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Utilization from Potato By-Products as Untraditional Source of Energy in Growing Rabbit Diets

H.A.A. Omer, F.A.F. Ali and SH.A.M. Ibrahim

Department of Animal Production, National Research Centre, Dokki, Cairo, Egypt

Abstract: Total numbers of 60 male growing New Zealand White rabbits were used to study the effect of dietary potato by-products (PBP) as a partial replacement at levels 25, 50, 75 and 100 % of yellow corn. Rabbits were classified into five equal groups (G_1-G_5) each contained 12 rabbits. The 1st group received the basal diet contained 26% yellow corn and served as control diet. The other four groups (G_2-G_5) received the basal diet with replacement (PBP) at the level of 25, 50, 75 and 100% of yellow corn, respectively. The chemical composition of potato by-products (PBP) was higher in crude protein, crude fiber, ash, neutral detergent fiber, acid detergent lignin and hemicellulose contents compared with yellow corn. On the other hand, yellow corn contents of organic matter, ether extract, nitrogen free-extract, gross energy, digestible energy, non fibrous carbohydrates, acid detergent fiber and cellulose were higher than PBP. The experimental diets were iso-caloric and iso-nitrogenous. Crude protein digestibility coefficient dietary treatments had no significant effects on other nutrient digestibilities (DM, OM, CF, EE and NFE). Rabbits received basal diet with replacement (PBP) at the level 75% of yellow corn recorded the highest digestibility coefficients for all nutrients and nutritive values. Nutritive value as total digestible nutrient insignificantly ($P<0.05$) increased, while digestible crude protein significant ($P<0.05$) increased with (PBP) gradually replacement of yellow corn in rabbit diets. Dietary (PBP) treatments significantly ($P<0.05$) increased the final body weight, total body weight gain and average daily gain. Dietary (PBP) treatments insignificantly ($P>0.05$) decreased the feed intakes as (DM, CP, DCP, TDN and DE) compared with control diets. Feed conversion (g intake /g gain) of DM, CP, DCP, TDN and (Kcal intake /g gain) of DE were improved when (PBP) used as a partial substitute of yellow corn in rabbit diets. The best feed conversion was recorded by the rabbits received basal diet with complete replacement (PBP) at the level 100% of yellow corn (G_5). Dietary PBP treatments had no significant ($P>0.05$) effects on digestive tract weight empty body weight; carcass weight; dressing percentages; carcass cuts and chemical analysis of the 9,10 and 11th ribs (DM, CP, EE and ash contents). Dietary treatments had no significant effects on external offal's and internal offal's except for liver (weight and % of SW), heart (weight and % of SW) and total giblets (weight and % of SW). Increasing the rate of replacement (PBP) from zero to 100% of yellow corn the total revenue, net revenue, economical efficiency and relative economic efficiency were increased. It can be concluded that (PBP) can be used as unconventional source of energy, economically and an effective substitute for yellow corn in rabbit diets without any adverse effect on the digestion coefficients and growth performance.

Key words: Potato by-products · Rabbits · Growth performance · Digestibility · Carcass characteristics · Economic evaluation

INTRODUCTION

In Egypt, there is a severe shortage in the traditional feedstuff in addition to the continuous increase in the prices from time to time. The high cost of yellow corn lead to identify the alternative untraditional low price as potato by-products (PBP) that could be used in animal diets [1, 2]. Potato is an international staple crop which has now spread to at least three-quarters of the world's countries [3]. The total world potato waste production is estimated to 12 million tons per year [4]. Potato waste meal (Potatoes, potato pulp and peeling) is produced by drying and grinding of this waste meal [5]. Potato waste is an excellent energy

Corresponding Author: H.A.A. Omer, Department of Animal Production, National Research Centre, Dokki, Cairo, Egypt.

source values similar to corn and barley, while being low in protein, vitamin A and calcium [6]. Potato peel, a waste by product of potato processing, is found to be a good source of dietary fiber and polyphenols [7], which is strongly antioxidant [8]. The biggest problem that has to be managed with potato waste is the water, where moisture content in potato is reach to 80 percent [9]. Pasteurization of vegetable by-products before feeding may be necessary to prevent the spread of pathogens [10].

Potato starch is known to have a higher concentration of phosphate groups in amylopectin results in resistance digestion by amylase, inducing a physiological effect similar to that of resistant starch and indigestible oligosaccharides [11]. The potato tuber is rich in carbohydrates, the principal of which is starch present as granules consisting of amylopectin and amylose in the ratio of approximately 3:1. In their native state, these starch granules show considerable resistance to pancreatic á-amylase [12]. Starch that escapes digestion in the small intestine (resistant starch) may act similarly to nonstarch polysaccharides in the colon [13]. Raw potato starch exerts complementary caecocolonic effects and could be beneficial by providing health-promoting effects throughout the caecocolon [14], which may adapt to produce more butyrate if given time and the proper substrate [15]. Potato increased short-chain fatty acid production in the cecum as well as increase the proportion of butyrate generated in the colon by bacterial fermentation as by non starch polysaccharides [16]. Feeding potato as resistant starch affects fecal and cecal microflora by stimulating of bifidobacteria and lactobacilli, may be useful for the suppression of pathogenic organisms in the colon [16].There is a little available information on the physiological effects of preprocessed starch like (PBP) in rabbit experiments. Either of potato starch or maize starch increased the amount of starch reaching the cecum and increased short-chain fatty acid production in the cecum; potato starch had the greatest effect and á-amylase maize starch the least [16]. Potato and maize starch had major effects on fecal and cecum weight but only slightly on shortened transit times [16].

The present experiment was designed to investigate, in the rabbit, the effects on digestion and performance of feeding diets in which potato by-products as a gradual replacement of yellow corn.

MATERIALS AND METHODS

Total number of sixty male New Zealand White rabbits aged 5 weeks with an average body weight of 721.4 ± 15.17 g, were divided into five equal groups each twelve animals. The basal experimental diet was formulated and pelleted to cover the nutrient requirements of rabbits according to N.R.C. [18] as shown in (Table 1).

Table 1: Composition (kg/ton) of the experimental diets

	Experimental diets				
Item	G_1	G_2	G_3	G_4	G_5
Yellow corn	260	195	130	65	-
Potato by-products (PBP)	-	65	130	195	260
Barley grains	100	100	100	100	100
Wheat bran	170	170	170	170	170
Soybean meal 44% CP	150	150	150	150	150
Lucerne hay	290	290	290	290	290
Di-Calcium phosphate	10	10	10	10	10
Lime stone	10	10	10	10	10
Sodium chloride	5	5	5	5	5
Vit. & Min. mixture*	3	3	3	3	3
DL-Methionine	1	1	1	1	1
Anti fungal agent	1	1	1	1	1
Price, L.E/Ton	2146	2029	1912	1795	1678

* 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. B_1, 1.0 g Vit. B_2, 0.33g Vit. B_6, 8.33 g Vit.B_5, 1.7 mg Vit. B_{12}, 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.

LE = Egyptian pound equals 0.18 American dollars approximately.

G_1: Rabbits received control diet that contained 26% yellow corn.

G_2: Rabbits received diet that replaced 25% of yellow corn in basal diet with sun dried potato by- products (PBP).

G_3: Rabbits received diet that replaced 50% of yellow corn in basal diet with sun dried potato by- products (PBP).

G_2: Rabbits received diet that replaced 75% of yellow corn in basal diet with sun dried potato by- products (PBP).

G_2: Rabbits received complete replacement (100%) of yellow corn in basal diet with sun dried potato by- products (PBP).

Potato by-products (PBP) were left to sun-drying and kept in clean bags until to using in rabbit ration formulations. The feeding period was extended for 56 days and the experimental groups were classified as follow:

- Group 1 basal diet contained 26% yellow corn and served as control diet (G_1).
- Group 2 basal diet with replacement (PBP) at the level 25% of yellow corn (G_2).
- Group 3 basal diet with replacement (PBP) at the level 50% of yellow corn (G_3).
- Group 4 basal diet with replacement (PBP) at the level 75% of yellow corn (G_4).
- Group 5 basal diet with replacement (PBP) at the level 100% of yellow corn (G_5).

Rabbits individually housed 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. Feed and water were offered *ad libitum.* Rabbits of all groups were kept under the same managerial conditions and were individually weighed and feed consumption was individually recorded weekly during the experimental period. At the end of the experimental period, all rabbits were used in digestibility trials over period of 7 days to determine the nutrient digestibility coefficients and nutritive values of the tested diets. Feces were daily collected quantitatively. Feed intake of experimental rations and weight of feces were daily recorded. Representative samples of feces was dried at 60°C for 48 hrs, ground and stored for later chemical analysis. Six representative rabbits from each treatment were randomly chosen and fasted for 12 hours before slaughtering according to Blasco *et al.*[19] to determine the carcass measurements. Edible offal's (Giblets) included heart, liver, testes, kidneys, spleen and lungs 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 giblets and external offal's were calculated as percentages of slaughter weight (SW). Hot carcass was weighed and divided into fore, middle and hind parts. The 9, 10 and 11^{th} ribs were frozen in polyethylene bags for later chemical analysis. The best ribs of samples were dried at 60°C for 24 hrs. The air-dried samples were analyzed for DM, EE and ash according to the A.O.A.C. [20] methods, while CP percentage was determined by difference as recommended by O'Mary *et al.* [21]. Chemical analysis of tested materials, experimental rations and feces were analyzed according to A.O.A.C. [20] methods. Neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid detergent lignin (ADL)} were also determined in tested materials and the experimental rations according to Goering and Van Soest [22]. Hemicellulose was calculated as the difference between NDF and ADF, while cellulose was calculated as the difference between ADF and ADL. Gross energy (kilo calories per kilogram DM) was calculated according to Blaxter [23], where, each g of crude protein (CP) = 5.65 kcal, each g of ether extract (EE) = 9.40 kcal and each g crude fiber (CF) and nitrogen-free extract (NFE) = 4.15 kcal. Digestible energy (DE) was calculated according to Fekete and Gippert [24] using the following equation:

- DE (kcal/kg DM) = 4253-32.6 (CF %)-144.4 (total ash)

Non fibrous carbohydrates (NFC) were calculated according to Calsamiglia *et al.* [25] using the following equation:

- NFC = 100 - {CP + EE + Ash + NDF}.

Diets were offered pelleted and diameter of the pellets was 4 mm. Economical efficiency of experimental diets was calculated according to the local market price of ingredients and rabbit live body weight as following:

- Net revenue = total revenue - total feed cost. Economical efficiency (%) = net revenue/ total feed cost %.

Statistical Analysis: Collected data were subjected to statistical analysis as one way analysis of variance using the general linear model procedure of SPSS [26] Duncan's Multiple Range Test [27] was used to separate means when the dietary treatment effect was significant

RESULTS AND DISCUSSION

Chemical Analysis and Cell Wall Constituents of the Tested Materials and the Experimental Diets: Chemical analysis and cell wall constituents of the tested materials and the experimental diets are presented in Table 2. The chemical composition of (PBP) was higher in crude protein, crude fiber, ash, neutral detergent fiber, acid detergent lignin and hemicellulose contents compared to yellow corn. While, yellow corn contents of organic matter, ether extract, nitrogen free-extract, gross energy,

Table 2: Chemical analysis and cell wall constituents (%) of the tested materials and the experimental diets

	Tested materials		Experimental diets				
Item	Yellow corn	Potato by-products	G_1	G_2	G_3	G_4	G_5
Chemical analysis (%)							
Dry matter	89.53	90.11	92.98	93.3	93.56	93.63	93.25
Chemical analysis on DM basis							
Organic matter (OM)	98.6	91.65	90.18	90.15	90.04	90.2	90.21
Crude protein (CP)	9.27	13.28	19.85	19.95	19.82	19.61	19.82
Crude fiber (CF)	2.27	4.55	8.4	8.38	8.3	8.75	8.56
Ether extract (EE)	4.01	1.08	1.1	1.08	1.06	1.07	1.05
Nitrogen-free extract (NFE)	83.05	72.74	60.83	60.74	60.86	60.77	60.78
Ash	1.4	8.35	9.82	9.85	9.96	9.8	9.79
Gross energy (Kcal/kg DM)1	4441	4059	4098	4097	4090	4098	4096
Digestible energy (Kcal/kg DM)2	3977	2899	2561	2558	2544	2553	2560
Non fibrous carbohydrates (NFC)3	52.69	37.03	29.64	29.03	28.58	28.44	27.76
Cell wall constituents							
Neutral detergent fiber (NDF)	32.63	40.26	39.59	40.09	40.58	41.08	41.58
Acid detergent fiber (?ADF)	22.45	5.8	18.78	17.7	16.61	15.53	14.45
Acid detergent lignin (ADL)	2.13	3.66	6.08	6.19	6.29	6.38	6.48
Hemicellulose	10.18	34.46	20.81	22.39	23.97	25.55	27.13
Cellulose	20.32	2.14	12.7	11.51	10.32	9.15	7.97

[1]Gross energy (kilo calories per kilogram DM) was calculated according to Blaxter [23], where, each g of crude protein (CP) = 5.65 kcal, each g of ether extract (EE) = 9.40 kcal and each g crude fiber (CF) and nitrogen-free extract (NFE) = 4.15 kcal.

[2]Digestible energy (DE) was calculated according to Fekete and Gippert [24] using the following equation:

DE (kcal/ kg DM) = 4253 - 32.6 (CF %) - 144.4 (total ash).

[3] Non fibrous carbohydrates (NFC), calculated according to Calsamiglia et al. [25] using the following equation:

NFC = 100 - {CP + EE + Ash + NDF}.

Hemicellulose = NDF - ADF.

Cellulose = ADF - ADL.

G_1: Rabbits received control diet that contained 26% yellow corn.

$G_{2:}$ Rabbits received diet that replaced 25% of yellow corn in basal diet with sun dried potato by- products (PBP).

$G_{3:}$ Rabbits received diet that replaced 50% of yellow corn in basal diet with sun dried potato by- products (PBP).

$G_{2:}$ Rabbits received diet that replaced 75% of yellow corn in basal diet with sun dried potato by- products (PBP).

$G_{2:}$ Rabbits received complete replacement (100%) of yellow corn in basal diet with sun dried potato by- products (PBP).

digestible energy, non fibrous carbohydrates, acid detergent fiber and cellulose were higher than PBP. These results were within the ranges obtained by Tawila *et al.* [1], Omer *et al*. [2] and Omer and Tawila [28], who noted that chemical composition of potato waste ranged from 40 to 146 g/kg DM for CP, 16 to 175 g/kg DM for CF, 780 to 820 g/kg DM for TDN, 400 to 415 g/kg DM for NDF, 58 to 64 g/kg DM for ADF, 36 to 42 g/kg DM for ADL, 323 to 347 g/kg DM for hemicellulose and 25 to 43 g/kg DM for cellulose, respectively.

The experimental diets were iso caloric and iso nitrogenous. Protein contents for the five tested rations (G_1-G_5) were ranged from 19.61 to 19.95%. On the other hand the digestible energy values were ranged from 2544 to 2561 (Kcal/ kg DM) for all diets. Increasing levels of PBP as a replacement of yellow corn lead to increase neutral detergent fiber, acid detergent lignin and hemicellulose contents in experimental diets, while non fibrous carbohydrates, acid detergent fiber and cellulose contents were decreased. These results may be due to increase these contents in PBP compared with yellow corn. These results are in agreement with those obtained in Ossimi lambs by Omer *et al.* [2].

Nutrient Digestibility and Nutritive Values of the Experimental Diets: Digestibility coefficients and nutritive values (%) of the experimental diets are shown in Table 3. Except for crude protein digestibility coefficient dietary (PBP) treatments had no significant effects on other nutrient digestibility coefficients (DM, OM, CF, EE and NFE). These results may be due to the effect of adaptation time on the concentration and pattern of

Table 3: Digestibility coefficients and nutritive values (%) of the experimental diets

	Experimental diets					
Item	G_1	G_2	G_3	G_4	G_5	SEM
Digestibility:						
Dry matter (DM)	75.29	77.68	81.1	82.85	82.63	1.39
Organic matter(OM)	74.91	75.57	76.83	77.91	76.42	0.75
Crude protein (CP)	79.95b	85.76a	88.03a	88.25a	87.17a	1.07
Crude fiber (CF)	38.1	38.43	45.87	50.15	45.14	2.72
Ether extract (EE)	40.84	43.56	34.51	50.85	36.08	3.42
Nitrogen-free extract (NFE)	78.95	77.92	78.15	79.05	78.01	0.64
Nutritive values:						
Total digestible nutrient (TDN)	68.11	68.71	69.64	70.97	69.42	0.69
Digestible crude protein (DCP)	15.87b	17.11a	17.45a	17.31a	17.28a	0.21

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

SEM, standard error of the mean

G_1: Rabbits received control diet that contained 26% yellow corn.

$G_{2:}$ Rabbits received diet that replaced 25% of yellow corn in basal diet with sun dried potato by- products (PBP).

$G_{3:}$ Rabbits received diet that replaced 50% of yellow corn in basal diet with sun dried potato by- products (PBP).

$G_{2:}$ Rabbits received diet that replaced 75% of yellow corn in basal diet with sun dried potato by- products (PBP).

$G_{2:}$ Rabbits received complete replacement (100%) of yellow corn in basal diet with sun dried potato by- products (PBP).

Table 4: Growth performance of the experimental groups

	Experimental diets					
Item	G_1	G_2	G_3	G_4	G_5	SEM
Initial weight, g	724	716	722	718	727	15.17
Final weight, g	2109b	2126b	2171ab	2210a	2232a	12.19
Body weight gain, g	1385b	1410ab	1449ab	1492ab	1505a	18.63
Duration period, day	56 days					
Average daily gain, g	24.73b	25.18ab	25.88ab	26.64ab	26.88a	0.33
Feed intake as:						
Dry matter, g/h/d (DMI)	113.4	110.4	106.5	103.4	96.98	2.89
Crude protein , g/h/d (CPI)	22.51	22.02	21.11	20.28	19.22	0.58
Digestible crude protein, g/h/d (DCPI)	18	18.89	18.58	17.9	16.76	0.48
Total digestible nutrient, g/h/d (TDNI)	77.24	75.86	74.17	73.38	67.32	1.98
Digestible energy, kcal/h/d (DEI)	290	282	271	264	248	7.32
Feed conversion (g intake/ g gain) of						
Dry matter	4.59b	4.38b	4.12ab	3.88ab	3.61a	0.12
Crude protein	0.91c	0.87bc	0.82abc	0.76ab	0.72a	0.02
Digestible crude protein	0.73ab	0.75b	0.72ab	0.67ab	0.62a	0.02
Total digestible nutrient	3.12b	3.01b	2.87ab	2.75ab	2.50a	0.08
Digestible energy (Kcal intake /g gain)	11.73b	11.20b	10.47ab	9.91ab	9.23a	0.31

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

SEM, standard error of the mean.

G_1: Rabbits received control diet that contained 26% yellow corn.

$G_{2:}$ Rabbits received diet that replaced 25% of yellow corn in basal diet with sun dried potato by- products (PBP).

$G_{3:}$ Rabbits received diet that replaced 50% of yellow corn in basal diet with sun dried potato by- products (PBP).

$G_{2:}$ Rabbits received diet that replaced 75% of yellow corn in basal diet with sun dried potato by- products (PBP).

$G_{2:}$ Rabbits received complete replacement (100%) of yellow corn in basal diet with sun dried potato by- products (PBP).

short-chain fatty acids formed in the cecum of rabbits given (PBP) as noticed in rat by Henningsson *et al.* [29], who add, the concentration of butyric acid was higher in the group fed raw potato starch than in that fed high-amylose maize starch at all adaptation times. These results may be attributed to that digestibility of the starch in plant foods is highly variable and is dependent on a number of factors, including the physical structure of both the starch and the food matrix as reported by Englyst *et al.* [30]. Similar results in the ranges obtained in sheep by Tawila *et al.* [1] and Omer *et al.* [2] and in Baladi goats by Omer and Tawila [28]. Rabbits received basal diet with replacement (PBP) at the level 75% (G_4) recorded the highest digestibility coefficients of (DM, OM, CP, CF, EE and NFE) and nutritive values as (TDN and DCP). These results may be due to the effect of (PBP) on formed some important biomolecules, such as ATP, GTP, cyclic AMP, NADH and coenzyme A, as reported in pigs by Martinez-Puig *et al.* [31] who add, potato starch diet had a higher purine base concentration in the middle colonic digesta and a greater SCFA concentration in the proximal colonic digesta than the corn starch-fed group.

Nutritive values as total digestible nutrient (TDN) insignificantly increased ($P<0.05$) while, digestible crude protein (DCP) was increased when PBP used as a replacement of yellow corn in rabbit diets. These results indicated that (PBP) act like resistant starch and raise cecum SCFA, probably through anaerobic bacterial activities and fermentation of residual starch, as reported in pigs fed raw potato starch diet by Martinez-Puig *et al.* [31], or may be due to the (PBP) exhibit the physical and physicochemical properties of a typical colloid in rabbit cecal microbial as reported by Mayer and Hillebrandt [32].

Growth Performance of the Experimental Groups: Growth performances of the experimental groups are presented in Table 4. Dietary (PBP) treatments significantly ($P<0.05$) increased the final body weight, total body weight gain, average daily gain and feed conversion. While showed insignificant effects ($P>0.05$) on feed intake. Rabbits received basal diet with replacement (PBP) at the level 100% of yellow corn (G5) increased the final body weight, total body weight gain and average daily gain by 4.77, 8.66 and 8.69%, respectively, compared to the control diet (G_1). These results may be due to the effect of (PBP) on suppression of pathogenic organisms in the rabbit cecum. Similar results in rat fed resistant starch stimulated of bifidobacteria, lactobacilli and SCFA may be useful for the colon [17].

Dietary (PBP) treatments insignificant ($P>0.05$) decreased feed intakes of (DM, CP, DCP, TDN and DE) compared with control diets contained yellow corn. Feed intake was decreased gradually with increasing the level of PBP as a replacement of yellow corn. These results may be due to the starch swelling in (PBP) that total pectin methyl esterase may modulate pectin cohesiveness, perhaps through increasing Ca (2+)-bridges, to provide greater resistance to fracture, as reported by Ross *et al.* [33].

Feed conversion (g intake /g gain) of DM, CP, DCP, TDN and (Kcal intake /g gain) of DE were improved when (PBP) used as a partial substitute of yellow corn in rabbit diets. The best feed conversion was recorded by the rabbits received basal diet with complete replacement (PBP) at the level 100% of yellow corn (G_5). These results may be due to the cecum development and stability of thermophiles in thermophilic aerobic digestion induced by (PBP) in addition the processing conditions, as reported in aerobic digestion populations by Ugwuanyi *et al.* [34], who add that the potato peel slurry process may be operated in a wide range of conditions.

Carcass Characteristics of the Experimental Groups: Effect of dietary treatments on dressing percentages, carcass cuts and chemical analysis of the 9, 10 and 11th ribs are shown in Table 5. Dietary PBP treatments had no significant ($P>0.05$) effects on digestive tract weight (full, empty and content); empty body weight; carcass weight; dressing percentages; carcass cuts (fore and middle parts) and chemical analysis of the 9,10 and 11th ribs (DM, CP, EE and ash contents). Similar results in pigs fed potato chip scraps in the diet [35] and can be an effective substitute for corn in the diet of nursery and growing and finishing pigs.

Data in Table 6 showed that dietary treatments had no significant effects on external offal's and internal offal's except for liver (weight and % of SW), heart (weight and % of SW) and total giblets (weight and % of SW). Rabbits received basal diet with replacement PBP at the level 75% of yellow corn showed the highest value of liver weight and total giblets weight. While, rabbits received basal diet with replacement PBP at the level 50% of yellow corn showed the highest value of heart weight. The improvement of liver, total giblets and heart weight may be due the (PBP) effect in reducing the hypertrophy by activate the liver antioxidant enzymes, as reported by Singh *et al.* [7], who noticed the activities of serum ALT and AST, hepatic and activities of various antioxidant enzymes liver and kidney in rat fed potato peel powder.

Table 5: Effect of dietary treatments on dressing percentages, carcass cuts and chemical analysis of the 9, 10 and 11th ribs

	Experimental diets					
Item	G_1	G_2	G_3	G_4	G_5	SEM
Slaughter weight (SW), g	2165	2150	2180	2170	2175	8.66
Digestive tract weight, g						
Full	444	407	416	441	428	9.5
Empty	208	191	195	207	201	4.42
Content	236	216	221	234	227	5.09
Empty body weight (EBW), g*	1929	1934	1959	1936	1948	8.54
Edible offal's, g (Giblets)	102c	120ab	115b	125a	105c	2.34
Head	129b	159a	131b	130b	131b	2.97
Carcass weight (CW^1)	1007	990	1030	970	1011	11.91
Carcass weight (CW^2)	1109	1110	1145	1095	1116	11.6
Carcass weight (CW^3)	1238	1269	1276	1225	1247	11.87
Dressing percentages (DP)%						
DP^1	46.51	46.05	47.25	44.7	46.48	0.52
DP^2	52.2	51.19	52.58	50.1	51.9	0.48
DP^3	57.49	57.39	58.45	56.56	57.29	0.43
DP^4	64.18	65.62	65.14	63.27	64.01	0.44
Carcass cuts						
Fore part weight, g	360	350	366	348	366	4.79
% of CW	35.75	35.35	35.53	35.88	36.2	0.19
Middle part weight, g	210	211	209	193	203	3.96
% of CW	20.85	21.31	20.29	19.9	20.08	0.28
Hind part weight, g	437	429	455	429	442	5.07
% of CW	43.4	43.34	44.18	44.22	43.72	0.21
Chemical analysis of the 9,10 and 11th ribs						
Dry matter	34.96	34.41	34.13	33.14	33	0.57
Chemical composition on DM basis						
CP	67.32	67.74	67.79	67.14	67.25	1.06
EE	24.07	24	24.08	24.47	24.46	1.2
Ash	8.61	8.26	8.13	8.39	8.29	0.19

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

SEM, standard error of the mean

*EBW: Empty body weight = Slaughter weight - digestive tract content.

CW_1: Carcass weight: included edible offal's (Liver, heart, kidneys, spleen, testes and lungs).

CW_2: Carcass weight: included edible offal's (Liver, heart, kidneys, spleen, testes and lungs).

CW_3: Carcass weight: included edible offal's (Liver, heart, kidneys, spleen, testes and lungs) + head.

DP ^{1}: Dressing percentages calculated as [carcass weight (CW_1) / slaughter weight (SW)].

DP ^{2}: Dressing percentages calculated as [carcass weight (CW_1) / empty body weighs (EBW)].

DP ^{3}: Dressing percentages calculated as [carcass weight + edible offal's (CW_2) / empty body weight (EBW)].

DP ^{4}: Dressing percentages calculated as [carcass weight + edible offal's + head (CW_3) / empty body weight (EBW)].

G_1: Rabbits received control diet that contained 26% yellow corn.

$G_{2:}$ Rabbits received diet that replaced 25% of yellow corn in basal diet with sun dried potato by- products (PBP).

$G_{3:}$ Rabbits received diet that replaced 50% of yellow corn in basal diet with sun dried potato by- products (PBP).

$G_{2:}$ Rabbits received diet that replaced 75% of yellow corn in basal diet with sun dried potato by- products (PBP).

$G_{2:}$ Rabbits received complete replacement (100%) of yellow corn in basal diet with sun dried potato by- products (PBP).

Table 6: Effect of dietary treatments on external and internal offal's (Giblets)

		Experimental diets					
Item		G_1	G_2	G_3	G_4	G_5	SEM
Slaughter weight (SW), g		2165	2150	2180	2170	2175	8.66
External offal's:							
Fur, legs ears and blood	weight, g	483	474	488	504	500	5.44
	% of SW	22.31	22.05	22.39	23.23	22.99	0.23
Internal offal's (Giblets):							
Liver	weight, g	58.00^{d}	69.00^{ab}	68.00^{bc}	78.00^{a}	59.50^{cd}	2.07
	% of SW	2.68^{d}	3.21^{ab}	3.12^{bc}	3.59^{a}	2.74^{cd}	0.09
Heart	weight, g	8.00^{ab}	9.50^{a}	9.25^{a}	8.00^{ab}	7.50^{b}	0.27
	% of SW	0.37^{bc}	0.44^{a}	0.42^{ab}	0.37^{bc}	0.34^{c}	0.01
Kidneys	weight, g	14	17.5	15	15	14.5	0.49
	% of SW	0.65	0.81	0.69	0.69	0.67	0.02
Testes	weight, g	8.5	9.5	8	8.5	8.5	0.21
	% of SW	0.39	0.44	0.37	0.39	0.39	0.01
Spleen	weight, g	1.5	1.5	1.25	1.5	1.25	0.11
	% of SW	0.07	0.07	0.06	0.07	0.06	0.05
Lungs	weight, g	12	13	13.5	14	13.75	0.35
	% of SW	0.55	0.61	0.62	0.65	0.63	0.02
Total giblets	weight, g	102^{c}	120^{ab}	115^{b}	125^{a}	105^{c}	2.34
	% of SW	4.71^{c}	5.58^{ab}	5.28^{b}	5.76^{a}	4.83^{c}	0.1

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

SEM, standard error of the mean

G_1: Rabbits received control diet that contained 26% yellow corn.

G_2: Rabbits received diet that replaced 25% of yellow corn in basal diet with sun dried potato by- products (PBP).

G_3: Rabbits received diet that replaced 50% of yellow corn in basal diet with sun dried potato by- products (PBP).

G_2: Rabbits received diet that replaced 75% of yellow corn in basal diet with sun dried potato by- products (PBP).

G_2: Rabbits received complete replacement (100%) of yellow corn in basal diet with sun dried potato by- products (PBP).

Table 7: Economical evaluation of the experimental groups

	Experimental diets				
Item	G_1	G_2	G_3	G_4	G_5
Marketing weight, Kg	2.109	2.126	2.171	2.21	2.232
Feed consumed (as it is, kg) / rabbit,	6.832	6.625	6.373	6.182	5.824
Costing of one kg feed, (LE)1	2.146	2.029	1.912	1.795	1.678
Total feed cost, (LE)	14.66	13.44	12.19	11.1	9.77
Management/ Rabbit, (LE)2	4	4	4	4	4
Total cost, (LE)3	35.66	34.44	33.19	32.1	30.77
Total revenue, (LE)4	46.4	46.77	47.76	48.62	49.1
Net revenue	10.74	12.33	14.57	16.52	18.33
Economical efficiency5	0.3012	0.358	0.439	0.5146	0.5957
Relative economic efficiency6	100	118.9	145.8	170.8	197.8
Feed cost / kg LBW (LE)7	6.95	6.32	5.61	5.02	4.38

[1] Based on prices of year 2011.

[2] Include medication, vaccines, sanitation and workers.

[3] include the feed cost of experimental rabbit which was LE 15/ rabbit + management.

[4] Body weight x price of one kg at selling which was LE 22.

[5] net revenue per unit of total cost.

[6] Assuming that the relative economic efficiency of control diet equal 100.

[7] Feed cost/kg LBW = feed intake x price of kg / Live weight.

LE = Egyptian pound equals 0.18 American dollars approximately.

G_1: Rabbits received control diet that contained 26% yellow corn.

G_2: Rabbits received diet that replaced 25% of yellow corn in basal diet with sun dried potato by- products (PBP).

G_3: Rabbits received diet that replaced 50% of yellow corn in basal diet with sun dried potato by- products (PBP).

G_2: Rabbits received diet that replaced 75% of yellow corn in basal diet with sun dried potato by- products (PBP).

G_2: Rabbits received complete replacement (100%) of yellow corn in basal diet with sun dried potato by- products (PBP).

Economical Evaluation: The economical efficiency of dietary treatments is presented in Table 7. The profitability of using (PBP) in rabbit diets depends on upon the price of tested diets and the growth performance of rabbits fed these diets. Costing of one kg feed, (LE) was decreased by 5.45%, 10.90%, 16.36% and 21.81% for G_2, G_3, G_4 and G_5 respectively compared to control diet (G_1). By gradually increasing the rate of (PBP) as a replacement of yellow corn, the total revenue, net revenue, economical efficiency and relative economic efficiency increased. These results were affected by low price of (PBP) and the improvement of growth performance for (PBP) treatments compared to the control group. Relative economic efficiency values were 118.9, 145.8, 170.8 and 197.8% for groups G_2, G_3, G_4 and G_5 received (PBP) as replacement of yellow corn by 25, 50, 75 and 100%, of yellow corn, respectively compared to the control diet (G_1). On the other hand feed cost / kg LBW (LE) were decreased with increasing the level of (PBP) replacements of yellow corn. These results may be attributed to many factors in the high nutritive value of potato tuber affected during the starch production contains cellulose, hemicelluloses, pectin, proteins, free amino acids, salts and exhibits physical and physicochemical properties of typical colloid as well as the economical properties, in a dried and pelleted form as animal feed as reported by Mayer and Hillebrandt [32].

CONCLUSION

Potato by-products can be used as a good alternative source of energy for yellow corn in rabbit diets with a good influence on crude protein digestion coefficient, growth performance and carcass characteristics as well as can be considered a cheap source of energy ingredients in rabbit diets formulations.

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