

PRODUCTIVE PERFORMANCE OF GROWING RABBITS FED DIETS CONTAINING DIFFERENT LEVELS OF FENNEL (*Foeniculum vulgare L.*) SEEDS BY-PRODUCT.

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SUMMARY

The present study aimed to investigate the effect of fennel seeds by-product (FSB) at different levels in rabbit feeds. The experiment was carried out at private farm in Giza, Egypt. Thirty-six unsexed White New Zealand rabbits breed aged 5-6 weeks with average weight of 682.85±3.75g were randomly assigned into four equal groups: the first group was basal diet (R₁ control), meanwhile, the other three experimental groups were received diets containing 20, 40 and 60% of FSB for (R₂, R₃, and R₄), respectively. The feeding period was extended for 56 days. Results showed that the best apparent digestibilities of DM, OM, CP, CF, NFE digestibility were recorded with rabbits fed 40% FSB diet (R₃) in comparison with the other tested control diets. All rabbits received diets containing FSB recorded higher (P<0.05) nutritive values expressed as TDN%, serum level of HDL and mean values of HDL-C/LDL-C ratio were significant (P<0.05) increase in diets containing FSB diets compared to control, the highest significant values recorded with diet (40%FSB). However, DCP%; serum total protein; albumin and albumin: globulin ratio values were not significant differences between the experimental groups. There was significant decreased (P<0.05) for treated diets of serum (AST) and (ALT), TG, TC, LDL, TC/ HDL and VLDL-C compared to the control group. The lowest significant values recorded with diet 40% FSB. The caecal NH₃-N concentration was higher ratios of R₃ followed R₂ and finally R₄, while, the TVFA_s was significant increased in R₃ and R₄ only compared to the control. Both body weight gain and average daily gain were significantly (P<0.05) improved (by 6.24%, 26.58% and 12.66%) and (by 6.22, 26.55 and 12.64%, in groups fed diets contained 20, 40 and 60% FSB, respectively, compared to those fed the control diet. Inclusion of 40 or 60% FSB in the rabbit diets led to significant (P<0.05) differences in hot carcass weights and dressing percentages compared to the 20% or control FSB groups. Incorporation FSB in rabbit diets significantly (P<0.05) increased the dressing percentage and decreased fat % of carcass boneless compared to control group. Increasing FSB% in the tested diets decreased FSB feed consumption by rabbits compared to control. No mortality was recorded in the rabbits fed diets incorporated 40 and 60% fennel seeds by-product (R₃ and R₄ diets), while rabbits fed diets containing 0 (control) and 20% FSB (R₁ and R₂ diets) were recorded 8.3% mortality rate. The major phytochemicals of the fennel seeds by-product are the total antioxidant capacity 183.82 mg/100g (ascorbic acid equivalent), the total phenols 113.96 mg/100g (garlic acid equivalent) and total flavonoid contents 67.10 mg/100 (catechin equivalents) addition of FSB improved feed conversion ratio; total cost, total revenue, net revenue, economic efficiency, relative economic efficiency and feed cost / kg LBW. Rabbits received R₃ which content 40% FSB recorded the best total cost. It can be concluded that adding 40% fennel seeds by-product in rabbit diets improved their nutrient digestibility, nutritive values, final body weight, average daily gain, feed conversion ratio and decreased mortality rate, as well as realized the highest value of relative economic efficiency.

Keywords: *fennel seeds by-product, rabbits, growth performance, nutrient digestibility coefficients, blood parameters and caecum activity and carcass characteristics.*

INTRODUCTION

Herbs are produced by huge amount in Egypt. Fennel plant is cultivated around 2143 feddan per year (Egyptian Ministry of Agriculture, 2014). Its seed contains 2-6% volatile oil which is used in human feed

additive for flavor. Many efforts have been devoted on using the green natural materials and/or medicinal plants as feed additives to improve the efficiency of feed utilization and productive performance (Aboul-fotouh *et al.*, 1999). The production of Fennel in Egypt was about 22,000 tons according to the economic made by F.A.O. (2008). Fennel (*Foeniculum vulgare L.*) seeds contain health-promoting volatile essential oil compounds such as fenchone, anethole, myrcene, limonene, chavicol, cineole, anisic aldehyde, and pinene as well as amino acids, phenolic compounds, and flavonoids (El-Deek 2003). Fennel seed meal is a by-product of oil extraction and contains both seeds and stem. Stefanini, *et al.* (2006) found that the main compounds of essential oils from plant parts were trans-anethole in dry seeds in summer (78.25%); limonene in stems/leaves in spring (42.30%); Fenchone in green seeds in autumn (16.98%) and summer (15.08 %); methyl-chavicol in green seeds in autumn (3.57%); and to inflorescences in anthesis phase in summer α -pinene (2.24 %), γ -terpinene (1.14 %) and myrcene (1.24%). In the summer was found 1.78% β -ocimene in leaves and 44.61% of exo-fenchyl acetate in leaves and stem. Fennel seeds are rich in total carbohydrates (61.0%) and low in total soluble sugars (7.6%). The seeds are rich in Ca, P and Mg and contain considerable amounts of K, Fe and Zn and traces of Mn. The major fatty acid components of fennel seeds are 18:1 (71.31%) and 18:2 (11.66%). Also, fennel seeds are high in isoleucine and histidine (Abou-Raiia *et al.*, 1991). The analysis of ethanolic and methanolic seed extracts showed the presence of nine components including linoleic acid (56%), palmitic acid (5.6%) and 5.2% of oleic acid (Gulfraz *et al.*, 2008).

Several previous studies showed that adding medicinal plants and herbs to the diets of rabbits, chicks, sheep, cows or buffaloes improved their feed intake and nutrient digestibility (Aboul-fotouh *et al.*, 1999 and EL-Ayek, 1999) feed conversion (Aboul-fotouh *et al.*, 1999; Allam *et al.*, 1999; Salem and EL-Mahdy, 2001). In this respect, Radwan and Khalil (2002) found that feeding growing rabbit on fennel hay (a by-product, after yielding fennel grains) at levels 34 or 50% of the diet improved nutrients digestion, growth performance and dressing percentage. Furthermore, the addition of fennel straw at a rate of 0-15% of the diet showed stimulatory properties of digestion in lactating cows (Grela and Kowalczyk, 2007). Extracts of *F.vulgare* and isolated compounds have been evaluated for several activities, namely, antiaging, antiallergic, anti colitic, anti-hirsutism, anti-inflammatory, antimicrobial and antiviral, antimutagenic, antinociceptive, antipyretic, antispasmodic, antistress, antithrombotic, anxiolytic, apoptotic, cardiovascular, chemo modulatory action, cytoprotection and anti tu-mor, cytotoxicity, diuretic, estrogenic properties, expectorant, galactogenic, gastrointestinal effect, hepatoprotective, human liver cytochrome P450 3A4 inhibitory, hypoglycemic, hypolipidemic, memory-enhancing property, nootropic, and oculohypotensive activities [Albert-Puleo (1980); Oktay *et al.* (2003); Pradhan *et al.* (2008); Nassar *et al.* (2010); Rasul *et al.* (2012); Rahimi and Ardekani (2013); and Tripathi *et al.* (2013)].

The present study was designed to evaluate the inclusion of fennel seed by product on growth performance of growing rabbit and the effect of phytochemical on its growth performance.

MATERIALS AND METHODS

Animal diets and management:

Dried fennel seeds grinder mill and sieves were used to obtain a powder particle size of less than 0.2 mm. Chemical composition of fennel seed by product and alfalfa hay was shown in Table (1). The basal diet and experimental diets were formulated and pelleted to cover the nutrient requirements of rabbits according to NRC, (1977) as shown in Table (2), while chemical analysis of the experimental diets was shown in Table (3). Thirty-six unsexed New Zealand rabbits breed aged 5-6 weeks and average weight of 682.85 \pm 3.75g were randomly assigned into four groups, 9 rabbits for each group in 3 replicates. The trial was done in the summer season (the temperature about 25^oC to 36^oC for the period from April to June) throughout year (2018). The feeding period was extended for 56 days. The experiment was carried out at privet farm in Giza, Egypt. The experimental groups were classified as the following: the first group was fed the basal diet (R₁) and served as control group, meanwhile, 20, 40 and 60% of the alfalfa in the control diet was replaced by fennel seeds by-product (FSB) for groups R₂, R₃ and R₄, respectively.

Table (1): Chemical analysis of the alfalfa hay and seed funnel by product (as dry matter basis).

Ingredient	DM	OM	CP	EE	CF	NFE	ASH	DE(Mcal/kg)	NDF
alfalfa hay	90.00	92.00	15.50	2.00	25.00	49.50	8.00	2.14	45.35
funnel seed									
by product	91.19	86.76	13.79	6.90	26.74	39.33	13.24	2.08	46.49

DE (Mcal/kg) = 4.36 – 0.049 x NDF, NDF% = 28.924 + 0.657 (CF%) according to Cheeke (1987).

Table (2): Composition of the experimental diets.

Ingredient	Experimental diet			
	(R ₁) Control	(R ₂)	(R ₃)	(R ₄)
alfalfa hay	27.00	21.60	16.20	10.80
Fennel seeds by-product	0.00	5.40	10.80	16.20
Wheat bran	27.00	27.00	27.00	27.00
Yellow corn grain	19.90	19.90	19.90	19.90
Soybean meal (44%)	19.40	19.40	19.40	19.40
Corn Gluten Meal	3.00	3.00	3.00	3.00
Calcium phosphate, dibasic	1.50	1.50	1.50	1.50
Sugar Cane Molasses	1.00	1.00	1.00	1.00
Salt	0.30	0.30	0.30	0.30
Limestone	0.15	0.15	0.15	0.15
Methionine	0.30	0.30	0.30	0.30
L-Lysine HCL 98%	0.15	0.15	0.15	0.15
Premix (Vit. & Min. mixture)	0.30	0.30	0.30	0.30
Total	100	100	100	100

R₁: Control diet. R₂: contained 20% from fennel seeds by-product. R₃: contained 40% from fennel seeds by-product. R₄: contained 60% from fennel seeds by-product. * Vit. & Min. mixture: Each kilogram of Vit. & Min. mixture contains: 2000.000 IU Vit. A, 150.000 IU Vita. D, 8.33 g Vit. E, 0.33 g Vit. K, 0.33 g Vit. B1, 1.0 g Vit. B2, 0.33g Vit. B6, 8.33 g Vit.B5, 1.7 mg Vit. B12, 3.33 g Pantothenic acid, 33 mg Biotin, 0.83g Folic acid, 200 g Choline chloride, 11.7 g Zn, 12.5 g Fe, 16.6 mg Se, 16.6 mg Co, 66.7 g Mg and 5 g M.

Table (3): Chemical analysis of the experimental diets.

Item	Experimental diet			
	(R ₁) Control	(R ₂)	(R ₃)	(R ₄)
Dry matter (DM)	96.16	96.82	96.61	96.61
Chemical analysis % (DM basis):				
Organic matter (OM)	94.39	94.28	94.18	94.07
Crude protein (CP)	20.52	20.43	20.34	20.24
Crude fiber (CF)	11.65	11.75	11.84	11.94
Ether extract (EE)	2.73	2.30	3.26	3.52
Nitrogen-free extract (NFE)	59.49	59.80	58.74	58.37
Ash	5.61	5.72	5.82	5.93
Digestible energy (Kcal/kg DM)	3045	3009	3010	2990

R₁: Control diet. R₂: contained 20% from fennel seeds by-product. R₃: contained 40% from fennel seeds by-product. R₄: contained 60% from fennel seeds by-product. Digestible energy (Kcal/kg DM) was calculated according to Fekete and Gippert (1986) using the following equation: DE (kcal/ kg DM) = 4253 – 32.6 (CF %) – 144.4 (total ash).

Each three rabbits were housed together in galvanized wire cages (30 x 35 x 40 cm). Stainless steel nipples for drinking and feeders allowing recording individual feed intake for each rabbit were supplied for each cage (*ad libitum*). Rabbits of all groups were kept under the same managerial conditions. Chemical analysis of diet samples and feces were analyzed according to AOAC (2005).

Digestibility trials:

At the end of the experimental period, four rabbits per group were used in digestibility trials over period of 7 days to determine the nutrient digestibility and nutritive values of the tested diets. Feed intake of experimental diets and weight of feces were daily recorded. Representative samples of feces were dried at 60°C for 27 hrs. and stored for later chemical analysis.

Slaughter trials:

At the end of the feeding period (56 days) all rabbits were fasted for 12 hours before slaughtering according to Blasco *et al.* (1993). Edible offal's (giblets) includes (heart, liver, testes and kidneys) were removed and individually weighed. Full and empty weights of digestive tract were recorded, and digestive tract contents were calculated by differences between full and empty digestive tract. Weights of carcass, giblets and external offal's were calculated as percentages of body weight at slaughtering (SW). Dressing percentages were calculated as carcass weight/ slaughter weight * 100. Physical composition (lean, bone and fat) were calculated as percentages of ribs weight (RW). Boneless samples of carcasses were frozen in polyethylene bags for later chemical analysis. Live body weight of rabbits and feed consumption were weekly recorded and feed conversion ratio was calculated.

Blood serum samples:

The blood samples were collected during slaughtering from 4 rabbits per group into labeled sterile sample bottles without anticoagulant. The blood samples were centrifuged at 3000 rpm for 15 min. and serum was kept frozen at (-18°C) for subsequent analysis. Various blood serum chemical parameters were calorimetrically determined using commercial kits, following the same steps as described by manufactures. Blood serum was analyzed for total protein (Armstrong and Carr, 1964); albumin (Doumas *et al.*, 1971). Globulin (was calculated by subtracting the albumin value from total protein value). Serum Glutamic Oxaloacetic Transaminase (AST) and Glutamic Pyruvic Transaminase (ALT) activities (Reitman and Frankel 1957), alkaline phosphatase (Belfield and Goldberg, 1971), total cholesterol (Roeschlau *et al.*, 1974) and Creatinine by (Bartles, 1972). Low density lipoprotein cholesterol concentration Friedwald *et al.* (1972). Then ratio of high density lipoprotein cholesterol to low density lipoprotein cholesterol (HDL/LDL) was measured. Very low density lipoprotein cholesterol (VLDL-C) was calculated using the following equation: $VLDL-c (mg/dL) = TG/5$

Caecal activity:

After slaughtering, caecum was taken for all slaughtered rabbits and caecum *pH* was immediately determined using digital *pH* meter, ammonia nitrogen (NH₃-N mg/100gm) according to Conway (1958) and Total volatile fatty acids (TVFA's MEq/100gm) concentrations of caecum content according to Eadie (1967).

Determination of total phenolics total antioxidant capacity and total flavonoids assay in fennel seeds by-product:

Fennel seed by product was analyzed for the total phenolic contents of dry herbs were determined by using the Folin-Ciocalteu assay by (Marinova *et al.*, 2005), The antioxidant activity of the plant extracts was evaluated by the phosphomolybdenum method of Prieto *et al.* (1999). Total flavonoid contents were measured by aluminum chloride colorimetric assay (Marinova *et al.*, 2005).

The major constituents in seed fennel by product essential oil:

The major constituents in seed fennel by-product essential oil determined by Gas chromatography/mass spectrometry analysis. GC-MS analyses of the essential oils were performed using an Agilent Technologies (Little Falls, CA, USA) 6890 N Network gas chromatographic (GC) system.

Statistical analysis:

The experimental data was set in a completely randomized design. Analyzes of variance has done by using the general liner model procedure Proc. GLM (SAS, 2002). Differences among means were determined using Duncan's test (Duncan, 1955).

RESULTS AND DISCUSSION

Digestibility coefficients and nutritive values:

Results of Table (4) showed that the best apparent digestibility's of DM, OM, CP, CF and NFE digestibility were recorded with rabbits fed 40% FSB diets in comparison with the other experimental and the control diets. The increased values of CP, CF, EE and NFE digestibility were significantly ($P<0.05$) higher by 5.50, 34.07, 8.89 and 11.98%, respectively, compared to the control group. These results are in harmony with the findings of Radwan and Khalil (2002) who found that digestion coefficient values of CF and EE were significantly improved by including fennel hay meal at levels of 34 or 50% in rabbit diets. They also, noted that OM, CP and NFE digestibilities were insignificantly difference between groups. The enhancement in all digestion coefficient and nutritive values may be attributed to promoting the growth of useful bacteria in the gut (Viveros *et al.*, 1993 and Kholif *et al.*, 2005). El-Deek *et al.* (2003) indicated that fennel stimulates the flow of digestive juice in the stomach and intestine and increase the efficiency of broken fats to fatty acids. They also noted that the anethole (active component in fennel seeds) affected pathogen microorganisms in digestive system and increased live body weight and improved feed conversion ratio.

On the contrary, Walaa *et al.* (2019) reported that, the control group recorded higher digestibility coefficients of CP, CF, EE and NFE without significant differences to groups of growing rabbits which fed diets containing fennel seed meal (FSM) at levels of 20 and 40%.

Table (4): Digestion coefficients and nutritive values (%) of the diets

Item	Experimental diet				
	(R ₁) Control	(R ₂)	(R ₃)	(R ₄)	± SE
Digestion coefficients:					
Dry matter (DMD)	74.20 ^c	77.49 ^b	81.19 ^a	78.48 ^b	1.14*
Organic matter (OMD)	78.45 ^c	81.34 ^b	85.99 ^a	88.12 ^a	2.67*
Crude protein (CPD)	65.93 ^b	67.37 ^a	69.56 ^a	68.17 ^a	3.43*
Crude fiber (CFD)	45.46 ^c	57.07 ^{ab}	60.95 ^a	62.01 ^a	2.87*
Ether extract (EED)	70.88 ^b	77.09 ^a	77.18 ^a	76.35 ^a	3.57*
Nitrogen-free extract (NFED)	64.51 ^c	68.64 ^b	72.24 ^a	68.71 ^b	3.01*
Nutritive value:					
Total digestible nutrient (TDN%)	59.29 ^c	63.78 ^{ab}	66.68 ^a	64.47 ^{ab}	2.92*
Digestible crude protein (DCP%)	12.36	12.60	12.99	12.71	1.82 NS

a, b and c: Means in the same row having different superscripts differ significantly ($P<0.05$). SE standard error of the mean. R₁: Control diet. R₂: contained 20% from fennel seeds by-product. R₃: contained 40% from fennel seeds by-product. R₄: contained 60% from fennel seeds by-product.

Rahimi *et al.* (2011) revealed that, beneficial effects of medicinal plants or active substances in animal nutrition may include the improvement of endogenous digestive enzyme secretion, stimulation of appetite and therefore increase feed consumption, activation of immune response and antibacterial, antiviral, antioxidant actions which may affect the physiological and chemical function of the digestive tract.

Nutritive values expressed as TDN% are shown in Table (4). Rabbits received diet containing fennel seeds by-product recorded the higher ($P<0.05$) nutritive values compared with the control group, the observed superiority with diet containing 20, 40 and 60% FSB increased by 7.58, 12.46% and 8.74%, respectively. However, nutritive value as DCP% were insignificantly higher in FSB groups than control. Walaa *et al.* (2019) reported that nutritive values as DCP and TDN of rabbits fed fennel seed meal were significantly ($P<0.05$) values of fed fennel seed meal compared of control group. Moreover, the higher nutritive values for FSB diets could be contain some active components stimulating the active enzymatic digestible, anethole and estrgole have digestive stimulating and appetizing effects (Cabuk *et al.*, 2003). Bown (2001) reported that fennel has been used in connection with the following conditions: appetite increase, up sed stomach and gastric juice production which relieves nausea and helpful for colic pain. Fennel is helpful for belching gas bloating, gastrointestinal cramps and sluggish digestion, because it has antispasmodic, antifungal properties and helps prevent

fermentation and gas in the stomach and bowels found that fennel has promoted iron absorption in rats and helps to improve the appetite.

Blood serum constituents:

Result of blood serum parameters in (Table 5) cleared that the diets containing fennel seed by-products had no significant effect ($P>0.05$) on blood serum total protein; albumin and albumin: globulin ratio. Whereas there was significant decrease ($P<0.05$) among values aspartate aminotransferase (AST) and alanine aminotransferase (ALT) compared to control. Rabbits fed diet (R4) recorded lowest significant ($P<0.05$) values of AST and ALT. The present results reveal that feeding rabbits with different levels of fennel seeds produce significant ($P<0.05$) decrease in serum AST and ALT levels and improved liver functions compared to the control. This effect may be related to antioxidant properties of fennel. These results are accordance with findings by Walaa *et al.* (2019) and Rezq (2012) who fed rabbits diets containing fennel meal with 20% and 40% FSM instead of clover hay. They found the serum total protein, albumin and creatinine values did not significantly differ between groups. However, values of serum globulin, AST, ALT, while total cholesterol were significantly decreased. Analyses of blood AST and ALT are very useful to get insight in the metabolic and health status of animals Ozbek *et al.* (2003). Fennel contains several types of phenolic and flavonoids that is known as antioxidants and had strong free radical scavenging. It is of the most effective antioxidants in the food industry (Choi and Hwang 2004). Chemical composition of fennel demonstrated the presence of anethole as the most potent antioxidant (DE Martino 2009). Also, Table (5) showed that the three groups that fed diets containing FSB recorded significantly ($P<0.05$) lower values of TG; TC; LDL; TC/ HDL and VLDL-C compared to control, the lowest values were recorded with diet (R4). Moreover, serum level of HDL and mean values of HDL-C/LDL-C ratio were significant ($P<0.05$) increase than control. Eleni and Bairaktari (2005) demonstrated that flavonoids and anthocyanins, a heterogeneous group of polyphenols, have exhibited variety of pharmacological activities, including the antiatherogenesis effect. Anethole (t-anethole) that is the main compound in all fennel volatile oils possesses significant antioxidant activity. The presence of t-anethole and flavonoids content in fennel may be associated with lowering TC, TG and LDL-c levels. Flavonoids are reported to increase HDL-C concentration and decrease in LDL and VLDL levels in hypercholesteremic rats (Patel *et.al.* 2009).

Table (5): Blood serum constituents of the experimental diets.

Item	Experimental diet				± SE
	(R ₁) Control	(R ₂)	(R ₃)	(R ₄)	
Total protein (g/dl)	6.27	6.29	6.49	6.31	0.70 NS
Albumin (g/dl)	3.87	3.9	3.98	3.915	0.12 NS
Globulin (g/dl)	2.40	2.39	2.51	2.395	0.25 NS
Albumin: Globulin ratio	1.66	1.63	1.56	1.62	0.31 NS
Creatinine (mg/dl)	2.07	1.78	1.69	1.75	0.65*
AST (U/ml)	31.50 ^a	28.50 ^b	25.00 ^c	27.50 ^b	1.05 *
ALT (U/ml)	35.00 ^a	34.00 ^a	32.50 ^c	34.00 ^b	1.52 *
Total Triglyceride (mg/ dl)	78.00 ^a	71.00 ^b	48.00 ^c	45.00 ^d	2.43*
Total cholesterol (mg/ dl)	88.00 ^a	87.00 ^a	81.00 ^b	76.00 ^c	3.70 *
HDL	31.07 ^c	45.89 ^a	41.74 ^b	40.19 ^b	2.24*
LDL	41.34 ^a	26.92 ^b	26.99 ^b	26.12 ^b	1.12*
HDL/LDL (mg/ dl)	0.75 ^c	1.70 ^a	1.55 ^b	1.54 ^b	0.03*
TC/HDL (mg/ dl)	2.83 ^a	1.90 ^b	1.94 ^b	1.89 ^b	0.85*
VLDL-C (mg/ dl)	15.60 ^a	14.20 ^b	9.60 ^c	9.00 ^c	1.86*

a, b and c: Means in the same row having different superscripts differ significantly ($P<0.05$).

AST: Glutamic Oxaloacetic Transaminase, ALTT: Glutamic Pyruvic Transaminase. R₁: Control diet. R₂: contained 20% from fennel seeds by-product. R₃: contained 40% from fennel seeds by-product. R₄: contained 60% from fennel seeds by-product. VLDL-c (mg/dL) = TG/5 values were calculated according to Friedewald *et al.* (1972).

Caecal activity:

The caecal pH, ammonia-N and TVF's concentrations were significantly ($P<0.05$) affected by the level of incorporation of FSB in the diets (Table 6). The pH meter not affected in different levels FSB, $\text{NH}_3\text{-N}$ concentration was higher ratios of R3 (FSB 40%) followed R2 (FSB 20%) and finally R4 (FSB 60%), while, the TVFA,s was significant increase in R3 and R4 compared to the control except R2 was decreased in TVFA,s compared to control. Abd-El-Hady (2014) noticed that the caecal activity of TVFA,s (MEq/100gm) was increased significantly when added 300 and 400 gm. Digestarom 7.20 and 7.27 (MEq/100gm) compared with control 5.17, NH_3N (mg/100gm) increased from 17 to 19.10 and 18.53 but pH not affected.

Table (6): Caecum parameters of the experimental diets.

Item	Experimental diet				± SE
	(R ₁) Control	(R ₂)	(R ₃)	(R ₄)	
pH	7.75	6.15	6.08	7.34	0.03 *
Ammonia-nitrogen ($\text{NH}_3\text{-N}$ mg/100gm)	20.57 ^c	25.04 ^b	29.05 ^a	21.95 ^c	1.47*
Total volatile fatty acids (TVFA's MEq/100 g)	8.47 ^b	7.57 ^b	9.59 ^a	9.44 ^a	0.76 *

a, b and c: Means in the same row having different superscripts differ significantly ($P<0.05$).

R₁: Control diet. R₂: contained 20% from fennel seeds by-product. R₃: contained 40% from fennel seeds by-product. R₄: contained 60% from fennel seeds by-product.

Productive performance.

Data of Table (7) showed that, dietary feeds containing different levels of FSB significantly ($P<0.05$) improved final weight, body weight gain and average daily gain.

Table (7): Growth performance of the experimental diets.

Item	Experimental diets				± SE
	(R ₁) Control	(R ₂)	(R ₃)	(R ₄)	
No. of animals	9	9	9	9	
Initial weight (g)	680.08	681.92	680.43	688.87	3.82 NS
Final weight (FW, g)	1858.67 ^c	1934.61 ^b	2172.35 ^a	2016.67 ^{ab}	12.37*
Total body weight gain (TBWG, g)	1178.59 ^c	1252.08 ^{bc}	1491.92 ^a	1327.80 ^b	11.45*
Experimental duration	56 days				
Average daily gain (ADG, g/day)	21.05 ^c	22.36 ^{bc}	26.64 ^a	23.71 ^b	1.40*
Feed intake as:					
Dry matter (DMI), g	97.42 ^a	95.64 ^b	90.21 ^{ab}	92.22 ^b	2.98*
Total digestible nutrient (TDNI), g	57.76	60.99	60.15	59.45	2.04
Crude protein (CPI), g	18.26	17.89	16.85	17.20	1.08
Digestible crude protein (DCPI), g	12.04	12.05	11.71	11.72	0.74
Digestible energy (DE), kcal	297.31	291.42	273.52	278.43	3.65
Feed conversion ratio (g intake /g gain) as:					
Dry matter (DM)	4.63 ^a	4.28 ^b	3.38 ^b	3.89 ^b	0.23*
Total digestible nutrient (TDN)	2.74 ^a	2.73 ^b	2.26 ^b	2.51 ^b	0.21*
Crude protein (CP)	0.87 ^a	0.80 ^b	0.63 ^b	0.73 ^b	0.06*
Digestible crude protein (DCP)	0.57 ^a	0.54 ^b	0.44 ^b	0.49 ^b	0.04*
Digestible energy (DE), kcal / g. gain	14.12 ^a	13.03 ^b	10.27 ^b	11.74 ^b	3.49*
Mortality rate%	8.30	8.30	0	0	---

a, b and c: Means in the same row having different superscripts differ significantly ($P<0.05$).

R₁: Control diet. R₂: contained 20% from fennel seeds by-product. R₃: contained 40% from fennel seeds by-product. R₄: contained 60% from fennel seeds by-product.

Final weight was improved by 4.09, 16.88 and 8.50%, for rabbits fed diets containing 20, 40 and 60% fennel seeds by-products compared to control group, meanwhile, body weight gain was significantly ($P<0.05$) improved by 6.24%, 26.58% and 12.66% and average daily gain by 6.22, 26.55 and 12.64% for R2, R3 and R4, respectively compared to the control (R1). Rabbits received R3 that contained 40% FSB recorded the best final weight, body weight gain and average daily gain. These results are in agreement with those obtained by Krieg *et al.*, (2009) who reported that, weight gain and feed intake of the growing rabbits fed diets containing medicinal herbs mixture of 300 mg (included fennel) was 18 and 14% higher, respectively, than those fed control diet. Mohamed and Abbas (2009) observed a higher of BW gain of broiler chickens by 6% when adding 1 g/kg of fennel. Radwan and Khalil (2002) evaluated of fennel hay in growing rabbit diets at level of 34 or 50% and they showed an improvement in growth performance compared with control group. Acimovic *et al.*, (2016) found that the different levels of fennel seeds (0.25, 0.50 and 0.75 g/kg) on growing Japanese quail were significantly increased live body weight gain of quail chicks. Diet containing 0.50 g/kg fennel seed recorded the best values of feed conversion ratio and economic efficacy among the experimental treatments.

Results of Table (7) also showed that dry matter feed intake was numerically insignificantly decreased in diets supplemented with 40 and 60% FSB compared to the control diets by 1.83, 7.40 and 5.34% for R2, R3 and R4, respectively. Feed conversion ratio expressed as (g intake /g gain) showed that were significant decreased for FSB diets compared with control diet. The lowest value of feed conversion was recorded with R3, these may be attributed to be the decrease of dry matter Intak and the increase of ADG. In this study, rabbits fed diet containing 40% fennel seeds by-product improved FCR by almost 27%. In this respect, Halle *et al.* (2004) noted that the addition of oregano and its essential oil reduced daily feed intake of broilers and significantly improved feed conversion ratio (FCR). Mohammed and Abbas (2009) reported that, broiler chickens containing fennel seeds at the dose of 2 and 3 g/kg improved FCR by almost 16%. Walaa *et al.* (2019) mentioned that, the groups of 20% FSM with enzyme, control and 40%FSM with enzyme recorded better values of FCR without significant differences. In the contrary, Krieg *et al.* (2009) reported that no differences in the feed conversion feed conversion between treatments of the growing rabbits fed diets containing medicinal herbs mixture of 300 mg (included fennel).

Mortality rate

Data presented in Table (7) showed that no mortality were recorded in the rabbits fed diets incorporated with 40 and 60% fennel seeds by-product, while rabbits fed diets containing 0 (control) and 20% fennel seeds by-product recorded 8.3% mortality rate. Diarrhoea in rabbits occurs mainly within the first three weeks post weaning causing a mortality rate up to 50% (Gidenne and Garcia, 2006). It is also reported that using phytogetic flavors reduced mortality due to optimization of immune system (Fortun and Boullier, 2007). Expectorant activity fennel stimulates the ciliary motility of the respiratory apparatus and enhance the external transport of extraneous corpuscles. This action suggests a use for fennel in treating bronchial and bronchopulmonary afflictions and in particularly polluted environments (Mueller-Limmroth and Froehlich, 1980). The volatile oil of fennel stimulates the contraction of the smooth muscles of the trachea, an action that could facilitate the expectoration of mucus, bacteria, and other corpuscles extraneous to the respiratory tracts (Reiteran and Brandt, 1985).

Carcass traits

Results of Table (8) showed that inclusion of FSB significant ($P<0.05$) increased in hot carcass weights and edible offal's compared to control. The highest ($P<0.05$) dressing percentage was recorded for R4 (60% FSB) whereas the lowest was recorded for R2(20%FSB) Radwan and Khalil (2002) found that dressing percentage of rabbits fed fennel hay meal at levels 34 or 50% was improved with increasing fennel hay meal level without holding significant differences in liver and heart percentages. On the contrary, Walaa *et al.* (2019) reported that, there were significantly decreased in values of carcass and dressing percentages with 40% fennel seed meal without enzyme compared with control group. Carcass weight that includes edible offal's (Liver, heart, kidneys and testes) was improved by 1.02, 17.19 and 18.06% for (R2, R3 and R4), respectively in comparison with the control (R1). This improvement in relative weights of hot carcass, dressing and liver as a result to the reduction in the alimentary tract percentage may be due to that addition of essential oils of medicinal herbs of fennel increased digestibility coefficient of nutrients and maintaining the acidic condition in the hindgut which is optimal for better feed utilization. In the contrary, Mohammed and Abbas (2009) denoted that, addition of 1, 2 and 3 g/ kg fennel seeds to the broiler did not significant effect on all carcass characteristics.

Chemical analysis of carcass boneless was significantly ($P<0.05$) affected by incorporated FSB in rabbit diets (Table 8). The crude protein was significant ($P<0.05$) increased in groups fed diets

containing FSB compared to those fed the control diet. On the other hand, ether extract values of 20% FSB containing diets were significant ($P < 0.05$) decreased compared to 40 and 60% FSB containing diets, while, ash contents recorded non-significant different among the experimental groups.

Data in Table (8) showed that incorporation of FSB in rabbit diets significantly ($P < 0.05$) increased of crude protein % of rib compared to control. The best value was recorded with R3 (40% FSB). On the other hand, fat% were significantly ($P < 0.05$) decreased compared to control group without R2 (20%FSB), the lowest fat% was recorded with R3 (40%) but the ash was non-significant decrease. These results agree with those of Omer *et al.* (2013). The decrease of fat of rib% of FSB may be associated with activities of antioxidant enzymes; the main compound in fennel is *t-anethole and flavonoids* (Table 9).

Table (8): caraccas traits of the experimental diets.

Item	Experimental diet				± SE
	(R ₁) Control	(R ₂)	(R ₃)	(R ₄)	
Slaughter weight (SW), g	1858.24 ^d	1949.12 ^c	2172.08 ^a	2016.65 ^b	10.03*
Empty body weight (EBW), g	1599.57 ^c	1618.33 ^c	1883.67 ^a	1692.67 ^c	9.21*
(Giblets) Edible offal's, g	97.36 ^c	105.33 ^b	124.67 ^a	115.78 ^a	4.54*
Hot carcass weight (CW), g	1192.33 ^c	1204.52 ^b	1397.34 ^a	1407.67 ^a	8.54*
Dressing percentage (DP)%	64.16 ^b	61.80 ^c	64.33 ^b	69.80 ^a	4.15*
Dressing percentage (DP)%*	68.74 ^b	65.35 ^b	67.56 ^b	74.68 ^a	2.16*
Dressing percentage (DP)%**	74.53 ^b	71.61 ^c	74.18 ^b	83.16 ^a	2.87*
Chemical composition (DM%) of caraccas boneless					
Ether extract (EE)	24.30 ^a	23.05 ^a	20.20 ^b	21.54 ^b	1.12*
Ash	2.22	2.07	2.76	2.31	0.60 NS
Crude protein (CP)	72.48 ^b	77.04 ^a	77.04 ^a	76.15 ^a	2.74*
Chemical composition of the 9 th , 10 th and 11 th ribs of the experimental groups					
Ether extract (EE)	26.02 ^a	25.25 ^a	22.60 ^c	23.15 ^b	1.45
Ash	2.19	2.02	2.00	2.07	0.14 NS
Crude protein (CP)	71.81 ^b	72.72 ^b	75.40 ^a	74.76 ^a	3.04*

a and b: Mean in the same row having different superscripts differ significantly ($P < 0.05$).

*R₁: Control diet. R₂: contained 20% from fennel seeds by-product. R₃: contained 40% from fennel seeds by-product. R₄: contained 60% from fennel seeds by-product. EBW: Empty body weight = Slaughter weight – digestive tract content. CW: Carcass weight + head + edible offal's include (Liver, heart, kidneys, testes, lungs and spleen). DP%: Dressing percentages calculated as $(CW / SW * 100)$; DP%* calculated as $(CW / EBW * 100)$; DP%** calculated as $(CW + \text{edible offal's} / EBW * 100)$.*

Phytochemicals of the fennel seed by product

Phytochemicals of the fennel seed by-product are shown in Table (9). The major constituents of fennel seed by product are the total antioxidant capacity (183.82 mg/100g ascorbic acid equivalent), the total phenols (113.96 mg/100g garlic acid equivalent) and total flavonoid contents (67.10 mg/100gm catechin equivalents). These values nearest with those obtained by Valentina *et al.* (2013). The antioxidant capacity, phenolic compounds exhibit a wide range of biological activities, including anti-carcinogenic, anti-inflammatory, anti-viral, anti-allergic, estrogenic, immunostimulating agents, antiallergenic, anti-atherogenic, anti-microbial, antithrombotic, antistress, antihyperglycemia, cardioprotective and vasodilatory effects. It is well known that plant phenolics, in general are the highly effective free radical scavenging and antioxidants (Tawaha *et al.*, 2007). These flavonoids exhibit remarkable antinociceptive and anti-inflammatory activity (Nassar *et al.* 2010). Further, quercetin, rutin, and isoquercitrin were reported to have the immunomodulatory activities (Cherng *et al.*, 2008). Fennel inhibits the oxidative stress induced by cyclophosphamide (Tripathi *et al.* 2013). Fennel has been reported to contain hydroxyl cinnamic acid derivatives, flavonoid glycosides, and flavonoid aglycones (Parejo *et al.* (2004). The total phenolic compounds in fennel methanol extract were higher than the flavonoid compounds (Roby *et al.*, 2013). The total phenolic and flavonoid contents of wild fennel (2.4% and 1.2% respectively) were less as compared to cultivated fennel (3.1% and 1.6%, resp.) Ghanem *et al.* (2012).

Table (9): phytochemicals evaluation of the Fennel seed by product

Phytochemical	Equivalent	Fennel seed by product
Total antioxidant capacity	mg/100g (ascorbic acid equivalent)	183.82
Total phenolic content	mg/100gm(gallic acid equivalents)	113.96
Total flavonoid contents	mg/100gm (catechin equivalents)	67.10

The major essential oils in seed fennel by product

The major constituents in fennel essential oils are shown in Table (10). The components determined by GC and GC/MS from fennel by product oil, representing Trans-Anethole (67.53g/100g), fenchone (4.98g/100g), followed by estragole (9.79g/100g) the limonene (4.58g/100mg). These results are agreement with those of Diao *et al.* (2014). Essential oil of *F.vulgare* showed appreciable antifungal activity against strains of pathogenic fungi, namely, *Aspergillus niger*, *Fusarium solani*, and *Rhizopus solani* (Anwar *et al.* 2009). Also, Martins *et al.* (2012) showed that the essential oils of fennel showed significant antifungal activity against the food spoilage fungi *Aspergillus niger* and *Fusarium oxysporum* and may have important applications as food additives.

Table (10): The major essential oils in seed fennel by product.

Compounds Content	(g/100g)
trans-Anethole	67.8
Fenchone	4.98
Estragole	9.79
Limonin	4.58

Economical Evaluation:

The economic efficiency of the experimental diets is shown in Table (11). The cost of one kg feed, (LE) was decreased by inclusion fennel seeds by-product in the diets (R2 to R4) compared to control diet (R1). Also, increasing FSB% in the tested diets decreased FSB feed consumption by rabbits compared to control. In addition, the marketing weight was increased by added FSB in diets.

Table (11): Economical evaluation of the experimental diets

Item	Experimental diets			
	(R ₁) Control	(R ₂)	(R ₃)	(R ₄)
Marketing weight, Kg	1.86	1.93	2.17	2.02
Feed consumed (kg) / rabbit	5.46	5.36	4.94	5.16
Cost of one kg feed, (LE) ¹	5.50	5.49	5.48	5.48
Total feed cost, (LE)	30.01	29.40	27.68	28.30
Price of buying one rabbit, LE	10	10	10	10
Management/ Rabbit, (LE) ²	5.00	5.00	5.00	5.00
Total cost, (LE) ³	45.01	44.40	42.68	43.30
Total revenue, (LE) ⁴	74.35	77.36	85.88	80.64
Net revenue	29.34	33.23	43.20	37.34
Economic efficiency ⁵	0.65	0.75	1.01	0.86
Relative economic efficiency ⁶	100.00	115.38	155.38	132.31

R₁: Control diet. R₂: contained 20% from fennel seeds by-product. R₃: contained 40% from fennel seeds by-product.

R₄: contained 60% from fennel seeds by-product. * Based on prices of year 2018. 1: Include medication, vaccines, sanitation and workers. 2: include the feed cost of experimental rabbit which was LE 25/ rabbit + management. 3: Body weight x price of one kg at selling which was LE 40. 4: net revenue per unit of total cost. 5: Assuming that the relative economic efficiency of control diet equal 100. 6: Feed cost/kg LBW = feed intake * price of kg / Live weight

Diet of FSB improved total cost, total revenue, net revenue, economic efficiency, relative economic efficiency and feed cost / kg LBW. Rabbits received R3(40% FSB) recorded the best total cost, total revenue, net revenue, economic efficiency, relative economic efficiency and feed cost /Kg LBW (LE). In this respect. The present works are in good agreement with those of Radwan and Khalil (2002) who found that economic efficiency values were increased by increasing fennel hay meal levels in rabbit diets. Acimovic *et al.*, (2016) used different levels of fennel seeds (0.25, 0.50 and 0.75 g/kg) on growing Japanese quail, they concluded that feed diet containing 0.50 g/kg fennel seed recorded the best values of net return as well as the highest value of economic efficacy among the experimental treatments.

CONCLUSION

Based on the results of the present study, using fennel seeds by-product (FSP) at level of 40% in diets of growing rabbit improved their digestibility and increased performance, feed conversion and decreased mortality rate as well as realized higher values of relative economic efficiency. This implies that FSP (especially at level of 40 %) may be beneficial as a suitable natural growth promoter in feeding rabbits.

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الكفاءة الإنتاجية للارانب المغذاة على علائق تحتوي على مستويات مختلفة من المنتج الثانوي لبذور الشممر
(*Foeniculum vulgare L.*)

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الهدف من هذه الدراسة هو بحث تأثير إدراج المنتج الثانوي لبذور الشممر (FSB) بمستويات مختلفة في غذاء الأرانب. أجريت التجربة في مزرعة خاصة بالجيزة ، مصر. تم تعيين ستة وثلاثين من الأرانب النيوزلاندى البيضاء الخليطة التي تتراوح أعمارهم بين 5-6 أسابيع بمتوسط وزن 3.75 ± 682.85 جم في أربع مجموعات متساوية، تم إطعام المجموعة الأولى من النظام الغذائي الأساسي (R1 Control)، وفي الوقت نفسه، كانت المجموعات التجريبية الثلاث الأخرى تلقى وجبات تحتوي على 20 و 40 و 60 % من FSB (R2 و R3 و R4) على التوالي. استغرقت فترة التغذية مدة 56 يوماً. أوضحت النتائج أن أفضل قابلية للهضم الظاهري لـ DM، OM، CP، NFE و تم تسجيلها مع الأرانب التي تغذت على عليقة تحتوي على 40% FSB (R3) مقارنة بالعلائق الغذائية الأخرى المختبرة ومجموعة الكنترول. أظهرت النتائج ان الأرانب المغذاة على العلائق المحتوية على FSB سجلت قيم غذائية ($P < 0.05$) معبر عنها ب TDN% للعلائق المحتوية 20 و 40 و 60% FSB اعلى معنوية ($P > 0.05$) عن الكنترول بنسب 7,58 و 12,46% و 8,74% على التوالي مقارنة مع. بينما اشارت النتائج الى عدم وجود فروق معنوية بين المجموعات التجريبية في DCP%.

تغذية الأرانب على العلائق المحتوية على FSB لم يكن لها تأثيراً معنوياً على البروتين الكلي ؛ والألبومين ونسبة الألبومين : الجلوبيولين في سيرم الدم. في حين أظهرت تلك العلائق انخفاضاً معنوياً ($P < 0.05$) بين المعاملات الغذائية لقيم (AST) و (ALT) بسيرم الدم مقارنة بالمجموعة الكنترول. سجلت الأرانب المغذاة على 60% FSB أدنى قيم AST و ALT بسيرم الدم. أيضاً، سجلت المجموعات الثلاثة المغذاة على FSB انخفاضاً معنوياً ($P < 0.05$) في كلا من TC، TG، HDL، LDL، TC / HDL، و VLDL-C مقارنة بمجموعة الكنترول، وقد سجلت اقل القيم مع المجموعة المغذاة على العليقة المحتوية على 40% FSB، علاوة على ذلك فإن مستوى HDL وقيم HDL-C / LDLC أظهرت زيادة معنوية ($P < 0.05$) بالمقارنة بعليقة الكنترول. تأثرت تركيزات pH الاغور والأمونيا- N و TVF تأثرت معنوياً ($P < 0.05$) بمستوى إضافة FSB بالعلائق التجريبية. لم يتم تسجيل نفوق في الأرانب التي تم تغذيتها على 40 و 60% FSB مقارنة بتلك المغذاة على العليقة المحتوية على 20% أو عليقة الكنترول والتي سجلت نسبة نفوق 8,3%. الزيادة الكلية لوزن الجسم تحسنت معنوياً ($P < 0.05$) بنسبة 6,24% و 26,58% و 12,66%، في حين ان متوسط الزيادة اليومية تحسن بنسبة 6,22 و 26,55 و 12,64% للمجاميع المغذاة على علائق محتوية على 20 و 40 و 60% FSB على التوالي مقارنة بعليقة الكنترول. كما وضحت النتائج في تحسن كفاءة التحويل الغذائي في العلائق المحتوية على FSB

أظهرت النتائج أن إضافة 40 أو 60% FSB لعلائق الأرانب أدت إلى اختلافات معنوية ($P < 0.05$) في أوزان الذبيحة الساخنة ونسب التصافي مقارنة بالمحتوية على 20% FSB أو الكنترول. كما أظهرت ان زيادة مستويات FSB بعلائق الأرانب أدى إلى زيادة معنوية ($P < 0.05$) في نسبة التصافي كما أدى إلى انخفاض نسبة الدهن في لحم الذبيحة الخالي من العظم مقارنة بالمجموعة المغذاة على عليقة الكنترول. أدت زيادة FSB% بالعلائق المختبرة إلى تقليل استهلاك الارانب للاعلاف مقارنة بمجموعة الكنترول. المواد الكيميائية النباتية الرئيسية للمنتج الثانوي لبذور الشممر هي مضادات الأكسدة الكلية 183,82 ملليجرام / 100 جم (مكافئ حمض الأسكوربيك) ، ومجموع الفينولات 113,96 ملليجرام / 100 جم (مكافئ لحمض الثوم) ومجموع محتويات الفلافونويد 67,10 ملليجرام / 100 جم (مكافئ كاتشين) بالإضافة إلى ذلك، أظهرت النتائج إلى أن إضافة FSB بعلائق الأرانب أدت الى زيادة الوزن التسويقي كما أدت الى تحسن إجمالي التكلفة وإجمالي الإيرادات وصافي الإيرادات والكفاءة الاقتصادية والكفاءة الاقتصادية النسبية وتكلفة العلف / كجم LBW. أظهرت الأرانب المغذاة على العليقة R3 (40% FSB) أفضل تكلفة إجمالية.

نستنتج من النتائج المتحصل عليها أن إضافة 40% FSB في عليقة الأرانب أدت إلى تحسن معاملات الهضم والقيم الغذائية ووزن الجسم النهائي ومتوسط الزيادة اليومية لوزن الجسم وتحسن معامل التحويل الغذائي وانخفاض معدل الوفيات، بالإضافة إلى تحقيق أعلى قيمة للكفاءة الاقتصادية النسبية.