and diabetes, as well as certain inflammatory diseases, such as arthritis and dermatitis [23]. The increase in the n-3 PUFA level in rabbit meat is feasible and could be achieved by feeding them n-3 PUFA rich diets. Furthermore, the supplementation of natural antioxidants in feed declines lipid peroxidation and enhances the stability of unsaturated fatty acids [29].

The current findings show that rabbits that received RSO, WGO, and their mixture had a significant ( $p = 0.001$ ) decrease in the meat content of lipids and had a positive effect on meat fatty acid composition, including a significant increase in TUFA and linolenic c18:3 n-3 and had a significant reduction in the meat content of SFA, palmitic c16:0, and oleic c18:1 compared to the control rabbits.

These results are in agreement with other studies that have shown that dietary manipulations in monogastric animals, including rabbits, can change the quantity and chemical composition of the fatty acid. Whereas, vegetable oils can lower the PUFA/SFA ratio and increase the n-3 value in rabbit meat [6,75,76]. In addition, supplementing the rabbit feed with 8% linseed increased the C18:3 n-3 concentration and decreased the n-6/n-3 ratio in rabbit meat compared to the control group [77]. Daily linseed oil supplementation for 30 days increased the amount of  $\omega$ -3 fatty acid in the muscular tissue lipids of bucks from 4.49 to 7.72%, i.e., by 1.72 times [78]. Moreover, the feeding of linseed oil rich in n-3 PUFA can be an effective method for increasing the tissue levels of these fatty acids in broiler chickens [79–81]. Blending different vegetable oils can modify the fatty acid composition



and raise levels of natural antioxidants and bioactive lipids in the mixes, thus, leading to an improvement in the nutritional value and oil stability [82].

#### 4.4. Serum Biochemical Parameters

Oral administration of RSO, WGO, and their mixture improved the serum total protein as well as albumin and globulin levels compared to the control group. In agreement with the current results, the serum total protein as well as albumin and globulin levels improved significantly ( $p \leq 0.05$ ) when the rabbits were given the mixture of moringa oil and RSO, followed by individual moringa oil and RSO supplementation or growing rabbits that received moringa oil alone or with onion oil [70,71]. The significant increase in serum total protein and albumin observed in rabbits that were administered orally with RSO, WGO, and their mixture indicated the ability of these oils to stimulate the regeneration of hepatic tissue, which increased protein synthesis in the liver and improved the functional status of the liver cells [12,83] or these oils had a positive effect on thyroid hormone secretion, which could affect the metabolism of nutrients (Table 5). In addition, the rocket seeds contain vitamin C and carotenoids [63], which play an important role in the protection against oxidative damage [84] as indicated in improving the serum antioxidant status of rabbits in the present findings (Figure 3). Moreover, WGO has a high content of other nutritional and health-benefit factors, such as vitamin E and phytosterol [85], which may be the reason for its improving effect on the blood protein profile. The increase in serum total protein and globulin is a general indication of the immune status of the animal, since the liver can synthesize enough globulin for immunologic action, as mentioned by Sunmonu and Oloyede [86]. These improvements signify better disease resistance and increase immune response and animal resistance against any physiological or physical stressors [87].

Oral administration of RSO and WGO or a mixture of them caused ( $p = 0.050$ ) a decrease in serum blood urea nitrogen. This reduction in urea nitrogen may be due to the improvement of NB as indicated in the present results (Table 3). In terms of lipid profile, it has been observed that oral administration of RSO, WGO, and MOs had a positive effect on serum total lipids, HDL-c, and LDL-c compared to the other groups.

In agreement with the current results, the supplementation of 1–3 mL/kg BW of RSO to the rabbit's diet decreased ( $p \leq 0.05$ ) the level of serum LDL-c and increased the serum HDL-c level compared to the control group [19]. In addition, Abozid et al. [88] discovered that RSO had a clear effect on improving the lipid profile due to its high concentration of plant sterols. Whereas, plant sterols reduce the incorporation of dietary and biliary cholesterol into micelles, leading to low cholesterol synthesis and cholesterol absorption as well as increasing LDL-c receptor activity, which eventually results in lower serum LDL-c concentration [89]. Moreover, total cholesterol, triglycerides, and LDL-c concentrations ( $p > 0.05$ ) decreased as well as the HDL-c ( $p \leq 0.05$ ) increased with the WGO treatment [90]. The lowering effect of WGO on triglyceride, cholesterol, and LDL-c may be attributed to the high content of vitamin E and phytosterol in WGO [85]. Furthermore, linoleic acid found in WGO leads to the abstraction of cholesterol and acts as the precursor of cell membrane phospholipids [67,91]. WGO contains policosanols, which can reduce the high concentration of blood total cholesterol [92].

#### 4.5. Antioxidants

Oxidative stress is defined as an imbalance between pro- and anti-oxidant species, which leads to molecular and cellular damage [93]. The oxidative damages could be mitigated by endogenous defense systems, such as CAT, SOD, and GPX system, but this system is not completely efficient, especially under stress [94]. The determination of single components of this system or so-called TAC could reveal the efficiency of enzymatic and non-enzymatic antioxidative systems [95].

Vegetable oils, such as olive oil, rice bran oil, corn germ oil, and wheat germ oil have been used as a source of plant antioxidants [96,97]. In the current findings, the oral administration of RSO and WGO or their mixture showed a significant decrease in TBARs



and a significant increase in blood serum antioxidant properties (CAT, SOD, and TAC). In accordance with the present results, the treatments with RSO and WGO have a positive effect on the antioxidant status, as they are very efficient scavengers of free radicals [18,98]. Whereas, RSO decreases hepatic lipid peroxidation as a result of increasing hepatic SOD activity [12]. In addition, RSO has a high content of natural antioxidants, such as phenolic compounds [99].

Wheat germ oil has a positive effect on the antioxidant defense system [23] due to its content of antioxidant compounds, such as alpha, beta, and gamma-tocopherols, tocotrienols [22], and fat-soluble carotenoids, such as lutein, zeaxanthin, and beta-carotene [24]. Moreover, WGO has remarkable antioxidant effects owing to the individual and synergistic effects of fatty acids, antioxidants, vitamins, phytosterols, and phenolic compounds [24,100]. Another prospective interpretation is that WGO promotes the tocopherol-mediated redox system and prevents the synthesis of eicosanoids (prostaglandins) that stimulate the lipid peroxidation process [101].

#### 4.6. Antibody Titers against SRBCs

Antibody titers against SRBCs of growing rabbits were improved significantly by oral administration of RSO, WGO, and their mixture. These results suggest that RSO, WGO, and their mixture might have synergistic effects on immune responses. In harmony with the current findings, the addition of 1 g RSO/kg diet or 1 g onion seed oil/kg diet and their combination in the growing rabbit's diet improved ( $p \leq 0.05$ ) antibody titer against SRBCs compared to the control group [17]. Moreover, dietary supplementation with watercress oil plus coconut oil resulted in improvement in the immunity of growing rabbits and may be associated with a reduction in pathogenic cecal bacteria and enhancing the antioxidant status [18].

The improvement of antibody titer against SRBCs may be due to carotenoids found in Rocket, *E. Sativa*, which can conserve phagocytic cells from antioxidative defects, improve T and B lymphocyte proliferative responses, and ameliorate the production of inevitable interleukins [102]. Moreover, carotenoids raise plasma IgG levels [103]. WGO contains higher amounts of vitamin E (more than approximately 50 mg vitamin E/100 g oil), whereas dietary vitamin E combined with Se in diets caused an improvement in the antibody titers against SRBCs of growing rabbits [65]. Otherwise, WGO is rich in n-3 PUFA as reported in the current study (Table 3 and Figure 3), mainly alpha-linolenic acid, which recovers the immune system [104].

## 5. Conclusions

The treatment with rocket seed oil, wheat germ oil, and their mixture increased body weight, improved feed conversion ratio, nutrient digestibility, and nitrogen balance. In addition, it enhanced the fatty acid profile and lipid content of the rabbit meat, and improved the blood metabolites. The combination of rocket seed oil and wheat germ oil had a synergistic effect on minimizing lipid peroxidation in blood serum and maximizing the antioxidant defense system, which probably translates into enhancing growth performance, muscle integrity, immunity, and disease resistance in growing rabbits. Getting such positive results is vital, especially under commercial production conditions. However, further studies could be needed to validate the efficacy of incorporating the studied oils into the rabbit's diets rather than the oral gavage to facilitate animal husbandry under commercial farming.

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**Data Availability Statement:** The data that support the findings of this study are available from the authors upon reasonable request.

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