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EFFECT OF DIFFERENT DIETARY LEVELS OF COCONUT OIL AS A SOURCE OF MEDIUM CHAIN FATTY ACIDS ON SOME PRODUCTION AND PHYSIOLOGICAL TRAITS OF GROWING RABBITS.

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Eighty New Zealand White (NZW) rabbits aged 5 weeks and weighed 603.2 g±10.93 were used in the present study to determine the effects of different levels of dietary coconut oil (CO) as medium chain fatty acid (MCFA) source on their productive capability, carcass characteristics, some heamatological and biochemical indices, lipid peroxidation, total antioxidant capacity and profitability. The present study lasted 5 weeks and was carried out during growing period (from weaning at 5 weeks to marketing age at 13 weeks of age). The growing animals were divided into four experimental groups of 20 rabbits each. These groups fed 0.0 (G_1) as a control group, 0.5 (G_2), 1.0 (G_3) or 1.5 (G_4) % CO / kg diet.

***The results revealed that**, daily body weight gain and final body weight of growing NZW rabbits were significantly (P≤0.05) higher due to treatment with CO compared to control being maximized with 1.0 and 1.5% CO. Rabbits received the CO with the highest levels had the highest digestibility coefficients of all nutrients, except CF and NFE values . The treatment groups, also increased significantly (P≤0.05) dressing, fore parts, trunk, hind parts and total edible parts percentages, blood picture and some blood serum constituents. Also, treated rabbits had significant (P≤0.05) increase in serum antioxidant capacity and decrease in serum lipid profile and thigh lipid peroxidation.*

***Conclusively,** dietary 1.0% CO/kg diet showed a beneficial role in enhancing growth performance and improving blood metabolites without any deleterious effects on liver and kidneys function with the best economic efficiency, under Egyptian environmental conditions.*

Key words: Rabbits, coconut oil, productive performance, digestion, blood parameters.

In general, rabbit does are nurse their kits till weaning age (4-5 weeks of age). Kits are until 18-19 days of age exclusively depending on milk of their mother (Fortun-Lamothe and Gidenne, 2000). Skřivanová *et al.* (2008) suggested that the rabbits milk fat contained antimicrobial compounds, identified as eight and ten carbon saturated fatty acids (caprylic and capric acid, respectively). Content of these acids in the rabbit's milk is very high, they represent from one third to one half of the total fatty acids in the rabbit's milk fat (Lebas *et al.,* 1996). Both acids are practically absent from the feed, thus, rabbits synthesize them in the mammary gland.

The nutritional alteration, which is associated by weaning (separation from the mother), caused one of the worst kinds of stress. This stress can not be easily tolerated by young animal, resulting in elevated cortisol levels in systemic circulation and hence immunosuppression and increased susceptibility to many diseases (Serkan *et al.*, 2012).

Recently, several authors attempted to alleviate post-weaning stress by using some natural feed additives (El-Kholy *et al.*, 2012 & 2014; and Gazal-Mervat *et al.*, 2013).

Coconut oil (CO) is composed primarily of short and medium chain fatty acids (MCFA) with lauric acid (12:0) and myristic acid (14:0) accounting for approximately 46.5% and 20.5% of the fatty acids content, respectively (Dauqan *et al.*, 2011). Coconut oil has high content of fatty acids, mainly myristic, palmitic, stearic, oleic and linoleic (Kobayashi, 2010). Besides that, *in vitro* test showed that several fatty acids in CO are potential as antibacterial (Bergsson *et al*., 2001), antivirus (Bartolotta *et al*., 2001), and immune-stimulant (Witcher *et al*., 1996), which are important to fight infection. The vitamin E, particularly the tocotrienol present in CO can suppress the synthesis of cholesterol in the liver (Qureshi *et al*., 1991). Also, Kapila and Dissanayake (2008) reported phenolic compounds in CO, such as caffeic acid, p-coumaric acid, ferulic acid and catechin, resulted in improvement of antioxidant related health benefits.

During the last decade, much research has been directed towards increasing intestinal MCFA content through different nutritional strategies, especially in post-weaning piglets (Decuypere and Dierick, 2003). Using of feed supplement containing with short and medium chain fatty acids are proposed as a valuable alternative to feed antibiotics and can be used to promote growth, as well as, serve as a preventive and curative treatment for gastrointestinal diseases (Decuypere and Dierick, 2003).

Very little information is available on using CO as a source of MCFA for improving growth performance and physiological indices of rabbits. Also, no mammalian studies showed whether or not it could be used beneficially than other source of energy especially during fattening period as

reimbursement for milk females. Moreover, inclusion level of CO in growing rabbit's diet is not definitely known.

Therefore, the current study was undertaken to investigate the effect of dietary CO at different levels on some growth performance and some physiological parameters of growing NZW rabbits and to determine the inclusion level and profitability of using CO in growing rabbit's diet, under Egyptian environmental conditions.

MATERIALS AND METHODS

The study was carried out at Sakha Experimental Station, belongs to Animal Production Research Institute, Ministry of Agriculture, Egypt.

Eighty New Zealand White (NZW) rabbits aged 5 weeks and weighed 603.2 g±10.93 were divided randomly into four experimental groups of 20 rabbits each. Four experimental diets were formulated to cover all essential nutrient requirements for growing rabbit according to NRC (1977). The first group was fed *ad libitum* a commercial pelleted diet and kept untreated and served as a control, while the other groups (second; third and fourth) were fed experimental diets with three levels of coconut oil (0.5, 1.0 and 1.5% of the diet). Fatty acids composition in CO is presented in Table 1. All diets were nearly iso-nitrogenous and iso-caloric on the basis of digestible energy and contained similar levels of micro elements. Table 2 shows the formulation and nutrient composition of these diets.

All rabbits were kept under the same managerial conditions. Feed and water were offered *ad libitum* throughout the experimental period (5 to 13 weeks of age).

Live body weight (BW, g), daily feed intake (DFI, g) and number of dead rabbits were recorded weekly. Daily weight gain (DWG, g) and feed conversion rate (FCR, g/g) were calculated weekly. Economical efficiency

Table 1: Fatty acids composition of coconut oil (Rossell, 1985).

Common name	Composition	%	
Caproic acid	C 6:0	0.4 - 0.6	Medium Chain Triglycerides (MCTs) 65 %
Caprylic acid	C 8:0	4.6 – 10	
Capric acid	C 10:0	5.0 - 8.0	
Lauric acid	C 12:0	45.1 - 53.2	
Myristic acid	C 14:0	16.8 - 21.	
Palmitic acid	C 16:0	7.5 – 10	
Stearic acid	C 18:0	2.0 - 4.0	
Oleic acid	C 18:1	5.0 - 10.0	
Linoleic acid	C 18:2	1.0 - 2.5	
Other	C 18:3 C 24:1	< 0.5	

Table 2: Ingredients and calculated chemical analysis of experimental diets (coconut oil levels, CO).

Ingredients	**Control (0 CO)**	**0.5 % (CO)**	**1% (CO)**	**1.5 % (CO)**
Yellow corn	0.70	0.00	0.00	0.00
Soybean meal 44	8.23	8.13	8.15	8.10
Wheat bran	49.15	52.02	52.00	51.90
Clover hay	30.82	31.70	31.70	31.35
Barely	4.00	0.50	0.00	0.00
Molasses	4.00	4.00	4.00	4.00
Coconut oil	0.00	0.50	1.00	1.50
Dicalcium-phosphate	1.00	1.00	1.00	1.00
DL Methionin	0.27	0.27	0.27	0.27
DL Lysine	0.13	0.18	0.18	0.18
Sodium chloride	0.30	0.30	0.30	0.30
Anti-coccidia	0.10	0.10	0.10	0.10
Premix[1]	0.30	0.30	0.30	0.30
Limestone	1.00	1.00	1.00	1.00
Total	**100**	**100**	**100**	
100				
Calculated analysis[2]:				
Digestible energy, kcal/kg	2510	2510	2513	2519
Crude protein (CP, %)	16.07	16.05	16.00	15.99
Crude fat, %	2.37	2.40	2.39	2.38
Crude fiber (CF, %)	14.00	14.09	14.08	14.10
Ca %	1.10	1.14	1.14	1.14
Total ph %	0.80	0.80	0.80	0.80
Lys	0.67	0.69	0.69	0.68
Meth + Ses	0.61	0.60	0.59	0.59
Sodium	0.20	0.20	0.20	0.20

[1]***Each 3 kg of Vit and Min in Premix contain***: 6000000IU Vit A, 900000 IU Vit D3 40000mg Vit E,2000mg Vit K, 2000mg Vit.B1, 4000mg Vit B2, 2000mg Vit B6, 10mg Vit B12, 50000 mg Niacin, 10000 mg pantothenic acid, 50 mg Biotin, 3000 mg Folic acid, 250000 mg choline, 50000mg Zn, 8500mg Mn, 50000mg Fe, 50000mg Cu, 200mg I , 100mg Se and 100mg Co.

[2] According to NRC (1977) for rabbit's requirements.

(EE, %) was calculated according to price marketing during 2014. Also, relative growth rate (RGR, %) and performance index (PI, %) were calculated on a group basis:

Relative growth rate, % = [(W2 - W1) x100]/ [1/2 (W2+W1)]

Whereas: W1= The initial weight, g and W2 = The final body weight,g.

Performance index, %= (Final live body weight (kg)/Feed conversion ratio) ×100

Digestibility trial was carried at the end of the study period using 20 male rabbits (5 rabbits / treatment) for 5 consecutive days to determine the digestion coefficients of nutrients, the chemical analysis of both feed and faeces was carried out according to A.O. A.C. (2005).

At the end of growing period, four rabbits were taken randomly/ treatment, fasted for 12 hrs, weighed and slaughtered to estimate some of carcass traits. Carcass parts were presented as a percent of live body weight. Meat samples were subjected to chemical analysis of moisture, crude protein, ether extract and ash (A.O.A.C., 2005).

For the detection of lipid peroxidation (LPO), the carcasses of four rabbits / group were immediately trimmed for thigh meat by removing bones and connective tissues. Subsequent, the thigh meat / group was separately sliced, over-wrapped in the transparent oxygen-permeable polyvinyl chloride film and stored at 4°C for 24 and 72 h. A second part of samples of thigh muscles was packed in the polyethylene sacks and was stored in freezer at -18°C. Ahead of LPO analysis, the frozen samples were defrost at the chilling conditions (4°C) for 12h, homogenized and analyzed immediately. Thiobarbituric acid reactive substances (TBARS) were expressed as the amount of malondialdehyde (MDA) calculated per 1g of meat sample. MDA was measured spectrophotometrically at 532 nm (Helios γ, v. 4.6, Thermo spectronic, GB) according to Marcinčák *et al.* (2006).

Immediately after slaughtering, blood samples of growing rabbits were collected from four rabbits/ each group. The samples were collected into dry clean centrifuge tubes; the serum was separated by centrifugation at 3000 r.p.m. for 20 minutes and kept in a deep freezer at -20 ^{0}C until biochemical analysis. Non-coagulated blood was tested shortly after collection for determination blood pictures including, red blood cells count (RBCs, $10^6/mm^3$), white blood cells count (WBCs, $10^3/mm^3$); different subclasses of WBC's (lymphocyte, neutrophils and monocytes percentages), hemoglobin (Hb, g/dl) concentration and hematocrite value (Ht, %) according to Drew *et al.* (2004). Total protein (TP, g/dl) and albumin (Alb, g/dl) levels were determined using commercial kits supplied by Randox (Randox Laboratories Ltd, Crumlin, Co, Antrim, UK) according to Henry *et al.* (1974). Globulin (Glb, g/dl) concentration was estimated by subtracting the values of Alb from the corresponding values of TP. Serum creatinine (CR, g/dl), urea-Nitrogen (urea-N, g/dl) and total antioxidant capacity (TAC, mmol/L) were determined by the colorimetric method with commercial kits provided by Bio-Diagonosis Co (Egypt). Serum samples were analyzed for concentrations of aspartate (AST, U/L) and alanine amino transaminases (ALT, U/L) using commercial kits (Linear Chemicals, Barcelona, Spain) according to the manufacturer

procedure. Also, the serum was assayed for total cholesterol, triglycerides and total lipids using standard protocol methods (Vogel and Vogel, 1997).

Statistical analysis:

Data were statistically analyzed according to **SAS (2000)** computer program using the following fixed model: $Y_i=\mu + T_i + e_i$

Where: Y_i = The observation; μ = Overall mean; T_i = Effect of treatments (i = 1, 2, 3 and 4); e_i= Random error component assumed to be normally distributed. Data presented as percentages were transformed to the corresponding arcsine values (Warren and Gregory, 2005) before being statistically analyzed. The differences among means were tested using Duncan's New Multiple Range Test (Duncan, 1955). All data are presented as least square means.

RESULTS AND DISCUSSION

Some growth performance traits:

Impact of different dietary levels of CO on final body weight (BW), DWG, DFI, FCR, RGR (%) and PI (%) of NZW rabbits are presented in Table 3. Values of final BW and DWG at (5-13 wks of age) were higher significantly ($P\leq0.01$) for rabbits in G_3 and G_4 than those in control group. The proportional increments were 5.9 and 9.1% for final BW and 7.9 and 10.7 % for DWG, for the two levels, respectively. These results are in agreement with Kamel and Attia (2011) who fed rabbits 1.0 and 1.5% lecithin as mixture of stearic, palmitic, lenoleic, and oleic acids. While, Shahram *et al.* (2013) showed no differences for DWG among broilers fed basal diet and basal diet plus 0.1, 0.15 and 0.2% MCFA. Also, present study showed that values of final BW and DWG in 0.5 % CO group (G_2) did not differ than that of control (G_1) group.

Concerning to the DFI and FCR, it is clear that DFI significantly increased as CO levels increased. However, the improvement in FCR was not significant due to the three levels of CO, the best FCR was recorded in G_2 by 4.5% proportional improvement compared to control (G_1). This result is in agreement with findings of Gerwe *et al.* (2009) who showed that dietary supplementation of 1% MCFA caused to increase significant in DWG without affected on FCR. In addition, these findings were confirmed upon examination of MCFA on broilers (Rahman *et al.*, 2010) who found that addition of 4% palm oil as MCFA in diet caused significant increase in FI.

As regard to RGR and PI, results indicated that there were significant differences among CO treatments. The highest values of RGR and PI (%) were observed in G_3 and G_4, without any significant differences between G_1 and G_2. Dierick *et al.* (2002) observed that the controlled release of MCFA

Table 3. Some growth performance of growing NZW rabbits from 5 to 13 wk of age as affected by different dietary levels of coconut oil.

Parameters	Treatments (coconut oil levels, %)				SEM	Sig.
	0 (G_1)	**0.5 (G_2)**	**1.0 (G_3)**	**1.5 (G_4)**		
No. of Animals	18	17	18	17	-	-
Initial body weight (g)	604.0	601.5	602.8	604.3	10.93	NS
Final body weight (g)	1913.1^{B}	1964.1^{B}	2026.8^{A}	2064.7^{A}	19.05	**
Daily weight gain (g):						
5-9 weeks	23.61^{B}	25.48^{AB}	26.49^{A}	16.11^{A}	0.720	*
9-13 weeks	23.10^{B}	23.13^{B}	24.53^{AB}	25.69^{A}	0.648	*
5-13 weeks	23.39^{B}	24.32^{B}	25.51^{A}	25.86^{A}	0.383	**
Daily feed intake (g/d):						
5-9 weeks	55.19^{C}	55.85^{BC}	57.06^{AB}	57.88^{A}	0.377	**
9-13 weeks	93.17^{C}	93.95^{C}	97.42^{B}	99.39^{A}	0.499	**
5-13 weeks	74.23^{C}	74.92^{C}	77.21^{B}	78.82^{A}	0.341	**
Feed conversion ratio (g/g):						
5-9 weeks	2.381	2.251	2.186	2.243	0.081	NS
9-13 weeks	4.093	4.185	4.002	3.908	0.126	NS
5-13 weeks	3.187	3.101	3.041	3.060	0.056	NS
Relative growth rate(%)	81.7^{B}	85.5^{AB}	88.0^{A}	86.3^{AB}	1.816	*
Performance index(%)	45.4^{B}	49.0^{AB}	51.0^{A}	51.1^{A}	2.196	*

SEM = Standard error of means, Sig.= Significance

** : Significant at 1% level of probability, * : Significant at 5% level of probability

NS: Non-significant.

A, B, C Means in the same row with different superscript are significantly different ($P \leq 0.05$).

(C6-C12) from coconut seeds oils resulted in significant suppression of the intestinal flora (Total anaerobic count, lactobacilli, *E. coli*), improved mucosal health and growth performance of piglets. On the other hand, these results are different than what has been observed by Skřivanová and Marounek (2002), who showed that caprylic acid (one of the CO constitute) added to a pelleted feed at 5 g / kg had no significant effect on the growth rate of rabbits.

The improvement in growth performance resulted from the dietary CO could be due to an increase in the efficiency of nutrients utilization; especially CP (Table 4) or antibacterial properties of MCFA (Messens *et al.*, 2010) or both. Also, Isaacs *et al.* (1995) demonstrated that antioxidant properties of CO may be affect positively the condition of the alimentary canal mainly through antimicrobial activity, which could be reflect on improvement of digestion processes. In addition, the MCFA are known to increase metabolism (Van Wymelbeke *et al*., 1998). On the other side, Hb content is a good and most useful variable for predicting growth performance among many blood parameters (Ashour *et al.*, 2004).

This theory simply explains in the present results where, the treated group recorded an increase in Hp concentration as mentioned later.

The present results showed that improvement effect of dietary CO in post-weaning rabbits can be due to MCFA, which may be useful at this time because weaning is considered a stressful event that is associated with depressed feed intake, growth performance and elevated incidence of enteric disease as reported by Rossi *et al.* (2010) in piglets.

Digestibility coefficients of nutrients:

Results reported in this study clearly indicate that dietary CO levels had some effects on the digestion kinetics in growing rabbits. Table 4 shows that rabbits received CO had high significant digestibility coefficients of all nutrients, except CF and NFE. Fekete *et al.* (1990) did not observe a significant effect on CF digestibility when MCFA was added to diets. The insignificant effect on CF digestibility may be discussed from the view point mentioned by Galindo *et al.* (2009) who showed that CO reduced the cellulolytic bacteria.

The increase of CP digestibility in treated groups can be due to the role of CO as MCFA in improvement of CP digestibility. It is well documented that MCFA do not require either bile salts for digestion or energy for absorption, utilization, or storage (Ferreira *et al.,* 2014). Consequently, the improving in the nutrients digestibility and nutritive values for treated groups may be reflected on better growth performance as shown in Table 3. On the other hand, the antioxidant properties of CO may be affect positively the condition of the alimentary canal mainly through antimicrobial activity; Isaacs *et al.,* 1995), absorption of nutrients. In the same trend, Dierick *et al.* (2002) observed that the controlled release of MCFA (C6-C12) from coconut seeds oils resulted in significant suppression of the intestinal flora (total anaerobic count, lactobacilli, E. coli) and improved mucosal health of piglets.

Some carcass characteristics and chemical meat composition:

Data in Table 5 were clearly that, dietary CO levels caused to increase values ($P<0.05$) of carcass, fore parts, trunk, hind parts and total edible parts percentages than that of the control group. However, there were insignificant differences in fore parts, trunk, hind parts, and GIT percentages of the rabbit received 0.5% CO (G_2) compared with that of the control group (G_1). Also, the results showed that the effect of dietary treatments on liver, kidney and heart% did not significant. These results are in agreement with Gaafar *et al.* (2014). On the other hand, Skřivanová *et al.* (2004) showed that carcass yield was not significantly different among control and treated rabbits with MCFA. It seems that the literature is still sparse on the effect of CO on rabbit's carcass traits.

Table 4. Digestibility coefficients and nutritive values of growing NZW rabbits as affected by different dietary levels of coconut oil.

Items	Treatments (coconut oil levels, %)				SEM	Sig.
	0 (G_1)	0.5 (G_2)	1.0 (G_3)	1.5 (G_4)		
Digestibility coefficients:						
Dry matter (DM)	65.68^{B}	67.18^{B}	69.13^{A}	69.63^{A}	0.499	**
Organic matter (OM)	67.67^{B}	68.78^{B}	70.45^{A}	70.32^{A}	0.474	**
Crude protein (CP)	73.03^{C}	74.64^{B}	76.04^{AB}	76.57^{A}	0.468	**
Crude fiber (CF)	29.63	29.93	30.51	30.61	0.336	NS
Ether extract (EE)	72.79^{B}	74.23^{B}	76.38^{A}	77.28^{A}	0.577	**
Nitrogen free extract (NFE)	56.37	55.14	54.43	53.84	0.711	NS
Gross energy (GE)	62.93^{C}	64.33^{B}	65.38^{AB}	66.05^{A}	0.399	***
Nutritive values:						
Total digestible nutrient (TDN, %)	51.65	51.34	51.34	51.13	0.402	NS
Digestible crude protein (DCP, %)	11.74^{C}	11.98^{B}	12.17^{AB}	12.24^{A}	0.081	**
Digestible energy (DE, kcal/g)	2.626^{C}	2.686^{B}	2.729^{AB}	2.757^{A}	0.017	**

SEM = Standard error of means, Sig.= Significance

** : Significant at 1% level of probability, NS: Non-significant.

$^{A, B, C}$Means in the same row the different superscript are significantly different ($P \leq 0.05$).

The increasing carcass traits for treated groups may be mainly related to the increase in growth performance and digestibility. Therefore, pre-slaughter weight is considered to be one of the most important factor affecting carcass traits in rabbits.

Concerning to chemical meat composition in Table 5, insignificant differences were found among all experimental groups including the control one for all chemical analysis of carcass meat. In literature, there is no information available on effects of CO on chemical meat composition. Generally, values of meat composition are within those obtained by Pla *et al*. (2004), who found that meat of rabbits had 70-76% moisture, 18-22% protein and 1.5-3% fat.

Some blood parameters :

Hematological indices:

With regard to the haemogram illustrated in Table 6, values of blood picture including RBCs, WBCs and Hb were significantly higher ($P \leq 0.05$ or 0.01) in growing NZW rabbits treated with CO levels than those in control group (G_1). However, these high values are still within normal ranges. Some blood hematological values (Hb, RBC, MCV, MCH and WBC) in 1.0 % group (G_3) did not differ than that of 1.5 % (G_4) group. These results suggest that

Table 5. Some carcass traits of growing NZW rabbits as affected by different dietary levels of coconut oil.

Parameters	Treatments (coconut oil levels, %)				SEM	Sig.
	0 (G_1)	0.5 (G_2)	1.0 (G_3)	1.5 (G_4)		
Carcass %	47.47^{B}	49.49^{A}	51.07^{A}	50.40^{A}	0.432	**
Fore parts %	11.48^{B}	12.23^{AB}	12.59^{A}	12.38^{A}	0.170	*
Trunk %	17.58^{B}	18.09^{AB}	18.74^{A}	18.37^{AB}	0.210	*
Hind parts %	18.41^{B}	19.17^{AB}	19.75^{A}	19.65^{A}	0.212	*
Liver %	3.10	3.16	3.18	3.26	0.119	NS
Kidney %	0.67	0.65	0.64	0.68	0.023	NS
Heart %	0.28	0.29	0.30	0.29	0.010	NS
Total edible parts(TEP)%	51.73^{B}	53.59^{A}	55.19^{A}	54.62^{A}	0.510	**
GIT %(1)	20.45^{A}	18.61^{AB}	16.36^{C}	18.08^{BC}	0.492	**
Chemical analysis of carcass meat						
Moisture %	75.54	74.44	74.65	75.00	1.11	NS
Ash %	4.11	4.01	3.98	4.02	0.43	NS
EE %	2.05	1.98	2.00	2.11	0.39	NS
CP %	18.65	18.71	19.10	18.66	0.71	NS

SEM = Standard error of means, Sig.= Significance

^{A,B,C,}Means in the same row the different superscript are significantly different ($P \leq 0.05$).
**: Significant at 1% level of probability, *: Significant at 5% level of probability, NS: Non-significant . (1) GIT: Gastrointestinal Tract

CO inclusion may enhance immune system activity through several fatty acids, which are potent as immune stimulant (Witcher *et al.*, 1996) and phenolic compounds in CO, such as caffeic acid, p-coumaric acid, ferulic acid and catechin, which improved antioxidant capacity (Kapila and Dissanayake, 2008). On the other hand, Nandakumaran *et al.* (2011) showed that no significant ($P \leq 0.05$) differences were observed in the WBCs, Hb and lymphocytes for oral administration with 4 ml / days CO in rats. In general, CO inclusion causes to increase in total RBC's, which in turn caused to increase in Hb values. This is due to the positive relationships between RBC's and Hb (Sturkie, 1986). Hemoglobin values, were increased due to dietary CO levels. This indicates the positive effects of this addition on hematological parameters and the positive impact on liver and spleen, as well as, other tissues like bone marrow, where RBCs are synthesized (Feldman *et al.*, 2000).

Table 6. Some blood hematological values of growing NZW rabbits as affected by different dietary levels of coconut oil.

Parameters	Treatments (coconut oil levels, %)				SEM	Sig.
	0 (G_1)	0.5 (G_2)	1.0 (G_3)	1.5 (G_4)		
Hemoglobin (g/ dl)	8.10^{B}	9.93^{A}	10.33^{A}	10.00^{A}	0.406	*
Haematocrit (%)	31.33^{B}	34.83^{AB}	37.67^{A}	36.00^{A}	0.601	*
RBCs (10^6/ mm^3)	3.53^{C}	4.35^{B}	5.03^{A}	4.57^{AB}	0.135	**
MCV(1) (fl)	88.33^{A}	73.00^{B}	83.00^{A}	85.00^{A}	2.887	*
MCH(2) (pg)	22.67^{A}	20.00^{B}	23.00^{A}	24.00^{A}	0.577	*
MCHC(3) (g/ l)	25.67	27.33	28.33	28.00	0.881	NS
WBCs (10^3/ mm^3)	6.83^{B}	8.77^{A}	9.93^{A}	9.67^{A}	0.456	**
Lymphocytes (%)	53.67^{BC}	55.67^{AB}	57.67^{A}	52.33^{C}	0.882	*
Neutrophils (%)	36.67^{B}	34.83^{B}	34.33^{B}	40.33^{A}	0.792	**
Monocyte (%)	6.00	6.33	7.33	5.67	0.667	NS

SEM = Standard error of means, Sig.= Significance

^{A,B,C,}Means in the same row the different superscripts are significantly different ($P \leq 0.05$).

**: Significant at 1% level of probability, *: Significant at 5% level of probability, NS: Non-significant, (1) Mean corpuscular volume, (2) Mean corpuscular hemoglobin, (3) Mean corpuscular hemoglobin concentration

Metabolic profile :

Diets containing CO levels caused to increase significant in TP, Alb and Glb compared to control group (Table 7). These increases were pronounced with the high levels of CO (G_3 and G_4) being, 21.1 and 21.5; 22.8 and 26.4; and 19.2 and 16.2%, respectively, but these increases were still within normal range as indicated by the non-sign of toxicity (Table 5). While, CO supplementation in the (G_3) group did not affect significantly the TP, Alb and Glb values compared to (G_4) group. The trends resulting from adding CO in the present study are in agreement with study involving rabbits fed lecithin as mixture of stearic, palmitic, lenoleic, and oleic acids (Kamel and Attia, 2011). In contrary to the present results, Gaafar *et al*. (2014) reported that dietary pumpkin and black seeds oils as MCFA to growing rabbit's diet did not significantly influence serum TP, Alb and Glb.

Concerning the effects of CO levels on TP and its fractions (Alb and Glb), it can be explained and interpreted the improvements in their profile in the present study especially with the high levels (G_3 and G_4). These improvements may be partially due to the increasing animal resistance to any physiological or physical stress. Furthermore, TP is a general indication of immune status (White *et al.*, 2002). Also, increased Glb concentration with CO supplementation as observed in the present study may be an indication of increased immunity in rabbits since the liver will be able to synthesize enough

Glb for immunologic action as mentioned by Sunmonu and Oloyede (2007). However, Glb level has been used as indicator of immune responses and source of antibody production. El-Kholy *et al.* (2012) stated that high Glb level signify better disease resistance and immune response. This result is in harmony with those of Witcher *et al.* (1996) who found that several fatty acids in CO are potent as immune-stimulant.

Data in Table 7 show the effect of CO treatment on CR and urea-N levels as an indicator of kidney function. The data indicated that there was non-significant difference between experimental groups and the control group (G_1) in serum CR and urea-N. In both treated and untreated rabbits, levels of CR and urea-N concentrations are within the normal range of rabbits, implying that supplementation of CO levels not cause any damaging effects on kidney. Although in rats receiving high dose of CO, relatively more saturated edible oil, treated animals were found to have significantly low urea level compared to control group in adult female rats (Nandakumaran *et al.*, 2011). Absence of significant difference in CR and urea-N in blood of control and CO treated rabbits implies that despite receiving amounts of the CO for a period of 56 days, CO did not cause any major defect in renal function in treated rabbits.

Enzymatic profile:

The effect of dietary CO levels on liver enzymes (ALT and AST) is shown in Table 7. The result showed that the concentrations of serum transaminase enzymes (AST and ALT) in treated groups decreased significantly ($P \leq 0.05$) compared to control one. El-Harairy *et al.* (2003) showed that increasing plasma total protein and their fractions (Alb and Glb) within the normal range may reflect an improve in the hepatic function. This phenomenon was observed in treated groups compared to control group. These results indicate normal liver function of rabbits received CO. On the other hand, the antimicrobial properties of CO, could be suppress the growth of most pathogenic bacteria, and this leads to optimal enzyme activity.

In liver, fatty acids from MCFAs are broken down and might be immediately used as energy. In the liver MCFAs rapidly undergo β-oxidation in the mitochondria, a process by which energy is released (Ooyama *et al.* 2009). Furthermore, binding of MCFAs to Acetyl-CoA, which enters the Krebs cycle, results in excretion of citrate into the cytoplasm, resulting in synthesis of Acetyl-CoA (outside the mitochondria), which is necessary for binding long chain fatty acids (LCFAs). The CoA part is replaced with carnitine which allows the LCFAs to enter the mitochondria. So, in contrast to MCFAs, LCFAs do not easily enter the mitochondria. Due to the fast absorption and hydrolisation of medium chain triglycerides (MCTs) they are

Table 7. Metabolic and enzymatic profiles of growing NZW rabbits as affected by different dietary levels of coconut oil.

Items	Treatments (Coconut oil levels, %)				SEM	Sig.
	0 (G_1)	0.5 (G_2)	1.0 (G_3)	1.5 (G_4)		
Total protein (g/dl)	4.88^{C}	5.24^{B}	5.91^{A}	5.93^{A}	0.26	*
Albumin (g/dl)	2.54^{C}	2.66^{B}	3.12^{A}	3.21^{A}	0.11	*
Globulin (g/dl)	2.34^{C}	2.58^{B}	2.79^{A}	2.72^{A}	0.17	*
Creatinine (g/dl)	0.91	0.90	0.90	0.93	0.09	NS
Urea-Nitrogen (g/dl)	14.13	14.33	14.21	14.34	0.31	NS
Aspartate aminotransferase (U/L)	22.21^{B}	22.32^{B}	20.11^{A}	20.41^{A}	0.66	*
Alanine aminotransferase (U/L)	14.00^{B}	14.11^{B}	13.13^{A}	13.15^{A}	0.55	*

SEM = Standard error of means, Sig.= significance

$^{A, B, C}$ Means in the same row the different superscript are significantly different ($P \leq 0.05$).

* : Significant at 5% level of probability, NS: Non-significant

quickly metabolized. As a result, energy derived from MCTs is used direct by organs and muscles, instead of being stored as fat (Ferreira *et al.* 2014).

Serum lipid profile:

The effect of diets containing CO levels on lipids profile is shown in Table 8. The rabbits from the groups receiving CO had lower total lipids, triglycerides and total cholesterol than those from the control group. This finding agrees with the results of a study conducted by Gaafar *et al.* (2014). On the other hand, these results are different from those reported by Pollisco and Carlos-Raboca (2011) who showed that no significant change was noted in terms of the total cholesterol and triglycerides in the CO group. Also, results indicated that CO at high levels (G_3 and G_4) had low values of total lipids, triglycerides and total cholesterol.

The impact of MCFA on serum lipids is more like that of a mono-unsaturated rather than saturated oil (Oguntibeju *et al.*, 2012). They added that there a several explanations: (1) CO is made up of 50% unsaturated fats and the saturated fatty acids present are palmitic (90%) and stearic (10%). Stearic acid as well as palmitic acid does not raise blood cholesterol levels in people whose blood cholesterol levels are in normal range (Hayes *et al*., 1995). (2) The vitamin E, particularly the tocotrienol present in CO can suppress the synthesis of cholesterol in the liver (Qureshi *et al*, 1991). (3) The position of the saturated and unsaturated fatty acid chains in a triglyceride backbone of the CO molecule determines whether the fat will elevate the cholesterol level in the blood (Kritchevsky, 2000). In CO, 87% of the unsaturated fatty acid chains are found in position 2 of the carbon atom of the

Table 8. Serum lipid profile of growing NZW rabbits as affected by different dietary levels of coconut oil.

Items	Treatments (coconut oil levels, %)				SEM	Sig.
	0 (G_1)	0.5 (G_2)	1.0 (G_3)	1.5 (G_4)		
Total lipids (mg/dl)	202.32^{A}	160.04^{B}	151.31^{BC}	144.24^{C}	13.10	**
Triglycerides (mg/dl)	96.36^{A}	81.66^{B}	75.22^{BC}	68.05^{C}	8.13	**
Total cholesterol (mg/dl)	101.44^{A}	88.31^{B}	71.72^{C}	55.77^{D}	7.15	**

SEM = Standard error of means, Sig.= Significance

^{A,B,C,D}Means in the same row the different superscript are significantly different ($P \leq 0.05$). **: Significant at 1% level of probability.

triglyceride backbone molecule (Ong and Goh, 2002). This could explain why CO is responsible for decreasing lipid profile. (4) It has an anticlotting effect and prevents the formation of thrombin in the blood vessels (Oguntibeju *et al.*, 2012). Ng *et al*. (1992) added that a MCFA diet increases the production of prostacyclin hormone that prevents blood-clotting or decreases the formation of blood-clotting hormone (thromboxane). Hornstra (1988) demonstrated that palm oil as MCFA has an anti-clotting effect, and is as antithrombotic as the highly unsaturated sunflower seed oil. A human study (Kooyenga *et al.,* 1997) showed that tocotrienol (from palm oil) supplementation can reduce stenosis of patients with carotid atherosclerosis.

Lipid peroxidation and antioxidant defense system:

Data presented in the Figure 1 revealed the different dietary levels of CO influences significantly the lipid peroxidation (LPO) by decreasing TBARS values. This result is in agreement with findings of Amata and Adejumo (2014).

Rabbit's thigh muscles are considered oxidative with more mitochondria and high content of myoglobin compared to glycolytic breast muscles. Oxidative muscles use fatty acids as energy substrates and have lower activities of phosphorylases than the glycolytic muscles which use glycogen as a source of energy. The low levels of lipid peroxidation in the thigh muscle for treated groups (G_3 and G_4) compared to those in G_1 confirmed the presence of low amount of fatty acids in treated groups compared to G_1. It is hypothesized that, in slaughtered animals the Fe containing haem groups of haemoglobin and myoglobin play an important role in the biochemical processes that turn the muscle into meat and thus influence the resistance of meat during its storage. The latter fact is of importance as the treated groups had significantly high concentration of Hb as compared to control group. On the hand, Ferreira *et al.* (2014) showed that energy derived from MCTs is used directly by organs and muscles, instead of

being stored as fat. Moreover, the CO supplementation into the growing rabbit's diet decreased MDA content in the leg muscle may be related to reduce the fat deposition by decreasing the activities of lipoprotein lipase and malate dehydrogenase activities or increasing the activity of hormone-sensitive lipase in the adipose tissue (Lu *et al.*, 2007). This could be explained probably due to a high bioavailability and digestibility of nutrients presented in treated groups compared to G1.

The effect of CO levels on total antioxidant capacity (TAC) was so clear, treated groups with high levels (G_3 and G_4) showed significant ($P \leq 0.05$) increase in their TAC by about 50.0 and 36.5% on averages, respectively (Figure 2). So, CO may possess a noticeable source of compounds with health protective potential and antioxidant activity. In this respect, Kapila and Dissanayake (2008) observed phenolic compounds in CO, such as caffeic, p-coumaric and ferulic acids and catechin, result in improvement of antioxidant related to health benefits.

In humans and animals, carotenoids, an important constituent of CO, play an important role in protection against photo-oxidative processes by acting as oxygen and peroxyl radical scavengers. Their synergistic action with other antioxidants makes them more potent compound. It has been suggested that different individual compounds exhibiting a variety of antioxidant activities which may provide additional protection against oxidative stress when ingested simultaneously (Esterbauer *et al*., 1991). A combination of lipophilic antioxidants present in MCFA results in an inhibition of lipid peroxidation which is significantly greater than the sum of the individual effects of other oxidative factors (Zhang *et al.*, 1995). This suggests that a cocktail of antioxidants may have more profound anti-oxidative effect due to the synergistic action more than the individual compounds (Zhang *et al.*, 1995).

The antioxidant properties of CO has been attributed to the synergistic actions of carotenoids and vitamin E in the presence of lycopene in natural food and this might provide the ultimate dietary supplement to fight disease associated with oxidative stress (Van Rooyen *et al.*, 2008).

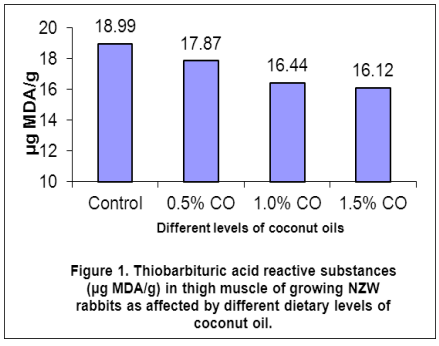

Figure 1. Thiobarbituric acid reactive substances (µg MDA/g) in thigh muscle of growing NZW rabbits as affected by different dietary levels of coconut oil.

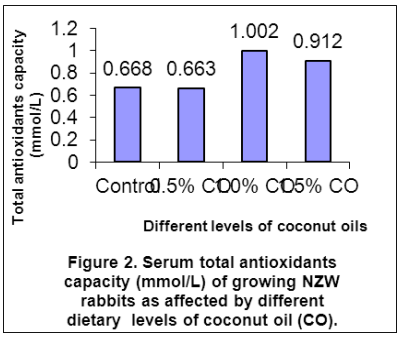

Figure 2. Serum total antioxidants capacity (mmol/L) of growing NZW rabbits as affected by different dietary levels of coconut oil (CO).

Economical evaluation :

Data concerning economical evaluation indicate an increase of net and relative revenue for rabbits treated with CO levels compared to those untreated (Table 9). The highest and pronounced increase of net revenue was observed for rabbits received 1.0% CO (G_3) being 10.4%. This result is in harmony with those of Gaafar *et al*. (2014) using dietary pumpkin and black seeds oils as MCFA to growing NZW rabbits.

Table 9. Economical traits of growing NZW rabbits as affected by different dietary levels of coconut oil at 13 weeks of age.

Parameters	Treatments (coconut oil levels, %)			
	0 (G1)	0.5 (G2)	1.0 (G3)	1.5 (G4)
Average feed intake (kg /head)	4.157	4.196	4.323	4.413
Price /kg diet (L.E.)	2.12	2.13	2.17	2.22
Total feed cost (L.E.)	8.81	8.94	9.38	9.80
Average weight gain (kg/head)	1.310	1.362	1.429	1.448
Selling price (L.E.)[1]	26.20	27.24	28.57	28.96
Net revenue (L.E.)[2]	17.39	18.30	19.19	19.16
Relative revenue (%)	100	105.2	110.4	110.2

Other conditions like management are fixed.

- Ingredients price (L.E. per ton) at 2013 were: 2500 yellow corn; 3000 barley; 1500 berseem hay; 1800 wheat bran; 3750 soybean meal (44%); 12000 coconut oil ; 250 limestone; 9000 premix; 40000 methionine; 1000 di-calcium phosphate; 1000 molasses; 250 salt; 20000 Bio-mos; 30000 Bio-plus.
- Adding 100 L.E. /ton for pelliting.

[1]Price of kg live body weight was 20 L.E.

[2]Net revenue = Selling price – Total feed cost

Conclusively, present study suggested that CO could be successfully incorporated into the diet of growing rabbits up to the level of 1.5%. However, 1.0% of CO in growing rabbit's diet improved their production performance and some physiological indices through alleviate post weaning stress with high profitability, under Egyptian environmental conditions.

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تأثير التغذية بمستويات مختلفة من زيت جوز الهند كمصدر للأحماض الدهنية المتوسطة السلسلة على الأداء الانتاجى والفسيولوجي في الأرانب النامية

خالد حسان الخولي١ـــ ميرفت نبيل ابراهيم١ـــ وائل عوض مرسى١ ـــ نهاد عبد الجليل رمضان٢ـــ وائل علي حسن علي١

١- قسم بحوث تربية الأرانب والرومي والطيور المائية.- معهد بحوث الإنتاج الحيواني، مركز البحوث الزراعية، الدقي، جيزة، مصر.

٢- قسم بحوث تغذية الدواجن - معهد بحوث الإنتاج الحيواني، مركز البحوث الزراعية، الدقي، جيزة، مصر.

أستخدم في هذه الدراسة ٨٠ أرنب نيوزيلندي أبيض عمر ٥ أسابيع بمتوسط وزن ٦٠٣±١٠,٩٣ لتقييم تأثير التغذية على زيت جوز الهند كأحد مصادر الأحماض الدهنية متوسطة السلسلة لعلائق الأرانب كإضافة غذائية على بعض معدلات الأداء الإنتاجية و الفسيولوجية في الأرانب.

استغرقت الدراسة ٥٦ يوماً، وأجريت خلال فترة النمو (من الفطام في عمر الأسبوع الخامس وحتى عمر التسويق في الأسبوع ١٣). قسمت الأرانب إلى ٤ مجموعات تجريبية متساوية لتضم كل مجموعة ٢٠ أرنب. حفظت المجموعة الأولى بدون معاملة (مجموعة المقارنة)، بينما أُضيف زيت جوز الهند لعليقة الأرانب بنسبة ٠,٥% في المجموعة الثانية وبنسبة ١% في المجموعة الثالثة وبنسبة ١,٥% في المجموعة الرابعة. أوضحت النتائج المتحصل عليها من هذه الدراسة أن قيم كل من الزيادة اليومية في وزن الجسم والوزن النهائي لأرانب النيوزيلندي البيضاء النامية كانت أعلى معنوياً (عند مستوى ٥%) في المجموعات المعاملة بزيت جوز الهند في المستويات العالية (١ و ١,٥%) مقارنة بالمجموعة الضابطة. وكانت قيم معدل المعاملات الهضمية أعلى معنوياً لكل العناصر الغذائية ما عدا الألياف وNEF في المعاملتين الثالثة والرابعة مقارنة بالمجموعة المقارنة. أدى تناول أرانب النيوزيلندي البيضاء للعليقة المضاف إليها زيت جوز الهند إلى زيادة معنوية في نسب التصافي وخصوصاً في الأجزاء الأمامية والخلفية، وأيضاً قيم صورة الدم متمثلة في كل من عدد كريات الدم الحمراء والبيضاء، وتركيز الهيموجلوبين، ونسبة الهيماتوكريت، بالإضافة إلى بعض مكونات الدم الأخرى. سجلت مستويات إنزيمين الـ ALT & AST الدالين على نشاط الكبد إنخفاضاً معنوياً كنتيجة لإضافة زيت جوز الهند لعليقة الأرانب النيوزيلندي البيضاء مقارنة بالمجموعة الضابطة.

التوصية: مما سبق فإن الدراسة أوضحت في مجملها أن إضافة زيت جوز الهند بنسبة ١% لأرانب النيوزيلاندى البيضاء النامية أعطى نتائج أفضل معنوياً في معدلات الأداء الإنتاجية والفسيولوجية مقارنة بالعليقة الخالية منه، بدون إي أثار ضارة على وظائف الكبد والكليتين كما حقق هذا المستوى أعلى كفاءة إقتصادية تحت ظروف البيئة المصرية.