Replacement of Clover Hay by Biologically Treated Corn Stalks in Growing Sheep Rations

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Abstract

Thirty-six male growing Rahmani lambs aged 6 months with an average weight 19.07 ± 0.21 kg were used to determine the effects of inclusion biologically treated corn stalks (BTCS) treated with *Trichoderma ressi* (*T. ressi*) on growth performance. Animals were divided into four equal groups and assigned for control ration contained 30% clover hay (CH) and another three experimental rations replaced CH in control ration (TMR_1) with BTCT at 33%, 66% and complete replacement 100% of CH for (TMR_2, TMR_3 and TMR_4), respectively. The results showed that treatment of BTCS decreased DM, OM, CF, EE contents, while CP and ash contents were increased in comparison with untreated corn stalks (UTCS). Also, it reduced all cell wall constituents (NDF, ADF, ADL, cellulose and hemicelluloses) compared to UTCS. biologically treated corn stalks containing diets significantly improved ($P<0.05$) all nutrient digestibility coefficients and cell wall constituent digestibilities compared to the control diet. Total digestible nutrient (TDN) was significantly improvement ($P<0.05$), while digestible crude protein (DCP) insignificantly ($P>0.05$) improved. Ruminal pH, ammonia nitrogen (NH_3-N) and total volatile fatty acids (TVFA's) concentrations were increased. Sampling time had no significant effect on ruminal pH while, it significantly ($P<0.05$) increased NH_3-N and TVFA's concentrations at 3 hours post feeding compared to before feeding. There were significant ($P<0.05$) interaction between dietary treatments and sampling time (TxS) on ruminal pH, NH_3-N and TVFA's concentrations. All blood plasma parameters were within the normal range. Blood plasma hemoglobin, glucose, total protein, albumin and albumin: globulin ratio were significantly increased ($P<0.05$). However, blood plasma urea, creatinine, triglycerides and cholesterol were significantly ($P<0.05$) decreased. Blood plasma GOT and GPT were insignificant ($P>0.05$) decreased. Final weight, total body weight gain, average daily gain (ADG) and relative gain were significantly ($P<0.05$) improved. ADG was improved by 10.53%, 18.42%, 27.89% for TMR_2, TMR_3 and TMR_4, respectively compared to the control ration (TMR_1). Daily feed intakes of DM, TDN, CP and DCP (g/h/day) were increased. Feed conversion (kg intake /kg gain) of DM, TDN, CP and DCP were significantly ($P<0.05$) improved. Feed cost (LE per kilogram gain) was improved by 9.59%, 14.82% and 22.46% for TMR_2, TMR_3 and TMR_4, respectively compared to the control diet TMR_1.

It could be concluded that biologically treated corn stalks can be successfully fed to lambs without any adverse effect on digestibility coefficients, ruminal fermentation, blood plasma constituents and performance. Also, BTCS can be used economically in formulation of sheep rations as a good alternative source of clover hay.

Keywords: *Trichoderma ressi,* Biologically treated corn stalks, Sheep, Nutrient digestibility coefficients, Ruminal fermentation, Blood constituents, Growth performance, Economic evaluation

1. Introduction

Recently, the agricultural policy in Egypt aimed to increase the area cultivated by strategically crops on behalf of that cultivated by clover. At the same time, several crops produced significant amounts of residues (stalks, cobs, straws…..etc). On the other hand, several researches have shown that these by-products had considerable amounts of nutrients that of suitable digestibilities.

It is useful to convert vast renewable resources from plant by-products and crop residues into food edible for humans. With recycling of these by-products, humanly inedible nutrients in them are utilized by animal which converting them into high-quality foods for human consumption and do not become a waste-disposal problem and reducing costs and imports of animal feedstuffs (Elkholy *et al.,* 2009a).

Recycling of plants by-products and crop residues to be used as animal feed help food processor to save money and also decrease the environmental pollution Elkholy *et al.,* 2009b).

In Egypt, among these crop residues left in field after harvesting is the corn crop resides which include (green corn, corn stover, corn stalk and corn cobs), there are about 26 million tons of plant by-products produced annually (El- Shahat *et al*., 2006 and Agriculture Economic and Statistics Institute, 2008), about 13600 thousands tons of them are from corn (El-Shaer, 2004).

Average crop residues of corn stalk in Egypt is 4.1 million tons (Badawi and Tantawi, 2004) of them 7.9 tons/Fadden in Sharkia governorate (Ministry of Agriculture 2006).

The main purpose of this study was to evaluate the use of low quality roughages as corn by-products (corn stalk) which treated with *Trichoderma ressi* to improve their nutritive value and to study the effect of replacement clover hay by BTCS in sheep rations on nutrient digestibility coefficients, ruminal fermentation, blood constituents, growth performance and economic evaluation.

2. Materials and Methods

Corn stalk was collected from local fields after harvesting and ground up to 2-3cm length then packed till using.

The microorganisms of *Trichoderma reesei* were preserved on Potato Dextrose Agar (PDA) medium at 25 ^{o}C until used. 100 g of corn stalks weighed, packed in heat resistant bags (10 x 20 cm) and sterilized by autoclaving for 121 ^{o}C for 30 minutes). Spore suspension of *T. reesei was* prepared and used to inoculate a sterilized liquid medium containing (g/L) 4% molasses, 0.4% urea, 0.2% KH_2 PO_4 and 0.03% $MgSO_47H_2O$ and incubated for 7 days. The treated corn stalk was moistened at 65 – 70% and put specific fungal spawn and left for three weeks.

Thirty-six of growing male Rahmani lambs, aged 6 months approximately with an average live weight of 19.07 ± 0.21 kg, were divided randomly into four equal groups (nine animals in each) and used to evaluate the effect of replacement 0%, 33%, 66% and complete replacement 100% of clover hay (CH) by biologically trated corn stalks (BTCS) in total mixed rations (TMR_1, TMR_2, TMR_3 and TMR_4, respectively). The animals were used in group feeding trial. The experimental rations were formulated to cover the requirements for total digestible nutrients and protein for growing sheep according to the NRC (1985). TMR was offered for sheep at 3% DM of their live body weight and adjusted every 2 weeks according to their body weight changes. The feeding trial lasted for 105 days, diets were offered twice daily (0800 and 1400 hours) while feed residues (if any) were removed and weighed once daily before morning feeding. Fresh water was available all the time in plastic containers. Live body weights were recorded weekly before morning feeding and after fasting overnight (feed and water).

At the end of the feeding trial, four animals from each group were used to determine digestion coefficients and nutritive values of the experimental rations. The nutritive values expressed as the total digestible nutrients (TDN) and digestible crude protein (DCP) of the experimental rations were calculated according to classic method by Abou-Raya (1967).

Rumen fluid samples were collected from animals used in digestibility trial (four animals for each treatment) at the end of the digestibility trial before feeding and 3 hours post feeding via stomach tube and strained through four layers of cheesecloth to study the effect of dietary treatments on ruminal fermentations, ruminal pH, ammonia nitrogen (NH_3–N), total volatile fatty acid (TVFA's) concentrations.

Blood samples were collected from the same lambs at the end of digestibility trials from the left jugular vein in heparinized test tubes at about 3 hours post feeding and centrifuged at 5.000 rpm for 15 minuets. Plasma were kept frozen at –20 °C for subsequent analysis of hemoglobin, glucose, total protein, albumin, GOT, GPT, urea, creatinine, triglycerides and cholesterol.

Representative samples of ingredients, untreated & biologically treated corn stalks, experimental rations and feces were analyzed according to A.O.A.C (2000) methods. Neutral detergent fiber (NDF), acid detergent fiber (ADF), and acid detergent lignin (ADL) were also determined in the ingredients untreated & biologically treated corn stalks and experimental rations according to Goering and Van Soest (1970) and Van Soest *et al.* (1991).

Ruminal pH was immediately determined using digital pH meter. Ruminal ammonia nitrogen (NH_3–N) concentrations were determined applying NH_3 diffusion technique using Kjeldahle distillation method according to A.O.A.C (2000). Ruminal total volatile fatty acids (TVFA's) concentrations were determined by steam distillation according to Kromann *et al.* (1967).

Plasma total protein was determined as described by (Armstrong and Carr, 1964); albumin (Doumas *et al.,* 1971); GOT and GPT according to Reitman and Frankel (1957); urea (Patton and Crouch, 1977); creatinine according to Folin (1994) triglycerides (Fossati and Principe, 1982); cholesterol (Allain *et al.,* 1974); and Plasma glucose was measured using the enzymatic glucose oxidase method (Bauer *et al.,* 1974). Globulin and albumin: globulin ratio (A: G ratio) were calculated.

Gross energy (mega calories per kilogram DM) was calculated according to Blaxter (1968), where, each gram of crude protein (CP) = 5.65 kcal, each gram of ether extract (EE) = 9.40 kcal, and each gram crude fiber (CF) and nitrogen-free extract (NFE) = 4.15 kcal.

3.1 Economic evaluation

The relation between feed costs and gain was calculated for the different experimental groups. The general equation by which the costs of 1 kg of live body weight gain was calculated as follows:

The cost for 1-kg gain = total cost (Egyptian pound (LE)) of feed intake/total gain (kilogram).

3.2 Statistical analysis

Collected data except for ruminal fermentation were subjected to statistical analysis as one way analysis of variance using the general linear model procedure of SPSS (1998). Duncan's Multiple Range Test (1955) was used to separate means when the dietary treatment effect was significant. On the other hand, ruminal parameters were subjected to statistical analysis as two factors-factorial analysis of variance.

4. Results and Discussion

4.1 Chemical analysis and cell wall constituents of ingredients and the experimental rations

From the data of Table (1) cleared that treatment of corn stalks with *Trichoderma ressi* decreased DM, OM, CF, EE contents, while CP and ash contents were increased in comparison with untreated corn stalks. These results were agreement with those obtained by Abd-Allah (2007) and Mahrous *et al.* (2009).

The improvement in CP content from 4.29 to 11.43% could be the result of the decrease of CF (Chandra *et al.,* 1991). The increase of ash was the reflection of the decrease in OM. These results indicated that the fungi soluble and structural carbohydrates. The improvement of CP content could be attributed to fungus growth on the produced cellulolytic enzymes by the fungal enzymatic system (El-Ashry *et al.*, 2003).

Biological treatment of corn stalks resulted in reducing all cell wall constituents (NDF, ADF, ADL, cellulose and hemicelluloses) compared to the untreated corn stalks. These results might be due to the break down of lignocellulose bonds where the cellulose can be hydrolyzed by fungi (El-Ashry *et al.*, 2002; El-Shafie *et al.;* 2007; Fayed *et al.,* 2009 and Mahrous *et al.,* 2009). McCarthy (1986) noted that fungus have a similar degradetive mechanism, as they degrade cellulose and hemicellulose by oxidize and solublize the lignin component.

Chemical analysis of the experimental rations (Table 2) showed that inclusion of BTCS in sheep rations slightly increased CF and ash contents, however it slightly decreased DM, OM, CP, EE, NFE and gross energy (GE) contents. On the other hand, with increasing the level of replacement of clover hay (CH) with BTCS increased cell wall constituents (NDF, ADF, ADL, hemicellulose and cellulose). These differences may be related to differ in chemical composition of CH compared to BTCS.

4.2 Nutrient digestibility and nutritive values of the experimental rations

Nutrient digestibility coefficients and nutritive values of the experimental rations are presented in Table (3). Biologically treated corn stalks with *T. ressei* containing diets significantly improved ($P<0.05$) all nutrient digestibility coefficients and cell wall constituent digestibilities compared to the control diet. Our data also, showed that, with increasing the level of replacement of CH by BTCS the nutrient digestibility coefficients and cell wall constituent digestibilities were increased. These results are in agreement with those obtained by Abd-Allah (2007) with biologically treated corn cobs by *T. ressei* and Mahrous *et al.* (2009) with biologically treated corn stalks by *T. ressei*. The increasing in CP digestibility may be due to the high CP content in the treated materials (Saleh *et al.*, 1998). Maseaki *et al.* (1992) noticed that the biological treated of straws as well as other fibrous roughage resulted in an increase of CP content and digestibility. Mahrous *et al.* (2009) showed that fungi treated corn stalks were resulted in more ($P<0.05$) digestibility coefficients of cell wall components compared with untreated materials. Also, they found that corn stalks treated with (*T. ressei* + *T. viride*) has higher digestibility coefficients of cell wall components than that of the other treatments. The improvement in cell wall digestibility coefficients as a result of biological treatments may be due to the effect of cellulose enzyme of fungi, which may be responsible for the stepwise hydrolysis of cellulose to glucose (Nsereko *et al.*, 2002).

Replacement CH at different levels by BTCS in sheep rations significantly improvement ($P<0.05$) total digestible nutrient (TDN) but insignificantly ($P>0.05$) improved digestible crude protein (DCP). These increases in TDN and DCP may be attributed to better digestibility of most nutrients in order to treatment. Mahrous *et al.* (2009) noted that treated corn stalks with (*T. ressei* + *T. viride*) were higher ($P<0.05$) values (60.37 and 9.26%) for TDN and DCP, respectively compared with the treatments. The biological treatments that used fungus (Mahrous *et al.*, 2005, Abd-Allah, 2007 and Mahrous *et al.,* 2009) or fibrolytic enzymes (David *et al.*, 1999) were tested to improve the nutritive value and digestibility of poor quality roughages.

4.3 Rumen fluid parameters of the experimental rations

Rumen fluid parameters of the experimental rations are presented in Table (4). Inclusion BTCS in sheep rations increased ruminal pH, ammonia nitrogen (NH_3-N) and total volatile fatty acids (TVFA's) concentrations compared to control diet. Abo Donia *et al* (2005) reported that biological treated peanut hulls and sugarcane bagasse increased significantly ($P<0.01$) pH values and concentration of NH_3-N in the rumen liquor compared with untreated rations.

Sampling time had no significant effect on ruminal pH while, it significantly ($P<0.05$) increased NH_3-N and TVFA's concentrations at 3 hours post feeding in comparison with before feeding. Increasing TVFA's might be related to the more utilization of dietary energy and positive fermentation in the rumen. These results are in agreement with those found by Mahrous *et al.* (2009) who noted that fed sheep on treated corn stalks containing diets recorded higher ($P<0.05$) NH_3-N concentration being 20.25, 18.65 and 22.38 (mg/100ml) for (T2, T3 and T4), respectively, compared with that of control ration (15.30 mg/100ml).

El-Badawi *et al.* (2007) found that ruminal NH_3-N concentration was obviously higher ($P<0.01$) after 3 and 24 hrs of feeding with mixtures contained 25 or 50% TSBP. Total VFA's concentration was higher ($P<0.05$) with control mixture than others after 3 or 24 hrs of feeding. Moreover, the TVFA's concentration was drastically fallen down with the mixture contained 50% TSBP. Ruminal pH or molar proportion of TVFA's did not obviously influenced by including SBP or TSBP in the feed mixtures. Salman *et al.* (1998) with corn stalks, reported that ruminal NH_3-N concentration had higher ($P<0.05$) of rams fed urea or fungal treated roughages than those fed untreated roughages. Yadov and Yadav (1988) noticed that increased ruminal NH_3-N concentration might be due to the higher intake of nitrogen and higher CP digestibility. Kumar *et al.* (1997) and Allah (2007) noticed high concentration of TVFA's in the rumen fluid when used biologically treated roughages, they attributed such increase to the high fiber breakdown. The rate of VFAS production may in this situation exceed the rate of VFA's absorption through the rumen epithelium, and VFAS concentration in the rumen juice is increased (Van't Klooster 1986).

It should be noted that TVFA's concentration in the rumen is governed by several factors such as dry matter digestibility, rate of absorption, rumen pH, transportation of the digesta from the rumen to the other parts of the digestive tract, and the microbial population in the rumen and their activities (Allam *et al.,* 1984).

The interaction between dietary treatments and sampling time (TxS) on the basic patterns of rumen fermentation by the experimental group lambs are shown in Table (5). There were significant ($P<0.05$) interaction between dietary treatments and sampling time (TxS) on ruminal pH, NH_3-N and TVFA's concentrations.

4.4 Blood plasma constituents of the experimental rations

Blood plasma constituents of the experimental rations are presented in Table (6). Inclusion of BTCS in sheep ration had no significant effect ($P>0.05$) on blood plasma globulin, GOT and GPT contents, while it significantly increased ($P<0.05$) hemoglobin, glucose, total protein, albumin and albumin: globulin ratio. On the other hand replacement CH by BTCS in sheep diets significantly decreased ($P<0.05$) blood plasma urea, creatinine, triglycerides and cholesterol. However, noticed insignificant decreasing ($P>0.05$) in blood plasma of GOT and GPT when CH replaced by BTCS in sheep rations. All blood plasma parameters were within the normal range. These results were in agreement with those found by Abd-Allah (2007). Mahrous *et al.* (2009) found no significant differences ($P<0.05$) between all treatments for serum urea-N, total protein, albumin, creatinine, GOT and GPT concentration of sheep fed ration containing untreated or biologically treated corn stalks, while all studied blood parameters were within the normal range.

Rakha (1988) reported the normal levels of serum urea-N in sheep and goats range from 8 to 40 mg/dl. The estimates of total protein was close to the value (6-9 g/dl) reported by Smith *et al.* (1979) and (6-8 g/dl) reported by Recce (1991). The normal plasma creatinine level is ranging 1.2 and 1.9 mg/dl in sheep blood (Kaneko, 1989). In general, the values recorded for GOT and GPT by Abd El-Kareem (1990) was from 24 to 65 and from 14 to 37 U/L for GOT and GPT, respectively.

Abu El-Nor and Kholif (1998), Sharma *et al.,* (1998) and Kholif *et al.* (2001) noted that serum glucose content increased significantly with yeast culture supplementation to buffaloes or cows rations. EL-Marakby (2003) cleared that there was no significant effect of feeding lambs on *Agaricus bisporus* spawning wheat straw on plasma total protein and transaminase (AST and ALT) values

4.5 Growth performance of the experimental rations

The results of growth performance of the experimental groups are presented in Table (7) showed that replacement of CH with BTCS in sheep rations significantly ($P<0.05$) improved final weight, total body weight gain, average daily gain (ADG) and relative gain. The replacement 33, 66 and 100% of CH with BTCS in sheep rations improved ADG by 10.53%, 18.42%, 27.89% for TMR_2, TMR3 and TMR_4, respectively compared with the control ration (TMR_1). These results were in agreement with those obtained by Mahrous *et al.* (2009) who fed Ossimi sheep on diets containing biologically treated corn stalks with *T. ressi* and with Abd-Allah (2007) who fed Rahmany × Ossimi) cross breed male lambs on diets containing biologically treated corn cobs with *T. ressi*. In contrast, Abedo *et al*. (2005) reported that weight gain was significantly ($P>0.05$) decreased with increasing the replacement level of Sugar beet pulp (SBP) to 50% of whole feed mixture. Allam *et al.* (2006) found that growing lambs fed on fungal treated roughages recorded high daily gain than control group.

Replacement CH with BTCS in sheep ration increased daily feed intakes of DM, TDN, CP and DCP (g/h/day). These results were in agreement with those noticed by Mahrous *et al.* (2009) who showed that total dry matter intake (g/h/d) was higher ($P<0.05$) for lambs fed biological treated corn stalks (1150, 1080 and 1030) for T4, T2 and T3 compared with control (930 g/h/d). Omer *et al.* (2009) noted that daily dry matter and nutrient intakes by the experimental group calves were not significantly affected ($P>0.05$) with enzymatic treatment.

Inclusion of BTCS in sheep diets significantly ($P<0.05$) improved feed conversion (kg intake /kg gain) of DM, TDN, CP and DCP. Mahrous *et al.* (2009) found that feed conversion expressed as (g DM/g gain) was better ($P<0.05$) with ration contained treated corn stalks (5.75, 5.96 and 6.05) for T4, T2 and T3 than control (6.47). Soliman *et al.* (1991) noted that the feed conversion (expressed as kg DM intake/kg gain) of chemically treated corn stalks was better than that of untreated corn stalks. Allam *et al*. (2006) found that animals fed biologically treated roughages were the most efficient groups followed by those fed chemically treated roughages. Abou-Ammou *et al.* (2007) noted that replace 50% of concentrate feed mixture with treated wheat straw in growing lamb rations can improve the daily gain and feed efficiency.

4.6 Economical evaluation of the experimental rations

Economic efficiency was represented by daily profit over feed cost. The costs were based on average values of year 2011 for feeds and live body weight. Feeding costs and profit above feeding costs are shown in Table (8). Inclusion BTCS in sheep rations caused slight decreasing in total daily feeding costs of experimental rations compared to the control ration. Meanwhile, average daily gain, daily profit above feeding cost, and relative economical efficiency were improved. Feed cost LE per kilogram gain was improved by 9.59%, 14.82% and 22.46% for TMR_2, TMR_3 and TMR_4, respectively compared to the control diet TMR_1. These results are in agreement with those found by Abd-Allah (2007) who indicated that the biologically treated corn cobs with *Trichoderma ressi* decreased the feed cost (h/d/LE), improved net feed revenue, improved economic feed efficiency of and improved the relative economic efficiency (%). On the other hand, Abd El-Aziz (2002) observed that replacing 40% of the CFM by biologically treated rice straw reduced the cost of feeding by 28.8%, while Allam *et al.* (2006) reported that the biologically treated sugar beet pulp was used to replace 0, 60, 75 or 100 % of corn grain for growing lamb decreased feed cost / kg gain.

5. Conclusion

Under this condition of this study noticed that sheep fed on biologically treated corn stalks containing diets showed the best improvement of nutrient and cell wall constituents digestibility coefficients, growth performance, economic efficiency with no deleterious effect on general health as compared to animals fed the control diet.

So it could be concluded the possibility of replacing clover hay by biologically treated corn stalks in sheep rations without adverse effect on growth performance, reducing feed costs/ kg ration, feed costs/kg weight gain and to improve economic efficiency.

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Table 1. Chemical analysis of feed ingredients

Item	Feed ingredients					
	Yellow corn	Soybean meal	Wheat bran	Clover hay	Untreated corn stalks	Biologically treated corn stalks*
DM	90.22	92.85	90.29	93.86	90.20	89.66
Chemical analysis on DM basis						
Organic matter (OM)	98.50	94.38	87.79	89.73	82.22	81.60
Crude protein (CP)	9.00	44.00	13.72	15.63	4.29	11.43
Crude fiber (CF)	4.60	4.93	10.25	24.15	31.13	29.05
Ether extract (EE)	4.80	0.60	2.81	1.82	2.75	1.05
Nitrogen-free extract (NFE)	80.1	44.85	61.01	48.13	44.05	40.07
Ash	1.50	5.62	12.21	10.27	17.78	18.40
Cell wall constituents						
NDF	32.63	35.18	44.21	46.18	74.79	68.38
ADF	22.45	26.72	32.16	33.86	47.88	44.11
ADL	2.13	6.84	4.05	6.88	11.36	7.87
Hemicellulose**	10.18	8.46	12.05	12.32	26.91	24.27
Cellulose***	20.32	19.88	28.11	26.98	36.52	36.24

NDF = Neutal detergent fiber

ADF = Acidl detergent fiber

ADL = Acidl detergent lignin

** Corn stalks treated with Trichoderma reesi*

** Hemicellulose = NDF – ADF*

*** Cellulose = ADF – ADL*

Table 2. Composition, chemical analysis and cell wall constituents of the experimental rations

Item	Experimental rations			
	TMR_1	TMR_2	TMR_3	TMR_4
1- Composition of experimental rations				
Yellow corn	40.00	40.00	40.00	40.00
Wheat bran	12.00	12.00	12.00	12.00
Soybean meal	15.00	15.00	15.00	15.00
Berseem hay	30.00	20.00	10.00	00.00
Biologically treated corn stalks	00.00	10.00	20.00	30.00
Limestone	1.50	1.50	1.50	1.50
Sodium chloride	1.00	1.00	1.00	1.00
Vitamins and minerals mixture[1]	0.50	0.50	0.50	0.50
Price, L.E/ Ton	1881	1811	1741	1671
2- Chemical analysis of experimental rations on DM basis				
Dry matter (DM)	91.92	91.50	91.08	90.66
Organic matter (OM)	91.01	90.20	89.38	88.57
Crude protein (CP)	16.54	16.12	15.70	15.28
Crude fiber (CF)	11.06	11.55	12.04	12.53
Ether extract (EE)	2.90	2.82	2.75	2.68
Nitrogen-free extract (NFE)	60.51	59.71	58.89	58.08
Ash	8.99	9.80	10.62	11.43
GE (kcal/ kg DM)[2]	4178	4133	4090	4044
Cell wall constituents of experimental rations				
Neutral detergent fiber (NDF)	37.49	39.72	41.94	44.15
Acid detergent fiber (ADF)	27.01	28.03	29.06	30.08
Acid detergent lignin (ADL)	4.43	4.54	4.63	4.73
Hemicelluose	10.48	11.69	12.88	14.07
Cellulose	22.58	23.49	24.43	25.35

[1] *Each 3 kg Vitamins and Minerals mixture contains: Vit. A 12500000 IU, Vit. D_3 2500000 IU,Vit. E 10,000 mg, Manganese 80000 mg, Zinc 60,000 mg, Iron 50000 mg, Copper 20000 mg, Iodine 5000mg, Cobalt 1000 mg and carrier ($CaCo_3$) add to 3000g. (Produced by Agri-Vet Comp)*

[2] *Hemicellulose = NDF – ADF*

[3] *Cellulose = ADF – ADL*

[4] *GE (Kcal/ Kg DM)[4]: Calculated according to Blaxter (1968). Each g CP= 5.65 Kcal, g EE= 9.40 Kcal and g (CF & NFE) = 4.15 Kcal.*

LE = Egyptian pound equals 0.18 American dollars approximately

Table 3. Nutrient and cell wall constituent digestibility coefficients and nutritive values of the experimental group lambs

Item	Experimental rations				SEM
	TMR_1	TMR_2	TMR_3	TMR_4	
Nutrient digestibility coefficients					
Dry matter (DM)	68.91^{b}	69.68^{b}	70.38^{ab}	72.86^{a}	0.55
Organic matter (OM)	73.46^{b}	74.22^{b}	76.19^{ab}	78.15^{a}	0.73
Crude protein (CP)	65.37^{c}	66.34^{bc}	69.50^{ab}	71.94^{a}	0.83
Crude fiber (CF)	60.25^{c}	62.75^{bc}	64.53^{b}	68.59^{a}	0.95
Ether extract (EE)	78.40^{b}	80.46^{b}	81.66^{ab}	84.25^{a}	0.76
Nitrogen-free extract (NFE)	76.06^{b}	77.31^{ab}	78.45^{ab}	80.36^{a}	0.70
Cell wall constituent digestibility coefficients					
Neutral detergent fiber (NDF)	65.06^{b}	67.50^{ab}	69.74^{ab}	73.44^{a}	1.35
Acid detergent fiber (ADF)	60.33^{d}	64.19^{c}	68.39^{b}	72.50^{a}	1.28
Hemicelluose	70.25^{c}	74.33^{b}	77.15^{ab}	80.03^{a}	1.06
Cellulose	69.56^{d}	75.21^{c}	79.44^{b}	82.71^{a}	1.32
Nutritive values (%)					
Total digestible nutrient (TDN)	68.61^{b}	69.21^{ab}	69.94^{ab}	71.34^{a}	0.45
Digestible crude protein (DCP)	10.81	10.69	10.91	10.99	0.08

a, b, c and d: means in the same row having different letters differ significantly (P<0.05)

SEM = standard error of the mean

Table 4. Effect of dietary treatments or sampling time on the basic patterns of rumen fermentation by the experimental group lambs

Item	Experimental rations				SEM
	TMR_1	TMR_2	TMR_3	TMR_4	
pH value	6.71^{b}	6.81^{ab}	6.92^{ab}	6.98^{a}	0.04
NH_3-N (mg/dl)[a]	16.21^{c}	17.36^{b}	18.35^{a}	18.81^{a}	0.58
TVFA's (mEq/dl)[b]	11.40^{c}	12.55^{b}	12.96^{b}	13.46^{a}	0.27
Sampling time	Before feeding		3 hours post feeding		
pH value	6.92		6.78		0.04
NH_3-N (mg/dl)	14.68^{b}		20.68^{a}		0.58
TVFAs (mEq/dl	11.37^{b}		13.81^{a}		0.27

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

[a] *NH_3-N ruminal ammonia nitrogen*

[b] *TVFAs total volatile fatty acids*

Table 5. Effect of interaction between dietary treatments and sampling time (TxS) on the basic patterns of rumen fermentation by the experimental group lambs

Item	Sampling time								SEM
	Before feeding				3 hours post feeding				
	TMR_1	TMR_2	TMR_3	TMR_4	TMR_1	TMR_2	TMR_3	TMR_4	
pH value	6.78^{ab}	6.90^{ab}	6.98^{a}	7.02^{a}	6.63^{b}	6.72^{ab}	6.85^{ab}	6.93^{ab}	0.04
NH_3-N (mg/dl)[a]	14.16^{e}	14.38^{e}	14.92^{de}	15.26^{d}	18.25^{c}	20.34^{b}	21.77^{a}	22.36^{a}	0.58
TVFA's (mEq/dl)[b]	10.58^{e}	11.22^{de}	11.64^{cd}	12.05^{c}	12.22^{c}	13.88^{b}	14.28^{ab}	14.86^{a}	0.27

a, b, c, d and e: means in the same row having different letters differ significantly (P<0.05)

[a] *NH_3-N ruminal ammonia nitrogen*

[b] *TVFAs total volatile fatty acids*

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Table 6. Effect of dietary treatments on blood plasma constituents by the experimental group lambs

Item	Experimental rations				SEM
	TMR_1	TMR_2	TMR_3	TMR_4	
Hemoglobin (g/dl)	10. 24[c]	10.32[c]	10.42[b]	10.66[a]	0.04
Glucose (mg/dl)	55.16[b]	57.21[ab]	60.71[a]	61.14[a]	0.94
Total protein, (g/dl)	6.16[b]	6.21[b]	6.33[a]	6.40[a]	0.03
Albumin (g/dl)	2.94[c]	3.02[bc]	3.11[ab]	3.16[a]	0.03
Globulin (g/dl)	3.22	3.19	3.22	3.24	0.02
Albumin: Globulin ratio	0.91[b]	0.95[ab]	0.97[ab]	0.98[a]	0.01
GOT (U/L)	21.16	20.83	20.66	20.43	0.14
GPT (U/L)	35.29	35.00	34.81	34.62	0.13
Urea (mg/dl)	28.11[a]	27.92[ab]	27.65[ab]	27.33[b]	0.12
Creatinine (mg/dl)	0.62[a]	0.60[ab]	0.58[ab]	0.56[b]	0.01
Triglycerides, (mg/dl)	53.51[a]	52.92[b]	52.76[b]	52.14[c]	0.15
Cholesterol, (mg/dl)	104.4[a]	100.2[b]	98.3[b]	93.1[c]	1.09

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

Table 7. Growth performance of the experimental group lambs

Item	Experimental rations				SEM
	TMR_1	TMR_2	TMR_3	TMR_4	
No. of animals	9	9	9	9	-
Initial weight (kg)	19.00	18.85	19.15	19.25	0.21
Final weight (kg)	39.00[d]	40.85[c]	42.75[b]	44.75[a]	0.44
Total body weight gain (kg)	20.00[d]	22.00[c]	23.60[b]	25.50[a]	0.38
Experimental duration, days	105	105	105	105	-
Average daily gain (g/day)	190[d]	210[c]	225[b]	243[a]	3.66
Relative gain (% of initial weight)[a]	105[c]	117[b]	123[ab]	132[a]	2.30
Average body weight [b]	29.00[c]	29.85[bc]	30.95[ab]	32.00[a]	0.28
Metabolic body weight size (kg $W^{0.75}$)	12.50[c]	12.77[bc]	13.12[ab]	13.45[a]	0.09
Feed intake of					
Dry matter (DM)					
g/h/day	1190[c]	1230[bc]	1285[ab]	1310[a]	15.59
g/ kg $W^{0.75}$	95.20	96.32	97.94	97.40	0.82
kg/100 kg body weight (BW)	4.103	4.121	4.152	4.094	0.03
Total digestible nutrient (TDN)					
g/h/day	817[b]	851[b]	899[a]	935[a]	13.44
g/ kg $W^{0.75}$	65.36[b]	66.64[ab]	68.52[ab]	69.52[a]	0.67
Kg/100 kg body weight (BW)	2.817	2.851	2.905	2.922	0.02
Crude protein (CP)					
g/h/day	197	198	202	200	1.67
g/ kg $W^{0.75}$	15.76[a]	15.51[ab]	15.40[ab]	14.87[b]	0.15
g/100 kg body weight (BW)	679[a]	663[a]	653[ab]	625[b]	7.25
Digestible crude protein (DCP)					
g/h/day	129[b]	131[b]	140[a]	144[a]	1.93
g/ kg $W^{0.75}$	10.32	10.26	10.67	10.71	0.09
g/100 kg body weight (BW)	445	439	452	450	3.64
Feed conversion (kg intake /kg gain) of					
Dry matter (DM)	6.26[c]	5.86[b]	5.71[ab]	5.39[a]	0.09
Total digestible nutrient (TDN)	4.30[b]	4.05[a]	4.00[a]	3.85[a]	0.05
Crude protein (CP)	1.04[c]	0.94[b]	0.90[b]	0.82[a]	0.02
Digestible crude protein (DCP)	0.68[b]	0.62[a]	0.62[a]	0.59[a]	0.01

a, b, c and d: means in the same row having different letters differ significantly (P<0.05)

SEM = standard error of the mean

[a] Relative gain (percent of initial weight)= gain/initial weight x 100

[b] Average body weight = (Initial weight + Final weight/2)

Table 8. Economic evaluation of the experimental group lambs

Item	Experimental rations			
	TMR_1	TMR_2	TMR_3	TMR_4
Daily feed intake (fresh; kg)	1.295	1.344	1.411	1.445
Value of 1-kg feed (LE)	1.881	1.811	1.741	1.671
Daily feeding cost (LE) [a]	2.436	2.434	2.457	2.415
Average daily gain (kg)	0.190	0.210	0.225	0.243
Value of daily gain (LE)[b]	5.130	5.670	6.075	6.561
Daily profit above feeding cost (LE)	2.694	3.236	3.618	4.146
Relative economical efficiency [c]	100	120	134	154
Feed cost (LE/kg gain)	12.82	11.59	10.92	9.94

LE = Egyptian pound equals 0.18 American dollars approximately

[a] *Based on prices of year 2010*

[b] *Value of 1- kg live body weight equals 27 LE (2011)*

[c] *Assuming that the relative economic efficiency of control diet equals 100*