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EFFECT OF USING PRICKLY PEAR AND ITS BY-PRODUCTS AS ALTERNATIVE FEED RESOURCES ON PERFORMANCE OF GROWING RABBIT.

***Fawzia A. Hassan1*, Samia M. Mobaraz2, Mohamed M. Basyony2 ; Khalid M. Mahrose3 and Shawky A. El-Medany*4**

1By-products Utilization Research Department, Animal Production Research Institute, Giza, Egypt

2 Poultry Nutrition Research Department, Animal Production Research Institute, Giza, Egypt

3 Animal and Poultry Department, Faculty of Technology and Development, Zagazig University, Zagazig, Egypt

4Regional Center for Food and Feed, Agriculture Research Center, Giza, Egypt

**Corresponding author: fawzia_amer@yahoo.com*

The present study aimed to evaluate the impact of different levels of dietary replacement of barely by prickly pear fruits (PPF) and peel (PPP) on growth performance, carcass traits and antioxidant status of rabbits. A total of 75 weaned male New Zealand White (NZW) rabbits (5 weeks old) with an average initial body weight of (596.00±13.05 g) were randomly assigned to five experimental groups (15 rabbits for each). Five experimental diets were formulated; the first was used as a control diet (0% PPF and PPP). The other four diets were formulated to replace barley with either PPF or PPP at the levels of 25 and 50%.

Results indicated that PPF and PPP are rich sources in vitamins C (2.4, 2.8µg/100g), vitamins E (25, 23µg/100g) and vitamin A (10, 13µg/100g). The content of gross energy (GE) in PPF was higher than that of PPP and barley. The obtained results revealed also that average of BW, BWG, FI and FCR were not affected (P<0.05) by feeding growing rabbits on diet containing either PPF or PPP under each tested level (25 and 50%) compared to rabbits group fed the control diet during (9-13) and (5-13) weeks old.

Feeding growing rabbits on diets contained 50% PPF or 50% PPP resulted in noticeable improvement in both average BWG and FCR in comparison to the other experimental groups including the control group during the whole period (5-13 weeks old). Digestibility of OM, CP, EE and CF were not affected significantly by the inclusion of PPF (25 and 50%) or PPP (25 and 50%) compared to the control *group. Besides, there were insignificant differences in TDN and DE among the control group and the other tested groups contained PPF or PPP under each tested level (25 or 50%). Rabbits fed a diet containing 25 and 50% PPP had the lowest (P<0.05) NH3-N concentrations while, rabbits fed 25% PPP supplemented diets had the highest (P<0.05) TVFA value. Rabbits fed diets containing 50% PPF or 50% PPP had heavier (P<0.05) liver, heart and edible giblets compared the control group while, rabbits fed diet containing 50% PPP showed the lowest (P<0.05) abdominal fat and the higher (P<0.05) values of serum antioxidant marker and enzymes (TAC, GSH-Px, SOD and CAT). Plasma triglycerides, cholesterol and LDL concentrations were decreased (P<0.05) while HDL concentration increased (P<0.05) in PPF and PPP supplemented groups compared to the control group. The inclusion of PPF or PPP in rabbit diets at a level of 25 or 50% improved economical efficiency and net revenue compared to the control group.*

Conclusively, *according to the circumstances of this experiment, PPF or PPP could be incorporated in growing rabbit diets up to 50% as a partial replacement of barley, without any significant impairment of the growth performance and to achieve a better antioxidant status of rabbits and higher economic efficiency of diets.*

Keywords: Prickly pear; growth performance; antioxidants; rabbits.

Cactus pear (*Opuntia ficus-indica* (L.) Mill.) considers an excellent natural biomass. It is a fast growing xerophtes draught resistant plant and well adapted to an arid and hot environment (Sahoo *et al*. 2017). It is important to find alternatives of feedstuffs to make its use more efficient within a context of sustainable animal production. Prickly pear can be considered as an excellent and cheap source for diet supplementation (Feugang *et al*. 2006), as a multipurpose crop (Nazareno, 2017), and as an alternative feed (Bouzoubaâ *et al*. 2016, Makkar, 2017, De Oliveira *et al*. 2017 and Cardosoa *et al*., 2019), due to its efficiency in converting water to dry matter, and thus to digestible energy balanced feed (Nobel and Bobich, 2002).

Prickly pear is moderately high in sugars, starch, ether extract, crude protein, amino acids, and fiber (Bhatt and Nagar 2013; Osuna-Martinez *et al*. 2014; Makkar 2017), and provides vitamins and calcium that are necessary for the animal (Rodriguez-García *et al*., 2007). It has been reported to have great DM digestibility and also to be highly palatable in wild and domesticated rabbits (Zeedan *et al*. 2015). Prickly pear fruit has increased levels of betalains, total carotenoids, ß-carotene, ascorbic acid, and is one of the best sources in total phenolic compounds (Ramadan and Mörsel, 2010 and Yahia and Mondragon-Jacobo, 2011).

The nutritional and health benefits of prickly fruit are related to its antioxidant properties due to ascorbic acid, polyphenolics, flavonoid compounds (*e.g*., kaempferol, quercetin, and isorhamnetin) and the mixture of yellow betaxanthin and red betacyanin pigments (Zenteno-Ramírez *et al*. 2018). Meanwhile, the free radical scavenging activity of the red cactus pears was related to the concentration of total phenolic compounds and ascorbic acid (Sumaya-Martínez *et al*. 2011).

Prickly pear has been grown for many years, especially in sandy areas, because it is extremely drought tolerant (Abdel-Nabey, 2001 and Zeedan *et al*., 2015). It is estimated that 58344 (tonnes/ year) in Egypt are cultivated with Opuntia in the producing area of 3996 ha. Prickly peels represent around 35-40% of the whole fruit (FAO 2014). Besides to that, Prickly pear peel could be replaced for yellow corn as a source of energy in quail diets without any adverse effect on the performance (Ragab, 2007).

Therefore, the current investigation was carried out to evaluate the effects of different levels of dietary substitution of barley by prickly pear fruits (PPF) and peel (PPP) as alternative feed resources and antioxidants on growth performance, carcass traits and antioxidant status of rabbits.

MATERIALS AND METHODS

Experimental design, animals and diets

The experiment was carried out at Borg-El Arab, Alexandria Governorate, Experimental Research Station, Animal Production Research Institute (APRI), Egypt. Prickly pear (*Opuntia ficus-indica*) fruits and peel were obtained from a private farm in El Kalubia Governorate, Egypt. A total of 75 weaned male New Zealand White (NZW) rabbits (5 weeks old) with an average initial body weight of (596.00±13.05 g) were randomly assigned to five experimental groups in a completely randomized design. Each group (5 replicates; 3 rabbits each) was housed in galvanized batteries (60×40×24 cm) and provided with feeders and automatic drinkers. Feed and water were offered *ad libitum*. Five experimental diets were formulated; the first was used as a control diet (0% PPF and PPP). The other four diets were formulated to replace PPF and PPP for barley at the levels of 25 and 50%. As shown in Table (1), all diets were formulated to be *iso-nitrogenous*,

Table (1): Feed ingredients and chemical composition of experimental diets (%DM basis).

Feed Ingredients (%)	Substitution level of barley by prickly pear fruit and peel				
	Control	**25% PPF**	**50% PPF**	**25% PPP**	**50% PPP**
Soybean meal (44%CP)	19	20	20	20	20
Prickly pear	--	5	10	5	10
Yellow corn	10	5	5	5	5
Barley	20	15	10	15	10
Wheat bran	10	16	16	16	16
Berseem hay	35	33	33	33	33
Molasses	3.0	3.0	3.0	3.0	3.0
Di- Ca- phosphate	2.0	2.0	2.0	2.0	2.0
Dl-Methionine	0.4	0.4	0.4	0.4	0.4
Salt	0.3	0.3	0.3	0.3	0.3
Vit.-Min. premix[1]	0.3	0.3	0.3	0.3	0.3
Total	**100**	**100**	**100**	**100**	**100**
Chemical composition(%DM basis)					
DM	88.38	88.30	88.49	88.87	88.24
OM	90.27	90.24	90.21	90.2	90.19
CP	17.30	17.34	17.41	17.32	17.43
CF	13.93	14.17	14.45	14.19	14.47
EE	2.20	2.18	2.19	2.17	2.20
NFE	56.84	56.55	56.16	56.52	56.09
Ash	9.73	9.76	9.79	9.80	9.81
NDF	33.31	33.45	33.50	33.59	33.63
ADF	18.02	18.10	18.15	18.23	18.39
ADL	5.39	5.41	5.42	5.45	5.46
Hemicellulose[2]	15.29	15.35	15.35	15.36	15.24
Cellulose[3]	12.63	12.69	12.73	12.78	12.93
Methionine[4]	0.64	0.64	0.64	0.64	0.64
Lysine[5]	0.80	0.80	0.80	0.80	0.80
Calcium[6]	1.01	1.01	1.01	1.01	1.01
Phosphorus[7]	0.66	0.66	0.65	0.65	0.65
Digestible energy(Kcal/Kg DM)[8]	2682.1	2657.9	2658.8	2649.9	2656.6

PPF = prickly pear fruit and PPP = prickly pear peel

(1) Each kg vitamins and minerals premix contains: Vit. and Min. mixture: Each kilogram of Vit. and Min. mixture contains: 2000.000 IU Vit. A, 150.000 IU Vita. D, 8.33 g Vit. E, 0.33 g Vit. K, 0.33g Vit. B1, 1.0 g Vit. B2, 0.33g Vit. B6, 8.33 g Vit.B 5, 1.7 mg Vit. B 1,2 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 Mn.

(2)Hemicellulose = NDF-ADF, (3)Cellulose = ADF-ADL.,(4,5,6,7) Calculated on the basis of the ingredients composition.,(8) Digestible energy (DE) was calculated according to Lebas (2013) using the following equation: $DE = 15.627 + 0.000982\ CP^2 + 0.0040\ EE^2 - 0.0114\ MM^2 - 0.169\ ADF \pm 1.250$ *MJ/kg DM. DE in M Joules /kg DM ; DM = Dry matter ; CP = %crude protein in DM; EE = % ether extract (lipids) in DM; MM =% minerals (ash) in DM; ADF = % acid detergent fibre in DM ; CF = % crude fibre in DM.*

iso-caloric, and to meet all the nutrient requirements of growing rabbits according to Lebas (2013).

The experimental period lasted 8 weeks. Body weight (BW; g) and feed intake (FI; g/rabbit/period) were recorded at 5, 9 and 13 weeks of age. Body weight gain (BWG; g/rabbit/day) and feed conversion ratio (FCR; g feed/ g gain) were calculated.

Digestibility trials

In vivo digestibility trials were carried out according to Perez *et al*. (1995). 15 male NZW rabbits were used to determine the nutrient digestibility coefficients and the nutritive value of the experimental diets (3 rabbits for each treatment). Rabbits were housed in individual metabolism cages, fed the experimental diets for a period of 1 week (adaptation period) then faeces were collected every 24 h for 4 consecutive days. Samples of faeces were then oven dried at 70º C for 48 h, ground and stored for chemical analysis. The nutritive value of the experimental diets as DCP and TDN value were calculated according to Cheeke *et al*. (1982). Digestible energy (DE, Kcal/Kg diet) was calculated as follow: DE=TDN × 44.3 according to (Schneider and Flatt, 1975).

Slaughter traits, blood constituents and antioxidant markers

At the age of 13 weeks old, 5 rabbits from each treatment were randomly selected and fasted for 12 h, weighed and slaughtered for carcass characteristics. Slaughter procedure and carcass analysis were carried out as described by Blasco and Ouhayoun (1996). After complete bleeding, the skin, viscera and tail were removed and the hot carcasses and its components were weighed as edible parts (liver, kidneys and heart), Dressing percentage was calculated by dividing the hot dressed carcass weight by pre-slaughter weight and expressed as a percentage according to Steven *et al*. (1981). Blood samples (5 ml from each rabbit) were collected during slaughter to determine blood biochemical components. Plasma was separated from blood by centrifugation at 3,000 rpm for 15 min and stored at -20^{o}C till assayed. Plasma total protein, albumin, triglycerides, total cholesterol, LDL and HDL-cholesterol were measured by colorimetric methods using commercial kits supplied by Bio-diagnostic, Egypt. All measurements were performed according to the manufacturer's instructions.

Total protein was determined according to Orsonneau *et al*. (1989). Albumin was determined according to the method of Doumas *et al*. (1971).

Plasma cholesterol, LDL- and HDL-cholesterol were determined according to the method of Lopez-Virella *et al*. (1977). Triglycerides were determined according to Wahlefeld (1974). Plasma globulin concentration was calculated by the difference between total protein and albumin so the Albumin/Globulin ratio was easily calculated. Superoxide dismutase (SOD), glutathione peroxidase (GSH-Px), total antioxidant capacity (TAC) and catalase (CAT) were determined by colorimetric techniques of Diamond Bio-diagnostic, Egypt. Glutathione peroxidase (GSH-Px) activity was assayed using the method of Chiu *et al*. (1976). Superoxide dismutase (SOD) activity was assayed according to Misra and Fridovich (1972). Total antioxidant capacity (T-AOC) was determined according to Koracevic *et al*. (2001), and catalase (CAT) activity was measured according to Aebi (1984).

Caecum parameters

Gastrointestinal tracts were individually removed from 5 slaughtered rabbits from each group. Cecum was weighed and pH of the caecal content was measured using digital pH meter (Orion Research Digital pH meter, model 201). Then, the caecal content was collected. The sample was filtered through four folds of gauze for determination of total volatile fatty acids (TVFA) by steam distillation (UDK 139- Semi-Automatic Distillation Unit) as described by Warner (1964). The N-ammonia concentration was determined by applying the Conway method (Conway, 1958).

Chemical analysis

Chemical analysis of PPF, PPP, diets and dried faeces were performed as recommended by A.O.A.C (2005) for determining moisture, crude protein (CP), crude fiber (CF), ether extract (EE), nitrogen free extract (NFE). Fiber fractions included neutral detergent fiber (NDF), acid detergent fiber (ADF), and acid detergent lignin (ADL) were determined sequentially according to Van Soest *et al*. (1991).

Gross energy (GE) of both PPF and PPP was determined by Isoperibol bomb calorimeter (Parr 1261, USA). PPF and PPP were ground by hammer mill and kept for mixing into the diet. Tannins were determined as described by Burn (1971). Saponins were determined according to Shany *et al*. (1970). Phytic acid was determined colorimetrically using DU 7400 spectrophotometer according to AOAC (2005). Vitamin E (α–tocopherol) was assayed using HPLC, according to Leth and Sondergaro (1983). Vitamin A was determined using HPLC, according to Leth and Jacobsen (1993). Vitamin C was assayed using HPLC, according to Danish official method (1996) as shown in Table 3.

Economical efficiency

To determine the economic efficiency of the experimental diets for body weight gain, the costs of feed required for producing one kg of body weight gain was calculated. The cost of the experimental diets was calculated according to the price of different ingredients prevailing at local market as well as the price of tested materials at the time of experimentation. Economical efficiency was calculated as a ratio between the return of weight gain and the cost of consumed feed.

Statistical analysis

Data were statistically analyzed by one-way ANOVA using the General Linear Model procedure of SAS (2009). Duncan's multiple range of test (Duncan, 1955) was applied to test the significant of differences between treatment means. The following model was adopted:

$$Y_{ij} = \mu + T_i + E_{ij}$$

Where: Y_{ij}= an observation, μ= the overall mean; T_i= the effect of the treatments and E_{ij}= the experimental random error.

RESULTS AND DISCUSSION

Chemical evaluation of prickly pear fruit and peel

The chemical composition of both PPF and PPP in comparison to barley grains is illustrated in Tables 2 and 3. The results as shown in Table 2. indicated that PPF and PPP had higher CF, Ash, NDF, ADF and ADL contents and lower CP content compared to barley. While, the content of GE in PPF was higher than that of PPP and barley. It is worthy to notice that EE content in PPF was higher than that of barley (3.5 vs. 2.0%). Table 3. represented a comparison between PPF and PPP concerning some vitamins content and some non-nutritional content. It could be noticed that PPF had a higher content of vitamin E and phytic acid content. Nevertheless, PPP contained a higher content of vitamins C, vitamin A, phenolic compounds, tannins and saponin contents than that of PPF.

The main components of prickly pear are carbohydrate-containing polymers, which contain a mix of mucilage and pectin (Gabriel *et al*. 2014). About 60% of the total energy requirements of the animals could be supplied by prickly pear (López-Garcia *et al*. 2001). The present results are somewhat coincided with those obtained by Rodriguez-Garcia *et al*. (2007) and Atef *et al*. (2013) who reported that prickly pear pulp contained 7.61% CP, 3.88% Ash, 85.75% Total carbohydrates, and 1.92% EE.

Guevara-Figueroa *et al*. (2010), Yahia and Mondragon-Jacobo (2011) and El-Mostafa *et al*. (2014) have already demonstrated that PPP and PPF are

Table (2). Chemical composition of prickly Pear fruit, peel and Barley (on dry matter basis).

Items (%)	DM	OM	CP	CF	EE	NFE	Ash	NDF	ADF	ADL	GE*
Barley	92.0	97.30	9.62	6.30	2.00	79.38	2.70	19.01	8.02	2.04	3770
PPF	90.2	90.55	7.60	15.6	3.50	63.85	9.45	24.70	13.70	11.20	4289.1
PPP	84.7	90.39	7.20	15.1	1.90	66.19	9.61	22.10	13.80	8.90	3726.6

***GE: Gross Energy (Kcal/Kg DM)**; PPF: Prickly Pear Fruit; PPP: Prickly Pear Peel. Dry matter (DM), organic matter (OM), crude protein (CP), ether extract (EE), crude fiber (CF), nitrogen free extract (NFE), neutral detergent fiber (NDF), acid detergent fiber (ADF), acid detergent lignin (ADL), and gross energy (GE).

Table (3). Vitamins content C, E and A and non-nutritional compounds content of prickly pear fruit and peel (on dry matter basis)

Components	**PPF***	**PPP****
Vitamins content		
Vit C (mg/100g)	2.4	2.8
Vit E (µg/100g)	25	23
Vit A (B-carotene) (µg/100g)	10	13
Non-nutritional compounds content		
Phenolic compounds (ppm as gallic acid equivalent)	11745	14585
Phytic acid (g/100 g Dry matter)	0.53	0.35
Tannins (%)	2.23	2.51
Saponin (%)	0.50	0.56

*Prickly pear fruit; **Prickly pear peel.

rich in vitamins A and E and free from alkaloids that are well-known anti-nutritional factors. Moreover, Fernández-López *et al*. (2010) stated that total phenol content of prickly fruit pulp (*Opuntia ficus-indica*) is 218.8 mg/100 g. Total antioxidant activities of differently colored PPF were strongly correlated with total phenolics, betalains and ascorbic acid concentrations (Yahia and Mondragon-Jacobo, 2011). Prickly pear possesses antioxidant, anti-lipidemic and antimicrobial properties (Gengatharan *et al*. 2015).

Prickly pear has antioxidant properties due to the existence of several compounds like vitamins E and C, phenolic compounds and other non-nutritional substances (Ramadan and Mörsel, 2010 and Yahia and Mondragon-Jacobo, 2011). Phenolic compounds are effective antioxidants, since they can delay prooxidative impacts on proteins, DNA and lipids by the generation of stable radicals (Shahidi *et al*. 1992). Furthermore, it must be taken into consideration that higher phenolic compounds are found in the prickly pear peel, rather than the pulp (Feugang *et al*. 2006) and that is already found in the current work. Hence, from a nutritional point of view processing both fruit and pulp appears to be beneficial to the health and performance rabbits.

Growth performance

The effect of different experimental diets on growth performance of growing rabbits is shown in Table 4. The obtained results revealed that average of BW, BWG, FI and FCR were not affected (P<0.05) by feeding growing rabbits on diet containing either PPF or PPP under each level (25 and 50%) compared to group of rabbits fed the control diet during (9-13) and (5-13) weeks old. However, group of rabbits fed 50% PPP diets consumed significantly (P<0.05) higher amount of feed than those groups fed the other tested diets except the control diet during (5-9 weeks old). Besides, the same group recorded higher average BWG than that group fed 25% during the same period (664.0 vs. 494.67 g). The observations herein are coincided with those reported by Islam *et al*. (2017) and Aware *et al*. (2017) who concluded that dietary supplementation with prickly pear in sheep and goat has a positive effect on BWG. On the other hand, Amogne (2007) reported insignificant differences in BWG of lambs, when prickly pear replaced 0, 20, 40, 60 and 80% of pasture hay.

Generally, feeding growing rabbits on diets contained 50% PPF or 50% PPP resulted in noticeable improvement in both average BWG and FCR in comparison to the other experimental groups including the control group during the whole period (5-13 weeks old). This improvement may be attributed to that prickly pear is palatable (Nefzaoui, 2017) and is characterized by high sugar (glucose and fructose) content (Feugang *et al*. 2006 and Bouzoubaâ *et al*., 2016). Prickly pear is also rich in water, minerals, vitamins and antioxidants as well as amino acids (8 of which are essentials) and fatty acids especially palmitic acid and Omega-6 (Feugang *et al*. 2006; Ramadan and Mörsel, 2010; Bhatt and Nagar, 2013; Osuna-Martinez *et al*. 2014 and Makkar, 2017). In addition, the high water content of prickly pear serves in nutrient accumulation and transportation (Aguilar-Yáñez *et al*. 2011). These nutrients could accelerate metabolism and increase energy digestibility and hence improve growth performance. Zeedan *et al*. (2015) attributed the improved growth performance of rabbits fed prickly pear to its mode of action that included maintenance of a beneficial microbial population and improvement of feed digestibility. The same authors added that dietary prickly pear supplementation improved feed digestibility and ammonia utilization thorough its conversion to protein. Ennouri *et al*.(2014) suggested that the improvement in growth performance of rabbits fed prickly pear is an effect of the activity of their

Table (4). Growth performance of growing rabbits fed diets containing prickly pear fruits and peel during different ages.

Items	Experimental diets					P value
	Control	25% PPF	50 %PPF	25% PPP	50% PPP	
No. of Rabbits	15	15	15	15	15	
Initial body weight (g/rabbit)	608.00 ±26.32	576.00 ±32.26	608.67 ±29.97	581.33 ±20.88	606.00 ±35.66	0.8850
Final body weight (g/rabbit)	1796.00 ±59.95	1715.67 ±68.60	1811.67 ±80.73	1735.00 ±53.11	1839.33 ±57.84	0.6326
Average body weight gain (g/rabbit)						
Weeks 5-9	582.00[ab] ±42.93	494.67[b] ±40.39	542.67[ab] ±33.12	545.33[ab] ±55.73	664.00[a] ±40.89	0.0497
Weeks 9-13	606.00 ±25.33	645.00 ±35.23	660.33 ±47.56	608.33 ±22.97	569.33 ±41.39	0.4216
Weeks 5-13	1188.00 ±47.03	1139.67 ±46.39	1203.00 ±59.89	1153.67 ±47.78	1233.33 ±40.93	0.6697
Average feed intake (g/rabbit)						
Weeks 5-9	1225.00[ab] ±55.90	1117.67[b] ±58.88	1181.47[b] ±46.78	1182.53[b] ±69.57	1361.13[a] ±49.56	0.0470
Weeks 9-13	2007.33 ±35.65	1970.13 ±50.23	1953.67 ±75.85	1913.67 ±53.76	1883.00 ±40.49	0.5110
Weeks 5-13	3232.33 ±65.42	3087.8 ±46.25	3135.13 ±81.76	3096.2 ±71.83	3244.13 ±68.16	0.3132
Feed conversion ratio (g feed/ g gain)						
Weeks 5-9	2.20 ±0.11	2.26 ±0.11	2.18 ±0.08	2.17 ±0.13	2.05 ±0.16	0.7358
Weeks 9-13	3.31 ±0.09	3.05 ±0.16	2.96 ±0.18	3.15 ±0.09	3.31 ±0.17	0.3414
Weeks 5-13	2.72 ±0.06	2.71 ±0.08	2.61 ±0.09	2.68 ±0.07	2.63 ±0.06	0.8118

[a,b] Means with different superscripts in each raw differ significantly (P<0.05).
PPF = Prickly pear fruit and PPP = Prickly pear peel

antioxidant, antimicrobial and anti-inflammatory compounds as well as nutrient utilization due the presence of flavonoids and phenolic acids. Moreover, prickly pear serves as a lifesaving crop for animals under hot weather conditions (Gabriel *et al*. 2014).

Digestibility coefficients and nutritive values

As presented in Table (5). Feeding growing rabbits on diets supplemented with PPF (25 and 50%) or PPP (25 and 50%) had no significant effect on digestibility coefficients of OM, CP, EE and CF compared to the control group.

Table (5). Effect of dietary inclusion of prickly pear fruits and peel on digestibility coefficients and nutritive values of experimental rabbit diets.

Items	Experimental diets					P value
	Control	25% PPF	50% PPF	25% PPP	50% PPP	
Digestible coefficient of nutrients (%)						
DM	72.54[a] ±0.03	72.47[ab] ±0.02	72.40[b] ±0.04	72.39[b] ±0.02	72.37[b] ±0.04	0.0343
OM	72.74 ±0.51	72.24 ±0.11	72.15 ±0.11	72.08 ±0.11	72.16 ±0.06	0.3692
CP	70.27 ±0.74	69.49 ±0.06	70.11 ±0.42	70.42 ±0.40	70.38 ±0.48	0.6446
EE	72.38 ±0.32	71.14 ±0.94	71.66 ±0.92	70.97 ±0.85	71.32 ±1.47	0.8518
CF	44.87 ±1.32	47.03 ±1.64	46.89 ±0.75	47.05 ±0.14	45.86 ±1.08	0.5831
NFE	77.39[ab] ±0.84	76.04[ab] ±0.57	78.38[a] ±1.35	74.90[b] ±0.80	77.79[a] ±0.34	0.0260
Nutritive values						
TDN	66.41 ±0.44	65.83 ±0.61	66.86 ±0.83	64.97 ±0.44	66.50 ±0.37	0.2149
DCP	11.81[a] ±0.12	11.52[b] ±0.01	11.55[ab] ±0.07	11.61[ab] ±0.07	11.62[ab] ±0.08	0.0166
DE (Kcal/kg)	2942.96 ±19.28	2916.26 ±26.72	2961.98 ±36.70	2878.17 ±19.37	2945.95 ±16.26	0.2153

PPF = prickly pear fruit and PPP = prickly pear peel. Dry matter (DM), organic matter (OM), crude protein (CP), ether extract (EE), crude fiber (CF), nitrogen free extract (NFE)
[a,b]Means with different superscripts in each raw differ significantly (P<0.05).

Conversely, the DM digestibility was decreased (P<0.05) with feeding growing rabbits on 50% PPF, 25% PPP and 50% PPP in comparison to the control group. On the other hand, NFE digestibility was higher (P<0.05) with rabbit groups fed 50% PPF and 50% PPP diets than rabbits group fed 25% PPP diet.

Data concerning the effect of experimental diets on the nutritive values as TDN, DCP and DE revealed that rabbits group fed 25% PPF was significantly lower in DCP than the control group. Meantime, insignificant differences were observed among 50%PPF, 25% or 50% PPP and the control group in DCP. Besides, there were no significant differences in TDN and DE among the control group and the other groups contained PPF or PPP under each tested level (25 or 50%). Prickly pear is highly digestible (Nefzaoui and Ben Salem, 2001; Zeedan *et al*. 2015).

Results in present research revealed that increasing the level of dietary PPF or PPP up to 50% was associated with slight decreasing in DM digestibility and noticeable increase ($P<0.05$) in NFE digestibility. In this respect, Ben Salem *et al*. (1996) and Zeeman (2005) found that diet DM and NFE digestibilities were improved because of the high content of easily digestible carbohydrates of prickly pear. Glucose and fructose in prickly pear were (34.0 and 30.4 g/kg) (Atef *et al*. 2013). Also, Salim *et al*. (2009) reported that pulp, skin and seeds of Opuntia ficus-indica contained outstanding content of soluble fiber and the adequate content and proportion of glucose to fructose. Similar results were observed by Amogne (2007) observed that DM and NFE digestibilities in lambs was significantly affected by the inclusion of prickly pear up to 80% as a replacement of pasture hay.

Caecum parameters

Regarding caecum parameters, the effect of experimental diets on cecum characteristics of growing rabbits is presented in Table 6. It could be noticed that caecum pH did not change due to the dietary inclusion of either PPF or PPE.

Feeding growing rabbits on diets containing PPF or PPP under each tested level except 25% PPF recorded lower ($P<0.05$) NH3-N concentrations than the control group. On the other hand, rabbits group fed 25% PPP supplemented diet had the highest ($P<0.05$) TVFA level, the respective values were (6.33 *vs*. 4.86, 5.20, 4.93 and 4.87mmol/100 ml) compared to the other experimental groups including the control group. Rabbit fed diets supplemented with PPF or PPP at 25 and 50% levels resulted in an increase in total TVFA concentrations compared to the control group. These results coincided with those reported by Cordova-Torres *et al*., (2017) who found that the dietary inclusion of prickly pear in sheep enables greater absorption of TVFA. In addition, Misra *et al*. (2006) indicated that increasing prickly pear inclusion in lamb diets up to 40% led to an increase in TVFA.

The cecum pH values ranged from 6.29 to 6.39. These values are lower than that reported by Belenguar *et al*. (2000) who showed that caecal pH in rabbits fed different diets based on barley or corn ranged between 6.01 and 6.17. The tendency to lower NH3-N concentrations could be attributed to greater ammonia utilization by cecal microbes. It is known that rabbits were characterized by night caecotrophy, in which were rabbits re-ingest the faeces and utilize the microbial protein. These observations were confirmed by Zeedan *et al*. (2015) who found that an increase in dietary prickly pear supplementation level up to 30% led to a decrease in NH3-N

Table (6). Effect of dietary inclusion of prickly pear fruits and peel on caecal fermentative activities in 13-week-old rabbits

Items	**Experimental diets**					
	Control	**25% PPF**	**50%PPF**	**25% PPP**	**50% PPP**	***P value***
pH value	6.39 ±0.18	6.31 ±0.35	6.37 ±0.01	6.29 ±0.19	6.37 ±0.09	0.9950
NH3-N (mg\100 dL)	33.42[a] ±1.67	28.82[ab] ±0.92	27.45[b] ±0.83	24.50 b[c] ±2.62	21.10[c] ±0.74	0.0023
TVFA (mmol/100 ml)*	4.86[b] ±0.44	5.20[b] ±0.33	4.93[b] ±0.83	6.33[a] ±0.33	4.87[b] ±0.40	0.015

[a,b] Means with different superscripts in each raw differ significantly (P<0.05).
* Total volatile fatty acids (TVFA).

levels. Carabaño *et al*. (2009) reported that increased availability of a fermentable substrate could promote microbial protein synthesis, thus reducing the ammoniacal nitrogen level in the caecum. In the present study, the concentration of NH3-N in the caecal content was not linearly affected by dietary PPF and PPP.

It has been known that VFA levels in rabbit caecum depend on the age of animals, the time after feeding and dietary composition (Piattoni *et al*. 1995), Due to the fact that the fibrous portion of prickly pear is highly digestible, TVFA level is increased (Lebas *et al*. 1986). Caecum fermentation produces TVFA, which are responsible for 30 to 40% of the rabbits energy requirement for maintenance (Marty and Vernay, 1984). Volatile fatty acids also aid in the control of pathogenic organisms by helping to maintain the normal pH (6–7) in the caecum (Prohászka and Szemerédi, 1984; Fortun-Lamothe and Boullier, 2007).

Carcass characteristics

Carcass characteristics of rabbits as affected by PPF and PPP inclusion are presented in Table (7). The obtained results indicated that rabbits fed diets containing 50% PPF or 50% PPP had heavier (P<0.05) liver, heart and edible giblets (as % of pre-slaughter weight) compared to the control group. Results also revealed that rabbits groups fed diet containing 25 or 50% PPP had lower (*P*<0.05) abdominal fat percentage than the other tested experimental groups including the control group. The other carcass characteristics, except kidneys % were not significantly influenced by the dietary levels of PPF and PPP.

Table (7). Effect of dietary inclusion of prickly pear fruits and peel on carcass characteristics of growing rabbits at 13 weeks of age.

Items	**Experimental diets**					***P value***
	Control	**25% PPF**	**50 % PPF**	**25% PPP**	**50% PPP**	
Pre-slaughter weight (g)	2066.00 ±199.76	1802.00 ±145.41	2062.00 ±91.45	1870.00 ±117.30	2084.00 ±107.17	0.4788
Hot carcass weight (g)	1361.00 ±117.54	1162.00 ±83.03	1317.00 ±70.67	1234.00 ±89.04	1384.00 ±83.84	0.4072
Dressing weight (%)	65.88 ±0.70	64.48 ±0.86	63.87 ±1.12	65.99 ±0.84	66.41 ±1.24	0.3261
Liver weight (%)	2.58^{b} ±0.05	2.89^{ab} ±0.20	3.16^{a} ±0.19	2.76^{ab} ±0.14	3.23^{a} ±0.16	0.0442
Heart weight (%)	0.34^{c} ±0.02	0.37^{bc} ±0.01	0.44^{a} ±0.01	0.40^{ab} ±0.02	0.42^{a} ±0.01	0.0017
Kidney weight (%)	0.59^{b} ±0.01	0.64^{ab} ±0.01	0.65^{ab} ±0.01	0.62^{bc} ±0.02	0.67^{a} ±0.02	0.0051
Abdominal fat (%)	1.38^{a} ±0.10	1.39^{a} ±0.10	1.16^{a} ±0.07	0.83^{b} ±0.04	0.64^{b} ±0.05	0.0001
Edible giblets (%)	3.51^{c} ±0.04	3.90^{abc} ±0.20	4.24^{ab} ±0.21	3.77^{bc} ±0.13	4.32^{a} ±0.17	0.0107
Total edible parts (%)	69.63 ±0.67	68.55 ±0.98	68.03 ±1.27	69.62 ±0.91	70.63 ±1.25	0.4502
Total non-edible parts (%)	30.37 ±0.67	31.45 ±0.98	31.97 ±1.27	30.38 ±0.91	29.37 ±1.25	0.4502

^{a,b,c} Means with different superscripts in each raw differ significantly (P<0.05).
PPF = prickly pear fruit and PPP = prickly pear peel; edible giblets (%) = (liver (g) + kidney (g) + heart (g)/pre-slaughter weight (g)]*100%; total edible parts (%)= (carcass weight (g) + weight of edible giblets (g)/pre-slaughter weight (g)*100%.

The results herein were in accordance with those found by Aguilar-Yáñez *et al*. (2011) who showed insignificant differences in carcass characteristics of lambs fed diets included fresh or dehydrated spineless cactus. Besides, Abu Shammalah, (2007) demonstrated that rabbits fed diet containing prickly pear at levels of 40, 60 and 80% of the diet had lower abdominal fat percentage than the control group. On the other hand, Zeedan *et al*. (2015) indicated that rabbits fed a diet containing 30% of prickly pear had the highest values of all carcass characteristics.

The beneficial effects of prickly pear in reducing abdominal fat in rabbit's carcass may be due to that prickly pear fiber increases fecal fat excretion by binding to dietary fat, thus reducing dietary fat available for absorption and producing a better quality of the meat (Uebelhack *et al*. 2014).

Blood constituents and antioxidant markers

The effects of PPF and PPP inclusion on blood constituents and antioxidant markers are shown in Table 8. Results clarify that rabbits fed diets containing PPF or PPP at levels of 25 or 50% had significantly higher ($P<0.01$) values of TAC, GSH-Px, SOD and CAT compared to the control group. It could be also observed that rabbits fed diets containing 25 and 50% PPP were the higher ($P<0.05$) in TAC compared to the other experimental rabbit groups including the control. These results confirmed that supplementing rabbit diets with PPF and PPP resulted in a positive effect on serum blood antioxidative properties as measured by total antioxidant capacity (TAC) as an indexe of oxidation and antioxidant enzymes such as glutathione peroxidase (GSH-Px), superoxide dismutase (SOD) and Catalase (CAT).

The additive and synergistic effects of phytochemicals in prickly pear are responsible for its antioxidants activity. The antioxidative ability of the prickly pear could neutralize reactive oxygen species (ROS) (Feugang *et al*., 2006). These ROS exert a multiplicity of biological effects across a wide range from physiological regulatory functions to damaging alterations strongly related with the pathogenesis of an increasing number of diseases (Osuna-Martinez *et al*. 2014 and Saih *et al.* 2017). The present study showed that prickly pear fruits and peel enhanced the antioxidative status of growing rabbits and protected against oxidative damage because of the presence of several antioxidants such as ascorbic acid, which is an important antioxidant and its content in prickly pear fruits and peel are considerably higher (2.4 and 2.8 mg/100 g), vitamin E (25 and 28, µg/100 g), B-carotene (10 and 13 µg/100 g) and phenolic acids (11745 and 14585 ppm as gallic acid equivalent).

Regarding blood constituents, The results of the present study demonstrated that plasma total protein, albumin, A/G ratio and HDL-cholesterol of rabbits fed diets containing PPF or PPE at each tested level (25 or 50%) were significantly higher ($P<0.05$) than those of the control group. On the contrary, plasma triglycerides, total cholesterol and LDL-cholesterol concentrations were significantly lower ($P<0.05$) in rabbit groups fed PPF and PPP diets compared to the control group. Similar results were obtained by Zeedan *et al*. (2015) who stated that rabbits fed diets contained 10, 20 and 30% cactus opuntia cladodes were lower ($P<0.05$) in cholesterol and LDL compared to the control group. In this work, all tested levels of prickly pear dietary supplementation reduced triglycerides, cholesterol and LDL, while increased HDL content.

Table (8). Effect of dietary inclusion of prickly pear fruits and peel on antioxidant markers and blood constituents of growing rabbits at 13 weeks of age.

Items	Experimental diets					*P value*
	Control	**25% PPF**	**50% PPF**	**25% PPP**	**50% PPP**	
Antioxidant markers						
TAC (mMol/L)	0.60^{c} ±0.34	0.94^{b} ±0.03	1.17^{b} ±0.015	3.27^{a} ±0.24	3.32^{a} ±0.028	0.0001
GSH-Px (mU/ml)	0.94^{d} ±0.007	1.04^{c} ±0.006	1.29^{c} ±0.033	2.74^{b} ±0.050	2.20^{a} ±0.019	0.0001
SOD (U/l)	24.54^{c} ±2.94	31.88^{b} ±3.65	44.68^{a} ±1.41	44.64^{a} ±0.91	48.64^{a} ±0.27	0.0001
CAT (U/g)	472.90^{c} ±34.65	586.88^{b} ±18.43	656.43^{a} ±5.32	652.66^{ab} ±2.67	656.80^{ab} ±0.27	0.0001
Blood constituents						
Total Protein (g/dl)	5.75^{c} ±0.086	6.49^{b} ±0.26	7.09^{a} ±0.22	6.83^{ab} ±0.10	6.57^{ab} ±0.11	0.0003
Albumin (g/dl)	2.33^{b} ±0.086	3.31^{a} ±0.26	3.50^{a} ±0.058	3.27^{a} ±0.12	3.42^{a} ±0.128	0.0001
Globulin (g/dl)	3.42 ±0.084	3.17 ±0.27	3.59 ±0.22	3.55 ±0.12	3.15 ±0.18	0.359
A/G ratio	0.68^{b} ±0.035	1.04^{a} ±0.15	0.97^{a} ±0.06	0.92^{a} ±0.05	1.09^{a} ±0.10	0.030
Triglycerides (mg/dl)	69.50^{a} ±2.66	44.23^{b} ±7.53	42.90^{b} ±7.48	41.83^{b} ±4.61	47.84^{b} ±3.48	0.0109
Total cholesterol(mg/dl)	103.21^{a} ±1.95	90.70^{b} ±1.76	90.17^{b} ±1.64	90.79^{b} ±1.25	91.20^{b} ±1.08	0.0001
HDL- cholesterol (mg/dl)	34.10^{b} ±0.31	43.21^{a} ±2.39	45.84^{a} ±2.94	46.33^{a} ±4.30	43.98^{a} ±1.76	0.027
LDL - cholesterol (mg/dl)	41.02^{a} ±2.11	30.85^{b} ±0.47	34.31^{b} ±1.55	33.73^{b} ±1.11	34.25^{b} ±1.55	0.0016

[a,b,c,d] Means with different superscripts in each raw differ significantly ($P<0.05$).

PPF = Prickly pear fruit and PPP = Prickly pear peel. Superoxide dismutase (SOD), glutathione peroxidase (GSH-Px), Total antioxidant capacity (TAC) and catalase (CAT). Albumin/globulin ratio (A/G), high density lipoprotein (HDL) and low density lipoprotein (LDL).

Prickly pear contains pectin, which interferes with cholesterol and lipids synthesis, through binding cholesterol to bile acids (Louacini *et al.* 2012; Zeedan *et al.* 2015 and Nazareno, 2017) and then when the concentrations of these compounds increase, they accelerate the catabolism of cholesterol (Louacini *et al.* 2012). Moreover, the interaction among flavonoids, betalaines and vitamin E seems to be responsible for the hypolipidemic activity of prickly pear (Lee and Lim, 2000).

Economical efficiency

As shown in Table 9. The inclusion of PPF or PPP in rabbit diets at 25, 50% showed an improvement in both economical efficiency and net revenue compared to the control group. This beneficial effect could be attributed to the reduction of total feed cost because prickly pear fruit and peel are so competitive in price as compared to other energy feed sources used in rabbits feeding like as barley. Additionally, rabbits fed 50% PPP recorded the best net revenue. This is improvement matched with that reported by Zeedan *et al.* (2015) who stated that inclusion of cactus opuntia cladodes at 10, 20 and 30% levels in growing rabbits diets improved the total revenue and economical efficiency.

Prickly pear fruits and peel will be available as alternative energy sources for rabbit nutrition especially when corn and barley are expensive or unavailable. Due to concerns about global desertification and declining water sources, Opuntia spp. are gaining in importance as an effective energy source of feed.

Table (9). Economic efficiency of the experimental diets containing prickly pear fruits and peels.

Item	Experimental diets				
	Control	**25% PPF**	**50% PPF**	**25% PPP**	**50% PPP**
Initial weight (Kg)	0.608	0.576	0.608	0.581	0.606
Final weight (Kg)	1.796	1.715	1.811	1.735	1.839
Average total weight gain/rabbit (kg)	1.188	1.139	1.203	1.154	1.233
Total revenue /rabbit (LE)[1]	41.58	39.865	42.105	40.39	43.155
Total feed intake/rabbit (Kg)[2]	3.232	3.087	3.135	3.096	3.244
Price of feeding/kg (LE)	3.85	3.25	3.15	3.2	3.1
Total feed cost /rabbit (LE)	12.44	10.03	9.88	9.91	10.06
Net revenue/rabbit (LE)[3]	29.14	29.83	32.23	30.48	33.10
Economic efficiency(EE)[4]	2.34	2.97	3.26	3.08	3.29
Relative economic efficiency (REE)[5]	100.00	127.00	139.40	131.42	140.58

[1] *Assuming that the price of one kg LBW equal, 35 L.E.*
[2] *According to the price of ingredients available at the experimental time.*
[3] *Net revenue/rabbit = Total revenue /rabbit (LE) - Total feed cost /rabbit (LE)*
[4] *EE = Net revenue / Total feed cost / rabbit (LE).*
[5] *REE = EE of treatments other than the control/ EE of the control group.*

In conclusion, the inclusion of the prickly pear fruits and peel in the rabbit diets at 25 and 50% as a replacement of barley had positive effects on the performance of rabbits and moreover, prickly pear fruits and peel are the excellent sources of dietary antioxidants components which may have beneficial effects on rabbit's health, being rich in bioactive antioxidant compounds (vitamin A, E, ascorbic acid and polyphenols) which make it a worth and viable feeding strategy. From the economical point of view especially within a sustainable animal production system, prickly pear could be promising energy feedstuff.

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تأثير استخدام التين الشوكي ومخلفاته كمصادر علفية بديلة علي أداء الأرانب النامية.

١فوزيه عامر حسان، ٢ساميه مصطفي مبارز، ٢محمد محمد بسيوني، ٣خالد محمد محروس، ٤شوقي احمد الميداني

١ قسم بحوث استخدام المخلفات - معهد بحوث الانتاج الحيواني- مركز البحوث الزراعية- الدقي- الجيزة- مصر.

٢ قسم بحوث تغذيه الدواجن - معهد بحوث الانتاج الحيواني- مركز البحوث الزراعية- الدقي- الجيزة- مصر.

٣ قسم الحيوان والدواجن- كليه التكنولوجيا والتنمية- جامعه الزقايق- الزقازيق- مصر.

٤المركز الاقليم للاغذيه والاعلاف – مركز البحوث الزراعيه-الجيزه-مصر.

استهدفت الدراسة الحالية تقييم تأثير إحلال مستويات مختلفه من ثمار وقشر التين الشوكي محل الشعيرعلي أداء النمو وصفات الذبيحه وحاله تضاد التأكسد. تم توزيع عدد ٧٥ ارنب نيوزلندي ابيض عمر (٥ اسابيع) عشوائيا بمتوسط وزن جسم (٥٩٦جم±١٣,٠٥) إلي ٥ مجموعات تجريبية. وشكلت خمسة علائق تجريبية، الأولي استخدمت كعليقه كنترول، والأربعة علائق الاخري تم استبدال الشعير بثمار وقشر التين الشوكي كلا علي حدي بنسبه ٢٥ و ٥٠%.

- اشارت النتائج إلي أن ثمار وقشر التين الشوكي غنيه بفيتامين C (٢,٤ ، ٢,٨ ميكروجرام/١٠٠جم)، وفيتامين E (٢٥ ، ٢٣ ميكروجرام /١٠٠جم)، فيتامين A (١٠، ١٣ ميكروجرام /١٠٠ جم). وكان محتوي الطاقه الكليه أعلي في ثمار التين الشوكي عن القشر والشعير. واظهرت **النتائج المتحصل عليها:** عدم وجود تأثير معنوي لكل من متوسط وزن الجسم الحي، ومتوسط الزياده الوزنية ومتوسط العلف المأكول ومعامل التحويل الغذائي بتغذيه الأرانب النامية علي علائق تحتوي علي كلا من ٢٥ و٥٠% ثمار وقشر التين الشوكي مقارنه بمجموعة الارانب المغذاه علي عليقه الكنترول خلال الفترتين (٩-١٣ اسبوع) و (٥-١٣ اسبوع) من عمر الارانب.

نتج عن تغذيه الأرانب النامية علي علائق تحتوي علي ٥٠% ثمار و٥٠% قشر التين الشوكي تحسن ملحوظ في متوسط الزياده الوزنية ومعامل التحويل الغذائي، مقارنه بباقي المجموعات التجريبيه شاملة مجموعة الكنترول أثناء فترة التجربه الكلية (٥-١٣ اسبوع).

لم تتأثر معاملات هضم للماده العضوية والبروتين الخام ومستخلص الأثير والألياف الخام بإدخال اي من ثمار التين الشوكي او قشره بنسب ٢٥ و٥٠% مقارنه بمجموعه الكنترول. ولم يكن هناك ايضا فروق غير معنويه في المركبات الغذائيه الكليه

المهضـومة والطاقـه المهضـومة فيمـا بـين مجموعـه الكنتـرول والمجموعـات الاخـري المختبرة التي تحتوي علي ثمار وقشر التين الشوكي تحت كل مستوي (٢٥ و ٥٠ %).
الأرانب المغذاه علي عليقه تحتوي علي ٢٥ و٥٠% قشر التين الشوكي كـان لهـا أقل تركيز معنوي للأمونيا ، بينمـا الأرانـب المغذاه علـي عليقـه تحتـوي علـي ٢٥% قشـر التـين الشـوكي كانـت أعلـي معنويـا فـي تركيـز الأحمـاض الدهنيـه الطيـاره ولقـد لـوحظ أن مجموعـة الأرانـب التـي تغذت علـي علائـق تحتـوي علـي ٥٠% ثمـار التـين الشـوكي او ٥٠% قشر التين الشوكي كان لها اوزان الكبد والقلب والأجزاء المأكولة اعلـي معنويـا مـن مجموعة الكنترول ، بينما اظهرت الارانب المغذاه علـي علائـق تحتـوي علـي ٥٠% قشـر التين الشوكي اقل دهن للبطن معنويـا و قيم اعلـي معنويـا لكـل مـن القدره التأكسديه الكليـه (TAC) وانــزيم الجلوتــاثيون بيرواكســديز(GSH-Px) والســوبر اكســيديز ديســميوتيز (SOD) والكتـاليز (CAT) فـي سيرم الـدم، كمـا قلـت تركيـزات الجليسـريدات الثلاثيـه والكوليسترول والكوليسـترول مـنخفض الكثافـه LDL، وازداد تركيـز الكوليسـترول عـالي الكثافـه (HDL) فـي مجموعـات ثمـار وقشـر التـين الشـوكي مقارنـه بمجموعـة الكنتـرول. وإدخـال ثمـار وقشـر التـين الشـوكي فـي علائـق الأرانـب بنسـبه ٢٥ أو ٥٠% حسـنت مـن الكفاءه الإقتصادية والعائد مقارنة بمجموعة الكنترول.

التوصية: يمكن إدخال ثمار وقشر التـين الشـوكي فـي علائـق الأرانـب الناميـة حتـي ٥٠% كإحلال جزئـي محـل الشـعير بـدون أي خلـل معنـوي علـي أداء النمـو وتحقيـق احسـن حالـه مضاده للتأكسد للأرانب واعلي كفاءه إقتصاديه للعلائق.