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Utilization of Artichoke (*Cynara scolymus*) By-Products in Sheep Feeding

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Abstract: This study was conducted to evaluate the effect of insert artichoke (*Cynara scolymus*) by-products in Rahmany sheep rations and its effect on animals performance. Twelve male growing Rahmany lambs aged 8 months with an average body weight 31.7 Kg ±0.38 were fed three rations (4 animals/ration). The three groups were fed concentrate feed mixture (FCM) to cover 50% of nutrients requirements, plus kidney bean straw, control (1st group), a 1:1 mixture of kidney bean straw and artichoke by-products (2nd group) or artichoke by-products only (3rd group). The roughages were fed *ad lib.* Daily live weight gain, dry matter intake and feed conversion were measured. Digestibility trials were conducted to determine the nutrients digestibility and nutritive values of the three tested rations. Rumen parameters were also measured. Obtained results showed that artichoke by-products had higher value of CP (16.6%) compared with kidney bean straw (10.04%) and nearly similar with CFM, but the CF content was higher in artichoke by-products (24.22%) compared with 20.72% for kidney bean straw and 11.17% for CFM. Amino acids estimation shows that artichoke by-products had higher values in most amino acids, while it had lower values in a few amino acids compared with kidney bean straw. The dry matter intake of group 3 was higher than the other tested rations. Nutrients digestibility and nutritive values in terms of TDN and DCP for group 3 were the highest, followed by group 2 and group 1, respectively. Concerning average daily gain, animal fed ration 3 recorded highest gain (262 g) followed by group 2 (257 g) then group 1 (248 g). The values of feed conversion recorded the best for group 1 followed by group 2, then group 3. Group 3 showed the lowest ruminal pH at zero time, while recorded the highest values ($P<0.05$) of ammonia nitrogen and TVFA's with G2 compared with G1 and ($P<0.05$) with G3. And the results indicated that all ruminal parameters values were in the normal range for all groups. In conclusion, insert the artichoke by-products in sheep ration improve animal performance.

Key words: Artichoke by-products · Growth performance · Kidney bean straw · Nutrients digestibility · Ruminal parameters · Sheep

INTRODUCTION

Recovering by-products for use as animal feed can help food processors save money, while preventing pollution. Offering by-products for use as animal feed is an economical and environmentally sound way for food processors to reduce waste discharges and cut waste management costs. Selling by-products can also produce additional revenue. Livestock producers can save money as well if by-products offer a less expensive source of nutrients than traditional feeds and if they support acceptable animal performance [1]. Artichoke (*Cynara scolymus* L.) represents an important component of the Mediterranean diet. Artichoke is a rich source of minerals, a low amount of lipids, dietary fibre and a high proportion of phenolics [2, 3]. It is a good source of natural antioxidants such as vitamine C, carotenoids, polyphenols, hydroxyl cinnamic acid and flavones [4, 5]. It is rich source of inulin and oligofructose, which belong to a class of carbohydrates known as fructose [6]. The CP content of artichoke by-product is nearly to alfalfa hay (15%) and has low crude fiber content, 14.5% [7]. In Egypt, there is an annual production of nearly 202458 tons of artichoke [8]. In Egypt, about 8617 faddans (one faddan = 0.42ha) are cultivated with artichoke, which produce about 7.84 tons/faddan [9]. Flower head of artichoke weights about 200 g, while artichoke bracts weights 70-80 g, about 37% of the flower head weight [10].

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Large amounts of artichoke bracts are produced annually by-products. The artichoke canning industry generates large amounts of agricultural wastes represent about 80-85% of the total biomass of the plant consisting mainly of the leaves [5]. Artichoke by-products proved to be excellent unconventional feedstuffs for ruminant, equivalent to any conventional feed like alfalfa or Tifon hay. This by-product has potential fermentation efficiency and could be incorporated in feed mixture to replace conventional roughage sources in ruminant diets without major problem [11, 12].

The aim of the current study was to evaluate the sheep performance fed ration containing artichoke by-products.

MATERIALS AND METHODS

This study was carried out at the Agricultural Production and Research Station, National Research Centre, Nubaria Province, Beheira Governorate and in the Laboratories of Animal Production Department, National Research Centre, Dokki, Giza, Egypt.

Animals, Experimental Design and Diets: Twelve growing male Rahmany lambs weighed average 31.7 Kg ±0.38 were randomly allocated into three groups (4 animals in each). The first received concentrate feed mixture (CFM) plus kidney bean straw, the second received CFM plus kidney bean straw + artichoke by-product (1:1) and the third group received CFM plus artichoke by-products. The chemical composition of the CFM, kidney bean straw and artichoke by-products are shown in Table 1. The experimental rations were fed individually two times daily at 8 a.m. and 4 p.m., while residues were removed and weighed once daily. The roughages (kidney bean straw and artichoke by-product) were fed *ad lib.,* while the three groups were fed CFM to cover 50% from recommended allowances of NRC [13]. Fresh water was freely available all time. Lambs weights were recorded at the beginning, thereafter at biweekly intervals and in the end of the experiment after water and feed were withdraw for 12 hrs. The feeding trials lasted for 90 days.

Apparent Digestibility: Three digestibility trials were applied during the last three days of the second month using three animals from each group. Silica (acid insoluble ash, AIA) was used as internal marker for determining the digestibility [14]. At 4 hrs after the morning feeding, fecal samples (approximately 100g weight) were collected from the rectum during the last three days every month and pooled by animal for each period, dried at 60°C for 48 hrs and then ground to pass a 1mm size in feed mill for chemical analysis. Dry matter excreted in feces was calculated by dividing silica input in the feeds (grams of silica per day) by silica output in the feces (grams of silica per day). The digestibility coefficient of certain nutrient was calculated according to the following formula [14]:

$$\text{Digestion coefficient of nutrient} = 100 - \left(\frac{100 \times \text{AIA in feed} \times \%\text{nutrient in feces}}{\%\text{AIA in feces} \times \%\text{nutirent in feed}} \right)$$

Rumen Liquor Parameters: Rumen fluid samples were taken individually from animals at the end of digestibility trials before feeding (zero time) and at 3 hrs post feeding using a stomach tube. Samples were filtered through four layers of surgical gauze, samples were separated into 2 portions, the first portion was used for immediate determination of pH value by Orion Research digital pH-meter, model 201. Ammonia-nitrogen (NH_3-N) concentration was determined according to Conway [15], while the 2nd portion was stored at-20°C after adding few drops of toluene and a thin layer of paraffin oil till analyzed for TVFA's according to Warner [16].

Proximate Composition: The moisture content of the samples was determined by oven-drying to constant weight at 105°C. Crude protein (CP), ether extract (EE), crude fiber (CF) and ash content were determined according to the standard methods of AOAC [17]. Nitrogen free extract (NFE) were calculated by difference.

Amino Acids Analysis: Amino acids content was determined as described by Spackman *et al.* [18] and Moore *et al.* [19]. The analysis was performed in Central Service Unit, National Research Center, Egypt, using LC 3000 Amino Acid Analyzer (Eppendorf-Biotronik, Germany). The technique was based on the separation of the amino acids using strong cations exchange chromatography followed by the ninhydrin colour reaction and photometric detection at 570 nm. Samples were hydrolyzed with 6 N HCl at 110°C in teflon-capped vials for 24 h. After vacuum removal of HCl, the residues were dissolved in a lithium citrate buffer (pH 2.2) then 20 µl of the solution were loaded onto the cation exchange column (pre-equilibrated with the same buffer), then four lithium citrate buffers with pH values of 2.2, 2.8, 3.3 and 3.7, respectively, were successively applied to the column at flow rate 0.2 ml/min. The ninhydrin flow rate was 0.2 ml/min at a pressure of 0 to 150 bar. The pressure of buffer was from 0 to 50 bar and at reaction temperature 130°C.

Statistical Analysis: Obtained data were subjected to statistical analysis using general linear models (GLM) procedure of SAS [20] and significance was declared at $P<0.05$.

RESULTS AND DISCUSSION

Chemical Analysis, Cell Wall Constituents and Amino Acids Content: The proximate chemical analysis of CFM, kidney bean straw and artichoke by-product are shown in Table 1. The data indicated that artichoke by-products contained a higher value of CP (16.61%) than kidney bean straw (10.04%) and nearly similar CP content relative to the CFM (15.32%). Also, artichoke by-product contained higher values of EE (5.46%) and CF (24.2%) compared with kidney bean straw. These results are in agreement with those reported by Hindrichsen *et al*. [21], who reported that artichoke by-product contain about 16.9% CP, but this value was higher than obtained by Ghanem [11], Serafettin and Mehmet [7], who reported that, CP of artichoke by-product was ranged between 11.43 and 14.38%. The protein content can vary between less than 5% to more than 23% DM [22, 23, 24]. However, kidney bean straw had two times ash content more than artichoke by-products. The NDF, ADF and cellulose content of artichoke is lower than kidney bean straw (Table 1). The results of fiber fractions of artichoke by-product are in agreement with those obtained by Meneses *et al*. [25], who mentioned that the ADL, NDF and ADF content of artichoke by-product were 10.3, 42.9 and 30.3%, respectively. The cell wall and lignin contents of artichoke by-products foliage increase during vegetative growth. The NDF content varies from less than 30 % to more than 50% DM [22, 23].

Results in Table 2 demonstrated the amino acids content (g/100g sample) in artichoke by-products and kidney bean straw. The major amino acids in artichoke by-products was glutamic and aspartic acid, while in kidney bean straw were proline and glutamic acid. These results indicated that artichoke by-products contain higher content of methionine, histidine, phenylalanine, leucine, valine, serine and isoleucine compared with kidney bean straw, but contain lower value of lysine, arginine, proline, aspartic acid, glutamic acid, alanine and cystin, while it contained the same content of thereonine, glycine and tyrosine. The essential amino acids concentration of leaf proteins is similar to that of cereal grains, but is richer in lysine [26]. Cieslik *et al*. [27] stated that the protein content of artichoke by-products varies from 5 to 12 % DM. The protein contains four times the amount of sulphur amino acids and over twice the amount of essential amino acids than chicory roots and potato tubers.

Table 1: Chemical composition and fiber fraction of feed ingredients (% on DM basis)

Item	Artichoke by-products	Kidney bean straw	Concentrate feed mixture*
Chemical composition:			
DM	92.30	92.50	92. 43
OM	87.34	74.80	92.08
CP	16.61	10.04	15.32
CF	24.22	20.72	11.17
EE	5.46	2.14	7.60
NFE	41.05	41.90	57.99
Ash	12.66	25.20	7.92
Fiber fraction:			
NDF	42.90	51.02	-
ADF	30.00	43.96	-
ADL	10.10	7.06	-
Hemicellulose	12.90	9.44	-
Cellulose	19.90	36.90	-

*Concentrate feed mixture (CFM): composed as 45% yellow corn, 35% undecorticated cotton seed meal, 17% wheat bran, 1.5% limestone, 1% sodium chloride and 0.5% minerals and vitamins mixture.

Hemicellulose = NDF-ADF. Cellulose = ADF-ADL.

Table 2: Amino acids concentration (g/100g sample) of artichoke by-products and kidney bean straw

Amino acids	Artichoke by-products	Kidney bean straw
Essential amino acids:		
Thereonine	0.14	0.14
Valine	0.55	0.14
Methionine	0.36	0.10
Isoleucine	0.25	0.14
Leucine	0.59	0.41
Phenylalanine	0.56	0.46
Histidine	0.36	0.15
Lysine	0.14	0.24
Arginine	0.26	1.21
Proline	0.51	2.65
Non essential amino acids:		
Aspartic acid	0.63	0.91
Serine	0.27	0.02
Glutamic acid	0.67	1.50
Glycine	0.15	0.15
Alanine	0.37	0.71
Cystin	0.26	0.36
Tyrosine	0.22	0.21

Table 3: Digestion coefficients and nutritive values of the experimental rations

	Experimental rations			
Item	G1	G2	G3	±SE
Apparent digestibility (%):				
DM	74.40[c]	76.50[b]	78.23[a]	2.34
OM	73.23[c]	75.37[b]	78.93[a]	2.89
CP	60.12[b]	62.31[a]	63.62[a]	1.23
CF	63.25[b]	66.75[a]	66.62[a]	1.25
EE	72.39[a]	71.44[a]	73.84[a]	0.82
NFE	69.53[b]	70.31[b]	73.40[a]	1.23
Nutritive value (DM %):				
TDN	64.53[b]	67.31[a]	67.60[a]	1.63
DCP	7.80[b]	8.60[a]	8.30[a]	0.84

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

Table 4: Growth performance of Rahmany lambs given the experimental rations

	Experimental rations			
Item	G1	G2	G3	±SE
Body weight gain:				
Initial body weight (kg)	31.10	32.00	32.00	
Final body weight (kg)	53.40[b]	55.10[a]	55.60[a]	1.27
Total body weight gain (kg)	22.30[a]	23.10[a]	23.60[a]	0.78
Average daily weight gain (g)	248[c]	257[b]	262[a]	4.97
Growth rate (%)*	71.70	72.18	73.75	1.50
Feed intake (g/h/d):				
DM:				
Concentrate	1264	1299	1307	--
Roughages	433	508	540	--
Total	1697	1807	1847	--
TDN	1095[b]	1216[a]	1249[a]	--
DCP	132.4	155.4	152.6	--
Feed conversion (kg intake/kg gain):				
DMI	6.87	7.06	7.02	--
TDNI	4.43	4.75	4.77	--
DCPI	0.54	0.61	0.58	--

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

*Growth rate (%) =Total BWG (Kg)/ Initial BW (Kg) x 100.

Nutrients Digestibility and Feeding Value: Results of the digestibility trials are shown in Table 3. The digestibility of all nutrients increased in group 3 (artichoke by-product) and the total digestible nutrients (TDN) and digestible crude protein (DCP) were significantly (P<0.05) higher for animals receiving the diets containing artichoke by-products only as a roughage compared with the other two rations, however the animal receiving kidney bean straw + artichoke by-product recorded the highest values compared with control ration. Sallam *et al*. [12] reported that on the basis of digestibility of artichoke by-product proved to be excellent unconventional feedstuffs for ruminants, equivalent to any conventional feed like alfalfa hay, they adding that artichoke have potential fermentation efficiency and could be incorporated in feed mixture to replace conventional roughage sources (e.g. hay and silage) in ruminant diets without any problem. Hindrichsen *et al*. [28] reported that artichoke diet recorded the highest values of OM and CP digestibility compared with the many other by-products diets, also Petkov *et al*. [29] found that, when fed to sheep, Jerusalem artichoke has high digestibility coefficients for all nutrients. Bramble *et al*. [30] found that, when J. artichoke replacing of 20% of steam flaked corn in beef steers diet the DM and CP digestibility were very high. Also, Sallam *et al.* [12] reported that the use of artichoke by-product in ruminants diet resulted in highest DMD and OMD compared with Tifon hay diet. At flowering stage, the whole plant showed an *in vitro* DM digestibility of about 60 % that was lower than that observed for sunflower forage [31]. The substitution of alfalfa up to 30% from Jerusalem artichoke foliage at full bloom did not affect on *in vitro* digestibility of diet [32].

Growth Performance: Data of growth performance of lambs fed experimental rations are presented in Table 4. Body weights of the three animal groups were similar at the start of the trial (31.1, 32.0 and 32.0 kg for G1, G2 and G3, respectively). However, at the end of the experimental period, G3 that fed artichoke by-product only as a roughage recorded the highest final body weight (55.6 kg). The highest values (P<0.05) of average daily weight gain was recorded as 262 g/h/d for sheep fed artichoke by-product and 257 g/h/d for G2 (artichoke and kidney bean straw diet) compared with the 248 g/h/d for kidney bean straw (control) diet. In field trials, Jerusalem artichoke forage was either completely or nearly completely rejected by grazing lambs when compared to other perennial grasses [33]. For Roe deer, the quantity of Jerusalem artichoke fodder should be limited in practice [34]. In growing steers, Jerusalem artichoke by-products could substitute for 20% of steam-flaked maize without altering DM and protein digestibility and nitrogen retention [30]. Jerusalem artichoke by-products were found to be a particularly good feed for animals in the late

Table 5: Ruminal parameters of lambs fed rations containing artichoke by-products and kidney bean straw

	Experimental rations			
Item	G1	G2	G3	±SE
Ruminal parameters				
pH				
Zero (hr)	7.3[a]	6.7[b]	6.5[b]	0.32
3 (hrs)	6.3[a]	6.3[b]	6.3[b]	0.29[NS]
NH_3-N(mg/100ml)				
Zero (hr)	18.9[b]	23.2[a]	22.4[a]	0.39
3 (hr)	19.2[b]	28.1[a]	26.8[a]	0.42
TVFA's (meq/100 ml)				
Zero (hr)	13.7[b]	14.0[a]	15.6[a]	0.09
3 (hr)	15.0[b]	19.5[a]	18.7[a]	0.23

a and b: Means in the same row with different superscripts are significantly ($P<0.05$) different.

Table 6: Economic evaluation of the experimental rations for growing lambs

	Experimental rations		
Item	G1	G2	G3
No. of animals	4	4	4
Purchase cost (L.E.*/head)[1]	1244.20	1280.0	1280.0
Feed cost (L.E./head)[2]	347.05	357.28	290.49
Management cost (L.E./head)[3]	18.0	18.0	18.0
Total cost (L.E./head)[4]	1609.25	1655.28	1588.49
Selling income (L.E./head)[5]	1975.80	2038.70	2057.20
Net revenue (L.E./head)[6]	366.55	383.42	468.71
Economic efficiency (%)[7]	23.00	23.00	30.00
Relative economic efficiency (%)[8]	100	100	130
Feed cost L.E./kg gain	15.56	15.46	12.30

* L.E. = Egyptian pound = 0.143 $ approximately for any treatment.

1. Initial body weight x price of one kg (40.0L.E.).
2. Calculated according to the local price in 2013 (2500, 900 and 700 L.E./ton for concentrate feed mixture, kidney bean straw and artichoke by-products, respectively).
3. Include operation and medicinal costs.
4. Include the purchase, management and feed costs.
5. Final body weight x price of one kg at selling (37.0 L. E.).
6. Selling income-total cost.
7. Net revenue/total cost x 100.
8. Economic efficiency for treatment/economic efficiency for control, assuming that relative economical efficiency of the control group equal 100.

fattening stage and for pregnant sows [35]. Jerusalem artichoke by-products are therefore worth using feeding as they may improve animal health (probiotic effect), animal welfare (preventing stereotypic behavior) and reduce the environmental impact of animal farming [36].

Average daily feed intake expressed as DM, TDN and DCP g/h/day for different groups are presented in Table 4. The highest value was recorded by G3 (1847 g/h/d) followed by G2 (1807 g/h/d) compared with G1 (1697 g/h/d). This might be due to the high palatability of artichoke by-product compared with kidney bean straw. The feed conversion expressed as intake of DM required per kg gain showed that the lambs fed (G1) had better feed conversion followed by (G3) and (G2). These results may be attributed to the high total DMI recorded for artichoke by-product compared with kidney bean straw. The same trend was observed for feed conversion as TDN and DCP values.

Rumen Fermentation Parameters: Effect of experimental rations on pH, NH3 and TVFA's concentrations of rumen liquor is show in Table 5.The pH values were in range of 6.0 to 7.3 which is necessary for the normally functioning rumen [37]. The highest value of pH (7.3) was recorded for G1 and the lowest (6.3) in G 3. Also, the concentration of TVFA's at zero h and 3h post feeding was higher ($P< 0.05$) in G2 and G3 compared with G1. Concentration of NH3 was increased significantly ($P<0.05$) at 0h and 3h post feeding with feeding artichoke by-products. The increase in rumen NH_3 concentration could satisfy the microbial needs for N. maximize rate of fermentation in the rumen and finally enhance the synthesis of microbial protein in the rumen. Sallam *et al*. [12] reported that artichoke by-product diet recorded the highest value of NH3-N concentration compared with other by-products.

Economic Efficiency: Results of economic evaluation of the three experimental rations are shown in Table 6. Feed cost/kg body weight gain were lower for lambs fed rations 3 (12.3) and 2 (15.46 L.E.) than those fed ration 1 (control, 15.56 L.E.). However, total cost/head recorded for groups 1 and 3 were nearly similar and both were lower than that observed for group 2. The profitability of using artichoke by-products as an unconventional cheap feedstuff in sheep rations depends on the price of this by-product and its effect on animal performance (feed conversion). The results obtained also indicated that group fed artichoke by-product as a sole roughage source (3) achieved the highest economic efficiency (30%) and relative economic efficiency (130%) compared with groups 1 and 2 which recorded the same values, these results agreed well with those obtained by Ghanem [11], who concluded that, substitution berseem hay with artichoke by-products (dried or silage) for feeding growing lambs resulted in

appreciable reduction in feed cost and economic efficiency without any adverse effect of animal performance.

Finally, the present study suggested that the possibility of using artichoke by-products as a good quality roughage in ration for growing sheep. Further work in needed to determine the proper level of artichoke by-products in rations for fattening or lactating ruminants.

CONCLUSION

In conclusion, on the basis of chemical composition, kinetics of amino acids, digestibility and growth performance of artichoke by-products proved to be excellent unconventional feedstuffs as a roughage for ruminants, equivalent to any conventional roughage feeds like kidney bean straw. This study suggested that artichoke have potential efficiency and could be incorporated in feed mixtures to replace conventional roughage sources (e.g. hay and silage) in ruminant diets without any problem. However, further studies are required and animal feeding tests should be carried out to investigate the effect of using artichoke by-products in rations for lactating animals on physiology and health status.

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