Nutritional evaluation of sprouted barley grains on agricultural by-products on performance of growing New Zealand white rabbits

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SUMMARY

Sprouted barley grains was produced using agricultural by-products as bedding media and the treatments were hydroponic barley with 0.5% urea (HBU), sprouted barley on rice straw with 0.5% urea (SBRSU), sprouted barley on wheat straw with 0.5% urea (SBWSU), sprouted barley on bean straw with 0.5% urea (SBBSU), sprouted barley on rice straw with 100 g poultry dropping (SBRSPD) and sprouted barley on rice straw with 100 g animal faeces (SBRSUAF). Three digestibility trials were conducted using mature male New Zealand White (NZW) rabbits with an average body weight of 2.5 kg and aged 8 months to evaluate sprouted barley grains (HB, SBRS and SBBS). A total of 40 NZW rabbits at 8 weeks of age (16 males with 1039±36.65 g live body weight (LBW) and 24 females with 934.75±39.78 g LBW). Rabbits in the 1st group were fed commercial rabbit diet (CRD) served as control (G1). While, 30% of CRD was replaced by HB (G2), SBRS (G3) or SBBS (G4), respectively during feeding period from 8 to 16 weeks of age.

Results showed that DM content increased in sprouted barley grains on agricultural by-products especially SBRSU, SBRHU and SBBSU. Hydroponic barley (HBU) showed the higher OM content and SBRSU had the higher CP content. While, HBU revealed the higher NPN content. The CF content increased and NFE content decreased in sprouted barley grains on agricultural by-products compared with HBU. The EE content increased in SBRSAF compared with the other sprouted barley grains. However, SBRHU had the higher contents of ash and celica. Fresh and dry yield ranged from 5.80 and 1.02 kg/kg barley grains HBU to 7.12 and 1.83 kg/kg barley grains for SBRHU. Sprouted barley grains on agricultural by-products increased

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the fresh yield by 12.07-22.76% and dry yield by 47.06-79.41% per kg barley grains compared to hydroponic barley grains.

The digestibility of DM and OM and TDN and DE values of HB were significantly higher (P<0.05) compared to SBBS, while the values of SBRS were intermediate without significant differences. Meantime, CF digestibility was significantly higher (P<0.05) for SBSR and SBBS compared with HB.

Chemical composition of commercial rabbit diets and different sprouted barley grains on agricultural by-products were nearly similar except the contents of OM and NFE were higher and CF and ash contents were lower in HB. The digestibility coefficients of different nutrients and nutritive values were nearly similar for CRD and the other diets contained 30% sprouted barley grains. Initial and final live body weight and total and daily weight gain were nearly similar for the rabbits fed the different experimental diets. However, means of final live body weight, total and daily weight gain were significantly (P<0.05) higher for male than female rabbits. Total feed intake, feed conversion ratio and performance index (PI) were nearly similar for the different groups and tended to increase in male than female rabbits.

The price of total weight gain was almost similar for male and female rabbits fed the different diets, while the mean price of total weight gain was significantly (P<0.05) higher for male than female rabbits. Meantime, male and female rabbits fed CRD (D1) revealed significantly (P<0.05) the higher total feed cost and lower net revenue and net revenue improvement compared with those fed diets contained 30% HB (D2), SBRS (D3) or SBBS (D4). The net revenue improvements were about 16 and 13% for male and female rabbits, respectively. The pH value and the concentrations of TVFA's and NH_3-N were insignificantly affected by feeding sprouted barley grains.

Neither the slaughter and carcass weights nor dressing percentage were insignificantly affected by sprouted barley grains inclusion in diets. Also, the weights and percentages of organs and offal were insignificantly affected by sprouted barley grains inclusion in diets except liver percentage, spleen weight and the weight and percentage of shoulder fat revealed significant differences (P<0.05). The physical characteristics of rabbit meat including pH value, color, tenderness and water holding capacity and chemical characteristics of rabbit meat including moisture, protein, ether extract and ash were not significantly affected with feeding sprouted barley grains.

Keywords: NZW rabbits, sprouted barley, digestibility, body weight gain, economic efficiency and carcass traits

INTRODUCTION

In Egypt, there is a large amount of agricultural wastes produced annually, after harvesting of grains. One of these wastes is rice straw which produced in an average of 3.5 million tons per year (Khattab et al., 2009). Rice straw is of poor nutritive value for ruminants related to its low protein content, high fibre content and low palatability. A big amount of rice straw is disposed by burning, so, air pollution increased which reflects on human health. Few attempts were tried to improve nutritive value of rice straw (Ibrahim et al., 2001; El-Tahan et al., 2003 and Mohammadi and AbdalLah, 2007).

Sprouting activities in the seeds have many changes as in seed protein converted to essential amino acids, carbohydrates are converted to sugars and fats are converted to essential fatty acids. These activities increase because of increasing enzymes levels (Chavan and Kadam, 1989). Due to their activities enzymes, sprouts are much easier to be digested than dry seeds (Goodwin and Mercer, 1993).

Hydroponic green forage is the product of the germination of cereal grains such as oats, maize, barley, wheat, rice and sorghum. This process takes place during a period of 9-15 days, using solar energy and mineral nutrient solution (FAO, 2001). Cement, galvanized sheet, glass, fiberglass, plastic or wooden trays or platters covered with polyethylene with a height of 2 to 5 cm are used for the process, placed on a wooden or metal frame, in a vertical or horizontal arrangement (FAO, 2001 and Samperio, 1997). At harvest, the plant is 15 to 20 cm in height, consisting of stem and green leaves. The animal consumes the whole plant including seed and roots (Resh, 2001). Because of its aspect, colour, taste and texture, it is considered a highly palatable feed that promotes digestibility of other nutrients (FAO, 2001).

Hydroponic production is a half-century old method of cultivating plants using a soil less medium. The true hydroponic method of growing plants in a water and nutrient solution is rarely used as it is more difficult to use than more frequently used method growing in sand, gravel or vermiculite medium in beds or containers. The idea is to achieve maximum and uniform growth of plants by carefully controlling the amount of water and nutrients (Atlas Global, 2004).

Fresh green barley grass produced is of such high quality that it is suitable even for all livestock (World wild–green field hydroponic, 2003). The fresh green feed is grown from any cereal grain seed, but the use of barley seed has been found on a worldwide basis to be more practical because of its price and availability. Crude protein in the fresh green feed is maintained at 16 to 17%. *In vitro* digestibility of over than 85% was observed (Atlas Global, 2004). It is high in vitamin E and beta carotene, which improves fertility in animals.

Hydroponically sprouted grains (barley) increased CP, CF, ash, minerals and vitamins contents (Morgan et al., 1992). A marked increase in both NPN and free amino acid as well as in-vitro digestibility and anti-nutritional factors. Vegetating some seeds or grains on some agricultural by-products is a type of hydroponics without soil, which include water culture or sand culture or gravel culture or any agricultural by-products (rice straw) as bedding material, whereas these by-products have the ability to save water for long time which enough to succeed the vegetation process and the efficient use of water by the production of hydroponic fodders of barley and other plants (Buston et al., 2002). Using sprouted barely on Tamarix (BTm) or rice straw (BRs) in feeding growing lambs revealed a significant ($P<0.05$) improvement in digestibility, nutritive values, nitrogen retention and rumen fermentation. Also, it improved average daily gain, feed conversion and economical feed efficiency (Fayed, 2011).

Morales et al. (2009) used hydroponic green barley forage (HGBF) at the levels of 0, 10, 20 and 30% in diets of growing New Zealand rabbits during the period from 35 to 70 days of age. They reported that both dry matter feed intake and growth rate decreased linearly with HGBF increase. Feed conversion and carcass yield percentage were not affected by treatments. Abd El-Rahman et al. (2011) fed rabbits on control diet and 5 experimental diets contained 28% hydroponically sprouted fenugreek seeds (SF) and/or hydroponically sprouted barley grains (SB) and their mixtures replacing with clover hay for 10 weeks. They found that rabbits fed D2 and D6 (28% SF and 28% SB) recorded the highest body weight gain compared with control. Feed intake was the lowest for D3 and D2 contained 21 and 28% SF, respectively. While, D4 (14% of each SF and SB mixture) was the highest total feed intake. Rabbit fed D2 (28%SF) recorded the better feed conversion followed by D6 (28%SB). The nutritive value as TDN and DCP was improved in D6, D2 and D5, respectively. Nitrogen balance was positive in all diets, D2 and D6 had the highest nitrogen balance value.

The objective of the present work is to study the effect of using dried agricultural by-products as media for growing barley grains to produce green fodder to increase the nutritive value, palatability of these by-products. Evaluation of replacing a commercial rabbit diet by sprouted barley grains on growth rate, digestibility, cecum parameters and carcass characteristics of growing-finishing rabbits.

MATERIAL AND METHODS

In vitro trial

Production of sprouted barley

Sprouted barley grains (SB) was produced using agricultural by-products such as rice straw (RS), wheat straw (WS), bean straw (BS) and rice hulls (RH) as bedding media for growing barley grains (BG). Sprouted barley was produced according to the method described by Mohammadi and AbdalLah (2007) using about 10 cm thick layer of chopped agricultural by-products. Barley grains were washed and soaked in tap water overnight (about 12 hours) before sowing and stored in a dark area to allow for initial germination. Then, soaked seeds were spread evenly on the top of dried cutting by-products (2-3 cm). Barley grains were used at 1 kg per 0.5 kg by-products in 1 m^2 and germination period on the media surface lasted about 12 days to get shoot sprouts with 15-20 cm of length. The 0.5% urea (46% N) or 100 g animal faeces or poultry dropping were used as a source of nitrogen fertilizer. Sprouted barley treatments were hydroponic barley with 0.5% urea (HBU), sprouted barley on rice straw with 0.5% urea (SBRSU), sprouted barley on wheat straw with 0.5% urea (SBWSU), sprouted barley on bean straw with 0.5% urea (SBBSU), sprouted barley on rice straw with 100 g poultry dropping (SBRSPD) and sprouted barley on rice straw with 100 g animal faeces (SBRSUAF). The fresh crop was weighed and the samples were taken and dried in air oven at 60 ^oC until complete drying to estimate the dry matter content and dry crop yield. Representative samples were ground and chemically analysed to determine the various components according to AOAC (2000).

In vivo trials

Sprouted barley

Sprouted barley grains (SB) was produced as shown previously on water (HB) or using about 10 cm thick layer chopped rice straw (SBRS) and bean straw (SBBS) as bedding media for growing barley grains. Germination period on the media surface lasted about 12 days to get shoot sprouts, shoot length was 15-20 cm. then, the shoot sprouts were partially wilted and used in feeding growing rabbits.

Evaluation trial

Three digestibility trials were conducted to evaluate sprouted barley grains (HB, SBRS and SBBS) using 12 mature male New Zealand White (NZW) rabbits (4 in each) with an average body weight of 2.5 kg and aged of 8 months. Rabbits were housed individually in metabolic cages. The experimental diets were offered daily and fresh water was provided all the time. Individual feed intake was accurately determined and faeces were collected for 5 days as a collection period and faeces of each animal was mixed. Samples of sprouted barley grains and faeces were dried at 60 ^{o}C for 48 hours, and then representative samples were ground for chemical analysis. Chemical analysis of different sprouted barley grains and faeces was determined according to AOAC (2000). The nutritive values as TDN, DCP and energy were calculated for the different sprouted barley grains.

Feeding trial

Experimental rabbits and diets

A total of 40 New Zealand White (NZW) rabbits with 8 weeks of age (16 males with 1039±36.65 g live body weight (LBW) and 24 females with 934.75±39.78 g LBW) were used in a complete randomized design of four treatments during feeding period from 8 to 16 weeks. Rabbits in the 1st group were fed commercial rabbit diet served as control (CRD, G1). While, in the 2nd, 3rd and 4th groups, 30% of CRD was replaced by hydroponic barley (HB, G2), sprouted barley on rice straw (SBRS, G3) or sprouted barley on bean straw (SBBS, G4), respectively. Commercial rabbit diet consisted of 30% berseem hay, 16% wheat bran, 20% soybean meal, 20% yellow corn, 10% barley grain, 2% molasses, 1% limestone 0.5% common salt and 0.5% premix. Each one kg of premix (minerals and vitamins mixture) contains 20000 IU vit. A; 15000 IU vit. D3; 8.33 g vit. E; 0.33 g vit. K; 0.33 g vit. B1; vit. B2, 1.0 g; vit. B6, 0.33 g; vit. B5, 8.33 mg; 1.7 mg vit. B12; 3.33 g pantothenic acid; 33 mg biotin; 0.83 g folic acid and 200 mg choline chloride. Rabbits in all groups were fed to cover their requirements according to NRC (1977).

Housing and management

Rabbits were housed in galvanized wire cages (40 x 50 x 60 cm) and fresh water was automatically available at all time. All rabbits were kept under the same managerial, hygienic and environmental conditions.

Experimental procedures

Live body weight and feed intake weekly were recorded throughout the experimental feeding period. Then, daily weight gain, feed conversion ratio and economic efficiency were calculated. Also, performance index (PI) was calculated according to North (1981) as given below:

PI = [final body weight (kg) / feed conversion ratio] × 100

Digestibility trial

Four digestibility trials were undertaken as shown previously to evaluation the experimental diets (CRD, HB, SBRS and SBBS) at the end week of the experimental period (16 weeks of age) using four male rabbits from each group. Chemical analysis of different sprouted barley grains and faeces was determined according to AOAC (2000). The nutritive values as TDN, DCP and energy were calculated for the experimental diets.

Caecal activity

Caecal contents of slaughtered male rabbits were taken for determination of pH using Bechman pH meter. However, samples from caecal contents were taken for determination of NH_3-N concentration according to the method of AOAC (2000) and TVFA's concentration according to Warner (1964).

Carcass traits

At the end of experiment, 3 male rabbits were taken randomly from each group. Animals were fasted for 18 hours before slaughtering, weighed and manually slaughtered. Weight of carcass plus head, kidneys, liver and heart was determined according to Blasco *et al*. (1993). The pH value was determined in fresh meat samples using Bechman pH meter. Tenderness and water holding capacity of meat and color intensity of meat extract were determined according to Yamazake (1981). Meat samples were subjected to chemical analysis of moisture, crude protein, ether extract and ash (AOAC, 2000).

Statistical analysis

Data were statistically analysed using general linear models (GLM) procedures adapted by IBM SPSS Statistics 22 (2013) for user's guide with one-way ANOVA. Duncan's multiple range test within SPSS program was done to determine the degree of significance among means (Duncan, 1955).

RESULTS AND DISCUSSION

In vitro trial:

Chemical composition of barley grains and agricultural by-products are presented in Table 1. The contents of DM, OM, EE and NFE were higher, however the contents of CF, ash and celica were lower in barley grains (BG). While, CP and NPN contents were higher in poultry dropping (PD). In addition, the contents of CF and celica were higher, however, the lower contents of CP, NPN, EE and NFE were lower in rice hulls (RH). While, ash and celica content were higher in animal feces (AF).

Table 1: Chemical composition of barley grains and agricultural by-products

Item	DM	Composition of DM, %							
	%	OM	CP	NPN	CF	EE	NFE	Ash	Celica
BG	97.64	96.94	12.44	1.87	6.26	2.71	75.53	3.06	1.78
RS	92.35	83.29	3.27	1.53	29.38	1.69	48.95	16.71	12.58
WS	95.37	90.95	3.90	1.79	38.54	0.76	47.75	9.05	7.34
RH	91.08	82.87	3.06	1.41	42.72	0.60	36.49	17.13	16.03
BS	91.16	85.44	7.76	2.28	32.24	1.63	43.81	14.56	5.84
PD	85.52	74.48	18.23	10.25	10.86	1.02	44.37	25.52	6.12
AF	62.53	62.02	12.84	7.56	9.34	0.74	39.10	37.98	14.52

The chemical composition of different sprouted barley grains is shown in Table 2. The DM content increased in sprouted barley grains on agricultural by-products especially SBRSU, SBRHU and SBBSU. Hydroponic barley (HBU) showed the higher OM content followed by sprouted barley on wheat straw (SBWSU) and sprouted barley on rice straw (SBRSU). At the same time, SBRSU had the higher CP content followed by HBU and SBBSU. While, HBU revealed the higher NPN content followed by SBRSU and SBRHU. The CF content increased in sprouted barley grains on agricultural by-products especially SBWSU, SBRHU and SBBSU. The EE content decreased in SBRHU and SBBRU, but increased in SBRSAF compared with the other sprouted barley grains. The content of NFE recorded an opposite trend to CF content, which decreased with sprouted barley grains on agricultural by-products and HBU had the higher NFE content. However, SBRHU had the higher contents of ash and celica followed by SBRSAF, while HBU had the lower contents.

Table 2: Chemical composition of sprouted barley grains

Item	DM	Composition of DM, %							
	%	OM	CP	NPN	CF	EE	NFE	Ash	Celica
HBU	17.65	96.40	17.01	5.52	12.73	3.31	63.35	3.60	1.36
SBRSU	24.36	92.79	20.58	4.89	18.39	3.24	50.58	7.21	4.45
SBWSU	23.45	94.85	16.42	3.83	27.23	3.03	48.17	5.15	3.23
SBRHU	25.74	85.51	15.89	4.55	28.71	1.44	39.47	14.49	12.33
SBBSU	24.82	88.80	17.97	3.74	26.26	2.27	42.30	11.20	4.87
SBRSPD	22.48	90.08	14.70	3.25	23.66	3.15	50.27	9.92	4.55
SBRSAF	22.53	87.75	16.52	2.98	25.48	4.30	41.45	12.25	7.15

The variations in the chemical composition of the different sprouted barley grains might be attributed to the differences in the composition of barley grains and agricultural by-products as shown in Table 1. This finding may be attributed to increase of the activity of sprouted barley hydrolytic enzymes and lead to improvements in chemical composition of agriculture by-products. These results are in accordance with those obtained by Fazaeli et al. (2012) who found that CP, Ash, EE, NDF, ADF and water soluble carbohydrate (WSC) were increased whereas OM and non-fibre carbohydrate (NFC) decreased (P<0.05) in the hydroponic barley when compared with the original grain.

The fresh and dry yield of sprouted barley grains expressed as kg per kg barley grains are presented in Table 3. The SBRHU showed the highest fresh and dry yield (7.12 and 1.83 kg/kg barley grains) followed by SBBSU (6.89 and 1.71 kg/kg barley grains) and SBRSU (6.63 and 1.62 kg/kg barley grains), while HBU had the lowest yield (5.80 and 1.02 kg/kg barley grains). Sprouted barley grains on agricultural by-products increased the fresh yield by 12.07-22.76% and dry yield 47.06-79.41% per kg barley grains compared to hydroponic barley grains. These results agreed with those obtained by Fazaeli et al. (2012) who reported that the amount of fresh hydroponic barley obtained per kg of planted barley grain was several times but this increase was due to the large uptake of water during germination of the seeds, resulted in a sharply reducing of DM percentage in hydroponic barley.

Table 3: Fresh and dry yield of sprouted barley grains

Item	Fresh yield		Dry yield	
	kg/kg grains	% of HBU	kg/kg grains	% of HBU
HBU	5.80	00.00	1.02	00.00
SBRSU	6.63	14.31	1.62	58.82
SBWSU	6.50	12.07	1.52	49.02
SBRHU	7.12	22.76	1.83	79.41
SBBSU	6.89	18.79	1.71	67.65
SBRSPD	6.65	14.66	1.50	47.06
SBRSAF	6.78	16.90	1.53	50.00

In vivo trails:

Evaluation trail

Chemical composition, digestibility coefficients and nutritive values of sprouted barley grains are shown in Table (4). The contents of DM, CF and ash were higher, however OM and NFE contents were lower in sprouted barley grains on rice straw or bean straw (SBRS and SBBS) compared to hydroponic barley grains (HB). While, CP and EE contents were nearly similar. This finding may be attributed to the increase of the activity of sprouted barley hydrolytic enzymes and lead to improvements in chemical composition of agriculture by-products.

There were significant (P<0.05) differences in the digestibility coefficients of DM, OM and CF as well as TDN, DCP and DE values among HB, SBRS and SBBS. The digestibility of DM and OM and TDN and DE values of HB were significantly higher (P<0.05) compared to SBBS, while the values of SBRS were intermediate between them without significant differences. Meantime, CF digestibility was significantly higher (P<0.05) for SBSR and SBBS compared with HB. While, the digestibility coefficients of CP, EE and NFE and DCP value were nearly similar for the different kinds of sprouted barley.

Table 4: Chemical composition, digestibility coefficients and nutritive values of sprouted barley grains

Item	HB	SBRS	SBBS	SEM
Chemical composition				
DM %	18.65	24.36	24.82	
Composition of DM %				
OM	96.40	93.79	92.80	
CP	17.01	16.88	16.97	
CF	12.73	18.39	19.26	
EE	3.31	3.24	3.12	
NFE	63.35	55.28	53.45	
Ash	3.60	6.21	7.20	
Digestibility coefficients %				
DM	67.96^{a}	65.42^{ab}	64.01^{b}	0.69
OM	69.41^{a}	66.81^{ab}	65.38^{b}	0.71
CP	68.04	67.32	66.88	0.42
CF	57.56^{b}	65.37^{a}	67.41^{a}	1.55
EE	75.82	74.28	73.94	0.52
NFE	72.69	71.14	70.08	0.56
Nutritive values				
TDN %	70.60^{a}	68.13^{ab}	66.98^{b}	0.66
DCP %	11.57	11.36	11.35	0.07
DE kcal/kg DM	3113^{a}	3004^{ab}	2953^{b}	29

a, b: values in the same row with different superscripts differ significantly (P<0.05)

Feeding trial

Chemical composition of commercial rabbit diets and sprouted barley grains are shown in Table 5. Chemical composition of commercial rabbit diets and different sprouted barley grains on agricultural by-products were nearly similar except the contents of OM and NFE were higher and CF and ash contents were lower in hydroponic barley (HB). So, the chemical composition was slightly varied among the different experimental diets except the contents of OM and NFE tended to be higher and CF and ash contents tended to be lower in D2 containing 30% hydroponic barley (HB).

The digestibility coefficients of different nutrients and nutritive values were nearly similar for the commercial rabbit diet and the other diets contained 30% sprouted barley. This finding may be attributed to that the chemical composition and nutritive values of sprouted barley were almost similar to the commercial rabbit diet. The values of the proximate analysis of the experimental diets showed iso-nitrogenous and iso-caloric values.

Digestible crude protein value was ranged from 11.26 to 11.36% and digestible energy ranged from 2822 to 2945 kcal / kg diet.

Table 5: Chemical composition, digestibility coefficients and nutritive values of experimental diets

Item	Experimental diets				SEM
	D1	D2	D3	D4	
Chemical composition					
DM %	91.27	45.30	52.07	52.76	
Composition of DM %					
OM	90.27	92.11	91.33	91.03	
CP	16.78	16.85	16.81	16.84	
CF	17.81	16.29	17.98	18.25	
EE	2.79	2.95	2.93	2.89	
NFE	52.89	56.02	53.61	53.05	
Ash	9.73	7.89	8.67	8.97	
Digestibility coefficients %					
DM	66.35	67.70	67.12	66.91	0.52
OM	67.70	69.08	68.49	68.27	0.53
CP	67.12	67.40	67.24	67.35	0.50
CF	65.90	64.96	66.54	67.51	0.56
EE	73.94	78.07	77.51	76.56	0.74
NFE	68.76	70.84	69.69	68.98	0.57
Nutritive values %					
TDN	64.01	66.80	65.73	65.23	0.57
DCP	11.26	11.36	11.30	11.34	0.08
DE	2822	2945	2898	2876	25

D1: commercial rabbit diet (CRD), D2: 70% CRD + 30% hydroponic barley (HB), D3: 70% CRD + 30% sprouted barley on rice straw (SBRS), D4: 70% CRD + 30% sprouted barley on bean straw (SBBS).

Results in Table 6 show that initial and final live body weight and total and daily weight gain were nearly similar for the rabbits fed the different experimental diets as well as for male and female and were not affected by HB, SBRS or SBBS inclusion. However, means of final live body weight, total and daily weight gain were significantly ($P<0.05$) higher for male than female rabbits. These results indicated that body weight gain was not affected by replacing of 30% of CRD with HB, SBRS or SBBS. These results may be attributed to that the experimental diets showed iso-nitrogenous and iso-caloric values (11.26 to 11.36% DCP and 2822 to 2945 kcal DE / kg diet). Energy and protein are the most important factors required to obtain maximum weight gain (Lebas, 1989). Santoma et al. (1989) proposed that feed of rabbits should contain around 10.5 MJ digestible energy / kg DM and diets offered *ad libitum* with at least 9.5 MJ/kg DM digestible energy (DE) optimized growth performance. Growth rate of rabbits decreased with diets contained low levels of fiber (De Blas et al., 1986). Steers fed rolled corn and rolled, sprouted durum had similar (P≥0.11) final body weight and average daily gain compared with steers fed whole, sprouted barley or durum (Reed et al., 2005). The replacement up to 50% of the commercial concentrate diet with hydroponic green oats forage did not significantly affect (P≤0.05) the final body weight of Californian rabbits (Carmona et al., 2011). Weight gain and final body weight of rabbits were not significantly (P>0.05) differed among the treatment groups of growing rabbits of mixed breed (Chinchilla x Dutch x California White) fed concentrate feed restriction in the presence of *ad libitum* forage (Adeyemi and Akanji, 2012). Forage supplementation had no significant influence on body weight gain of rabbits (Moussa et al., 2014).

Table 6: Body weight and body weight gain (g) of growing male and female rabbits fed the experimental diets

Item	Sex	Experimental diets				Mean	MSE
		D1	D2	D3	D4		
Initial weight	Male	1001.25	1037.50	1067.50	1013.75	1030.00	36.65
	Female	961.67	936.67	921.67	955.00	943.75	39.78
	Mean	977.50	977.00	980.00	978.50	978.25	28.50
Final weight	Male	2359.50	2427.50	2435.20	2360.20	2395.60*	39.11
	Female	2256.30	2221.20	2170.30	2213.50	2215.10	46.49
	Mean	2297.00	2303.70	2276.30	2272.20	2287.30	34.65
Total gain	Male	1358.20	1390.00	1367.80	1346.50	1365.60*	13.74
	Female	1293.70	1284.50	1248.70	1258.50	1271.30	13.04
	Mean	1319.50	1326.70	1296.30	1293.70	1309.00	12.00
Daily gain	Male	24.25	24.82	24.42	24.04	24.39*	0.25
	Female	23.10	22.94	22.30	22.47	22.70	0.23
	Mean	23.56	23.69	23.15	23.10	23.38	0.21

* Significant difference in mean values between male and female rabbits (P<0.05)

Total feed intake, feed conversion ratio and performance index for growing male and female rabbits fed the experimental diets are presented in Table 7. The total feed intake, feed conversion ratio and performance index (PI) were nearly similar for the different groups and tended to increase in male than female rabbits. The replacement up to 50% of the commercial concentrate diet with hydroponic green oats forage did not significantly affect (P≤0.05) feed intake by Californian rabbits (Carmona et al., 2011). Feed intake and feed: gain ratio of rabbits were not significantly (P>0.05) differed among the treatment groups of growing rabbits of mixed breed (Chinchilla × Dutch × California White) fed concentrate feed restriction in the presence of *ad libitum* forage (Adeyemi and Akanji, 2012).

Table 7: Total feed intake, feed conversion ratio and performance index (PI) for growing male and female rabbits fed the experimental diets

Item	Sex	Experimental diets				Mean	MSE
		D1	D2	D3	D4		
Total feed intake (as fed, kg)							
	Male	5.65	4.02	4.10	3.98	4.44	
CRD	Female	5.40	3.73	3.70	3.78	4.16	
	Mean	5.50	3.85	3.86	3.86	4.27	
	Male	0.00	6.95	5.81	5.49	4.56	
SB	Female	0.00	6.44	5.24	5.21	4.22	
	Mean	0.00	6.64	5.46	5.32	4.36	
Total feed intake (on DM, kg)							
	Male	5.15	4.96	5.15	4.99	5.06	0.11
DM	Female	4.93	4.60	4.65	4.74	4.73	0.13
	Mean	5.02	4.75	4.85	4.84	4.86	0.09
	Male	3.30	3.32	3.39	3.26	3.31	0.07
TDN	Female	3.16	3.08	3.06	3.09	3.09	0.08
	Mean	3.21	3.17	3.19	3.16	3.18	0.06
	Male	580	564	582	566	573	12
DCP	Female	555	523	525	537	535	15
	Mean	565	539	548	549	550	10
	Male	14536	14618	14925	14357	14609	316
DE	Female	13914	13559	13473	13625	13643	364
	Mean	14163	13983	14054	13918	14029	261
Feed conversion (kg/kg gain)							
	Male	3.80	3.58	3.76	3.70	3.71	0.08
DM	Female	3.82	3.58	3.71	3.76	3.72	0.09
	Mean	3.81	3.58	3.74	3.73	3.72	0.06
	Male	2.43	2.39	2.48	2.42	2.43	0.05
TDN	Female	2.44	2.39	2.44	2.45	2.43	0.06
	Mean	2.44	2.39	2.45	2.44	2.43	0.04
	Male	428	407	426	420	420	9
DCP	Female	430	407	420	426	421	10
	Mean	429	407	422	424	420	7
	Male	10714	10551	10915	10649	10707	232
DE	Female	10766	10552	10761	10811	10722	247
	Mean	10745	10552	10822	10746	10716	173
Performance index (PI, %)							
	Male	62.31	68.37	64.68	63.79	64.79*	1.06
	Female	59.61	62.15	58.37	58.92	59.76	0.73
	Mean	60.69	64.64	60.90	60.87	61.77	0.72

* Significant difference in mean values between male and female rabbits (P<0.05)

Daily feed intake (g of DM) and feed efficiency are similar for rabbits fed commercial pelleted diets alone or with green forage (Moussa et al., 2014). Feed conversion of rabbits was not affected by replacing a commercial feed with hydroponic green barley forage (Morales et al., 2009). Steers fed rolled corn and rolled, sprouted durum had similar (P≥0.11) gain: feed ratio compared with steers fed whole, sprouted barley or durum (Reed et al., 2005).

Table 8: Economic efficiency for growing male and female rabbits fed the experimental diets.

Sex	Experimental diets				Mean	MSE
	D1	D2	D3	D4		
Price of total weight gain (LE):						
Male	29.88	30.58	30.09	29.62	30.04*	0.30
Female	28.46	28.26	27.47	27.69	27.97	0.29
Mean	29.03	29.19	28.52	28.46	28.80	0.26
Total feed cost (LE):						
Male	16.94[a]	15.54[ab]	15.02[ab]	14.56[b]	15.51	0.40
Female	16.21[a]	14.41[ab]	13.56[b]	13.82[b]	14.50	0.45
Mean	16.50[a]	14.86[ab]	14.14[b]	14.12[b]	14.91	0.32
Net revenue (LE):						
Male	12.94[b]	15.04[a]	15.07[a]	15.05[a]	14.53	0.47
Female	12.25[b]	13.84[a]	13.90[a]	13.87[a]	13.47	0.38
Mean	12.53[b]	14.33[a]	14.37[a]	14.34[a]	13.89	0.30
Net revenue improvement %:						
Male	100.00[b]	116.23[a]	116.46[a]	116.31[a]	113.12	3.85
Female	100.00[b]	112.98[a]	113.47[a]	113.22[a]	109.92	3.90
Mean	100.00[b]	114.28[a]	114.67[a]	114.46[a]	111.20	3.59

a, b: values in the same row with different superscripts differ significantly (P<0.05)
* Significant difference in mean values between male and female rabbits (P<0.05)

Results in Table 8 show that the price of total weight gain was nearly similar for male and female rabbits fed the different diets, while the mean price of total weight gain was significantly (P<0.05) higher for male than female rabbits. Meantime, male and female rabbits fed commercial rabbit diet (D1) revealed significantly (P<0.05) the highest total feed cost followed by those fed HB diet (D2), while those fed SBRS and SBBS diets (D3 and D4) had the lowest total feed cost. On the other side, the net revenue and net revenue improvement were significantly (P<0.05) higher for male and female rabbits fed diets contained 70% CRD plus 30% HB (D2), SBRS (D3) or SBBS (D4) compared to those fed CRD (D1). The net revenue improvements were about 16 and 13% for male and female rabbits, respectively. The increase in net revenue with feeding sprouted barley grains attributed to that replacing 30% of commercial rabbit diet by sprouted barley grains reduced feed cost. Using sprouted barely on Tamarix (BTm) or rice straw (BRs) in feeding growing lambs revealed a significant (P<0.05) improvements in economical feed efficiency (Fayed, 2011).

Caecal fermentation activities of male rabbits fed the experimental diets are presented in Table 9. The pH value and the concentrations of TVFA's and NH_3-N were insignificantly affected by feeding sprouted barley grains.

Table 9: Caecal fermentation activities of male rabbits fed the experimental diets

Item	Experimental diets				MSE
	D1	D2	D3	D4	
pH value	6.80	6.73	6.87	6.80	0.05
TVFA's (meq/dl)	10.40	10.13	11.07	11.33	0.26
NH_3-N (mg/dl)	11.19	11.00	11.76	10.84	0.40

a, b: Values in the same row with different superscripts differ significantly (P<0.05)

Table 10: Carcass characteristics of male rabbits fed the experimental diets

Item	Experimental diets				MSE
	D1	D2	D3	D4	
Slaughter weight (g)	2295.00	2331.70	2358.30	2328.30	33.97
Carcass weight (g)	1199.37	1239.53	1228.91	1191.86	22.02
Head (g)	123.33	126.67	120.00	126.67	2.37
Head %*	5.39	5.43	5.09	5.44	0.10
Liver (g)	71.67	66.67	70.00	81.67	2.79
Liver %*	3.12^{ab}	2.86^{b}	2.96^{ab}	3.51^{a}	0.11
Heart (g)	7.17	7.50	7.67	7.50	0.21
Heart %*	0.31	0.32	0.32	0.32	0.005
Kidneys (g)	16.67	15.00	15.00	16.67	0.83
Kidneys %*	0.72	0.64	0.63	0.71	0.03
Spleen (g)	1.63^{b}	1.38^{c}	1.60^{b}	1.90^{a}	0.06
Spleen %*	0.07	0.06	0.07	0.08	0.003
Lungs (g)	15.00	11.67	13.33	15.00	0.90
Lungs %*	0.66	0.50	0.56	0.64	0.04
Tests (g)	5.00	5.00	8.33	6.67	0.65
Tests %*	0.22	0.21	0.35	0.28	0.02
Abdominal fat (g)	13.33	10.00	20.00	13.33	1.93
Abdominal fat %*	0.57	0.43	0.83	0.56	0.07
Shoulder fat (g)	6.67^{bc}	5.00^{c}	11.67^{a}	10.00^{ab}	0.94
Shoulder fat %*	0.29^{bc}	0.21^{c}	0.50^{a}	0.43^{ab}	0.04
Dressing1 %	52.26	53.16	52.11	51.19	0.52
Dressing2 %	56.42	56.98	56.04	55.74	0.47

a, b, c: values in the same row with different superscripts differ significantly (P<0.05)
Dressing1%= Carcass weight*100/ Slaughter weight
Dressing2%= Carcass + liver+ heart +kidneys weights*100/ Slaughter weight
* % of slaughter weight

Results of carcass characteristics of male rabbits fed the experimental diets are shown in Table 10. Neither the slaughter and carcass weights (2328.30 and 1215.10 g on average, respectively) nor dressing percentage

(52.18 and 56.29% on average) were insignificantly affected by sprouted barley grains inclusion in diets. Also, the weights and percentages of organs and offal were insignificantly affected by sprouted barley grains inclusion in diets except liver percentage, spleen weight and the weight and percentage of shoulder fat revealed significant differences (P<0.05).

These results agreed with the findings of Morales et al. (2009) who found that dressing out percentage of rabbits were not affected by replacing a commercial feed with hydroponic green barley forage. The replacement up to 50% of the commercial concentrate diet with hydroponic green oats forage did not significantly affect (P≤0.05) the slaughter weight and dressing out percent of Californian rabbits (Carmona et al., 2011). Dressing percentage, retail cuts, physical structure and weights of internal organs (livers, kidneys, lungs and hearts) were not affected by the experimental treatments (P>0.05) of growing rabbits of mixed breed (Chinchilla × Dutch × California White) fed concentrate feed restriction in the presence of *ad libitum* forage (Adeyemi and Akanji, 2012). Forage supplementation had no significant influence on carcass productivity of rabbits (Moussa et al., 2014).

Table 11: Physical and chemical characteristics of meat of male rabbits fed the experimental diets

Item	Experimental diets				MSE
	D1	D2	D3	D4	
Physical characteristics					
pH	5.91	5.77	5.80	5.83	0.05
Color intensity	0.172	0.173	0.163	0.143	0.008
Tenderness (cm)	2.48	2.50	3.53	2.52	0.02
Water holding capacity(cm)	5.71	5.74	5.83	5.79	0.04
Chemical characteristics %					
Moisture	73.59	73.67	73.55	73.45	0.18
Protein	22.29	21.84	21.50	21.69	0.40
Ether extract	1.77	2.04	1.94	1.75	0.10
Ash	0.87	0.87	0.77	0.98	0.04

The physical and chemical characteristics of rabbit meat are shown in Table 11. The differences in physical characteristics of rabbit meat including pH value, colour, tenderness and water holding capacity were not significant among the experimental groups. These findings indicated that sprouted barley grains had no effect on characteristics of rabbit meat because pH value represents a key role in the maintenance of the meat quality during storage and depends on the balance of muscle energy metabolism. Also, chemical characteristics of rabbit meat including moisture, protein, ether extract and ash were not significantly affected with feeding sprouted barley grains.

CONCLUSIONS

From these results it could be concluded that it can be produced sprouted barley on agricultural by-products, which increased the fresh and dry yield. Replacing 30% of commercial rabbit diet by sprouted barley on agricultural by-products did not have any adverse effect on rabbit performance.

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