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PROTEIN DEGRADABILITY OF SUNFLOWER MEAL AS AFFECTED BY HEAT, FORMALDEHYDE AND POLYETHYLENE GLYCOL TREATMENTS IN THE RUMEN OF SHEEP AND ITS EFFECT ON DIGESTIBILITY, RUMINAL DEGRADATION KINETICS AND RUMEN FERMENTATION

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SUMMARY

The present study was conducted to evaluate the effect of heat (H), formaldehyde (F) or polyethylene glycol (P) treatment alone or in combination on protein degradability of sunflower meal (SFM) in the rumen of sheep. Feeding values, nitrogen utilization, rumen function and microbial protein synthesis were also investigated. Six adult male Barki sheep were assigned to be fed on six experimental rations using 6x6 Latin square designs. Six experimental concentrate feed mixtures (CFM) were formulated, included untreated or treated SFM. The treatments were heat (SFMH), formaldehyde (SFMF), polyethylene glycol (SFMP) and their combinations (SFMHF or SFMPF). Animals were fed with one of the CFM's in addition to ad libitum rice straw (RS). The results showed that the treatments did not change measured nutrient content and fiber fractions of SFM. However, all treatments decreased amounts of the phenolics compounds (total phenol and total tannins). There were no significant differences in the digestibility coefficients among the rations contained untreated or treated SFM, except for ration contained SFM treated with polyethylene glycol ($P<0.05$). Ration contained SFMHF had higher digestibility coefficients for OM, CP, CF and NFE being 67.17, 63.91, 65.41 and 68.46%, respectively. The lowest digestibility values showed with ration contained SFMP being 62.26, 55.97, 61.77 and 63.03%, respectively. There was no significant difference among the treatment for EE digestibility. The highest ($P<0.05$) TDN value was 62.49% for SFMHF diet, while the lowest was 57.75% for SFMP ration. The same trend was noticed for DCP values were 7.27% and 5.5% for SFMHF and SFMP rations, respectively. The highest nitrogen balance (NB) value was 6.94 (g N/day) for SFMHF ration and the lowest was 4.76 (g N/day) for SFMP ration. Highest NH_3-N value was 18.01 (mg/100 ml R.L.) obtained for SFM ration, and the lowest was 14.49 (mg/100 ml R.L.) for SFMHF ration. There were no significant differences among the diets for TVFA's concentrations. The effective degradability (ED) of CP, DM and OM was significantly ($P<0.05$) decreased when SFM was treated by H and F compared to the

control diet. The ED values were 45.18, 72.89 and 69.44% for CP, DM and OM, respectively. There were no significant differences for CP degradability among the rations. There were significant ($P<0.05$) increases in the purine derivatives in the urine followed treatment of SFM and hence resulted in significant increase ($P<0.05$) in the calculated flow of microbial nitrogen from the rumen. These results suggested that when SFM was treated with heat combined with formaldehyde could be the most effective in reducing DM , OM and N degradability in the rumen and enhance the amount of bypass protein content of the ration.

***Keywords**: heat, formaldehyde, polyethylene glycol, sunflower meal, rumen fermentation, degradability, purine derivatives, microbial nitrogen synthesis.*

INTRODUCTION

In developing countries feed inadequacy is the major impediment coming in the way of development of livestock sector. Ruminants have protein requirement at two levels, firstly, to meet the N needs of rumen microbes, and secondly, to meet the amino acids requirement of the host ruminants. Rumen degradable protein (RDP) serve as the N source for microbes, while the part which escape from rumen fermentation, i.e. ruminally undegraded protein (UDP), along with microbial protein, degraded in the fourth stomach and small intestine, to supply amino acids to the host ruminants. Moreover, rumen microbial protein synthesis cannot supply sufficient quantities of amino acids to meet the requirement of high producing cattle. It is generally presumed that feeding bypass protein is mostly beneficial to high yielding animals, in which synthesized microbial protein in the rumen may not be sufficient to meet the amino acids requirement at tissue level (Walli, 2005). Use of undegradable protein sources in ruminant diets has become a common practice in diet formulation.

Sunflower meal (SFM) is the fourth largest protein source for animal rations following by soybean meal, cotton seed meal and canola meal (Hesely, 1994). Improvement of ruminant protein is a matter of practical concern that the amounts of protein and amino acids delivered to the intestine commonly limit productivity of these animals is shown by their responses to post ruminal supplementation (Broderick *et al.*, 1991 and Ipharraguerre *et al.*, 2005). Various techniques have been reported to protect dietary protein from excessive microbial degradation, i.e. physical, chemical or their combination. Degradability of dietary protein in the rumen depends on the dietary protein source and their processing treatments. There is need various treatment to evaluate the efficiency of protein protection. Therefore, the objectives of this study were to evaluate the heating and/or formaldehyde and/or polyethylene glycol treatments of SFM on protein digestion, nitrogen balance, ruminal fermentation and microbial protein synthesis.

MATERIALS AND METHODS

The present study was carried out at Nubaria Research Station of Animal Production Research Institute, Egypt.

Protein source treatments

Sunflower meal (SFM) was sprayed with commercial formaldehyde solution

(40%) at the rate of 1 g HCHO/ 100 g crude protein of tested materials as suggested by Ferguson *et al.* (1967). SFM was heated at 130 °C for 30 min according to Walli and Sirohi (2004), and was left to cool at room temperature for three days before being mixed with other ingredients in order to formulate concentrate feed mixture (CFM). Polyethylene glycol (PDG) was used as a supplement of 10 % total phenolics of sunflower meal (Howard *et al.*, 2002).

Animals and rations

Six experimental concentrate feed mixtures (CFM) including untreated or treated SFM were formulated. The six experimental CFM's included: untreated sunflower meal (SFM); sunflower meal treated with heating (SFMH); SFM treated with formaldehyde (SFMF); SFM meal treated with combination of heat and formaldehyde (SFMHF); SFM treated with polyethylene glycol (SFMP) and SFM treated with combination of polyethylene glycol and formaldehyde (SFMPF). Six adult male Barki sheep (weighed 50 ± 2.00 kg) were used in a 6x6 Latin square design for digestibility trials. Animals were housed in six metabolic cages and fed one of the CFM individually at 2% of body weight plus ad libitum rice straw (RS) according to the NRC (1990) twice daily (8 am and 4 pm).

Digestibility and nitrogen balance trials

Sheep were fed with the experimental diets for a preliminary period of 21 days, followed by 7 days for collection feces and urine. Sub samples (10%) of feces and urine were taken once daily and kept at -18 °C until analyses. Fecal samples were dried at 60 °C for 72 hrs. Feed and fecal samples were ground through 1 mm screen on a Willy mill grinder and were analyzed for crude protein (CP), crude fiber (CF), ether extract (EE) and crude ash according to AOAC (1995). Total N were also determined in urine samples. Values of the total digestible nutrients (TDN) were calculated according to the classical formula of Maynard *et al.* (1978) on a dry matter basis. Cell wall constituents (neutral detergent fiber, NDF, acid detergent fiber, ADF and acid detergent lignin, ADL) were determined according to Van Soest *et al.* (1991). Hemicellulose and cellulose were calculated by the difference between NDF and ADF for hemicellulose and ADF and ADL for cellulose.

Ruminal fermentation

Rumen liquid samples were taken at 0, 3 and 6 hrs after feeding the experimental rations from three rumen-fistulated adult female Osimi sheep (weighed 47.00 ± 2.0 kg) for each treatment in order to determine pH, ammonia nitrogen (NH_3-N) concentrations and total volatile fatty acid (VFA) concentrations. Orion 680 digital pH meter was used for pH determination. Rumen samples were strained through four layers of chesses cloth for each sampling time, for determination of NH_3-N using magnesium oxide (MgO) as described by AOAC (1995), and VFA concentration was determined using steam distillation methods (Warner, 1964).

Rumen degradability measurement

Two bags (6 cm X 12 cm and 53 µm pore size) containing 5 g of ground samples of each diet were used at each incubation time. The incubation times

were 3, 6, 12, 24, 48 and 72 h. After removal from the rumen, the bags were rinsed and manipulated in cold water until the water ran clear, then squeezed prior to storing at -20°C. Later, bags were thawed and washed again in running tap water as described by Kamel *et al.* (1995) to eliminate the microorganism attached to residual sample. Two bags were washed in running water for 15 minutes to determine the initial water losses. Bags were dried in oven at 60 °C for 48 hrs, and DM, OM and CP disappearance were recorded for each time. The kinetics of DM, OM and CP degradation were estimated by the model of Ørskov and McDonald (1979) as described by El-Waziry *et al.* (2000). The effective degradability (ED) for the tested diets was estimated from the equation of Ørskov and McDonald (1979) as follows: $ED = a + bc / (c + k)$ where, the a, b and c are constants in the equation, and are defined as the rapidly degraded fraction, slowly degraded fraction and the rate of degradation, respectively. While k is the out flow rate assumed to be 0.05 / h under the feeding condition in the current study according to Kirkpatrick and Kennelly (1987).

Measurement of the excretion of purine derivatives

Twenty-four hours collection of urine was made for one week of each collection period. Urine was collected from the three animals housed in the metabolic cages into containers which had 75 ml H_2SO4 (1 mol/l), to keep pH of the final urine < 3. The collected urine was then diluted to a fixed volume of 5 L with water. One sub sample was stored at -20 °C for determining of purine derivative (PD) according to the procedure of Chen *et al.* (1990).

Statistical analysis

The data were carried out according to Steel and Torrie (1964). Significance of the difference in values was calculated by using Duncan's Multiple Range Test (Duncan, 1955).

RESULTS AND DISCUSSION

Chemical analysis and digestibility trails

Measured nutrient content, fiber fractions and phenolics compounds of the experimental diets (concentrate feed mixture contained untreated and treated sunflower meal) and rice straw are shown in Table (1). Nutrient content and fiber fractions of SFM did not affect significantly by the treatments. However, all treatments decreased total phenolics of SFM by about 17.8, 16.9, 27.8, 48.6 and 62.6 (%) and total tannins by about 76.3, 49.6, 82.4, 86.3 and 90.1 (%) for SFMH, SFMF, SFMHF, SFMP and SFMPF, respectively.

Table (2) shows the digestibility of nutrients of the experimental diets. The digestibility coefficient of DM was ranged from 56.68 to 61.61%, and there were no significant differences between the diets contained untreated or treated SFM, except for diets contained SFM treated with polyethylene glycol ($P<0.05$). There were significant ($P<0.05$) differences for the digestibility coefficients of OM, CP, CF and NFE, but not for EE. However, digestibility of nutrients was increased by all treatments, except PEG. The results

Table (1). Nutrients content, fiber fractions and phenolic compounds of the experimental CFM and rice straw (DM basis)

tems	SFM	HSFM	SFMF	SFMHF	SFMP	SFMPF	RS
)ry matter	89.75	90.43	89.32	90.03	88.30	87.12	90.45
)rganic matter	91.57	91.42	91.26	91.19	91.65	91.55	87.44
:rude protein	13.68	13.56	13.62	13.51	13.65	13.67	3.85
:rude fiber	5.80	5.38	5.41	5.35	5.78	5.88	37.59
:ther extract	2.37	2.21	2.27	2.15	2.34	2.39	0.89
\litrogen free extract	69.72	70.27	69.96	70.18	69.88	69.61	45.11
\sh	8.43	8.58	8.74	8.81	8.35	8.45	12.56
:iber fractions							
\DF	22.68	22.42	22.64	22.25	22.65	22.63	79.45
\DF	17.49	17.21	17.32	17.19	17.50	17.44	55.38
\DL	6.38	6.27	6.36	6.24	6.35	6.31	26.71
-lemicellulose	5.19	5.21	5.32	5.06	5.15	5.19	24.07
:ellulose	11.11	10.94	10.96	10.95	11.15	11.13	28.67
'henolic compounds							
Total phenol	6.01	4.94	4.99	4.35	3.09	2.25	-
Total tannins	1.31	0.31	0.66	0.23	0.18	0.13	-

FM, concentrate feed mixture, contained untreated sunflower meal, SFM; HSFM, SFM treated / heat; SFMF, SFM treated by formaldehyde; SFMHF, SFM meal treated by combination of :at and formaldehyde, SFMP, SFM treated by polyethylene glycol; SFMPF, SFM treated by)mbination of polyethylene glycol and formaldehyde; RS, rice straw; NDF, neutral detergent ber; ADF, acid detergent fiber; ADL, acid detergent lignin.

Table (2). Digestibility coefficients (%), nutritive values (%) and nitrogen utilization of the experimental diets and rice straw fed to sheep (Mean ± SE)

Item	SFM	HSFM	SFMF	SFMHF	SFMP	SFMPF
Digestibility coefficients (%)						
DM	60.3±0.6^{ab}	61.3±0.1^{ab}	61.6±0.5^{a}	61.2±.0.4^{ab}	56.7±0.8^{c}	59.9±0.5^{b}
OM	64.9±0.1^{bc}	66.2±0.1^{ab}	66.9±0.2^{a}	67.2±0.5^{a}	62.3±0.7^{c}	64.6±0.39^{d}
CP	60.1±0.1^{c}	61.7±0.6^{b}	62.2±0.4^{b}	63.9±0.5^{a}	56.0±0.4^{d}	61.9±0.02^{b}
CF	63.6±0.9^{c}	65.0±0.2^{ab}	64.7±0.1^{ab}	65.4±0.3^{a}	61.8±0.3^{d}	64.0±0.3^{bc}
EE	75.8±1.6	74.15±0.20	73.90±1.24	74.25±0.28	75.35±0.61	74.97±0.36
NFE	65.7±0.2^{b}	67.3±0.3^{ab}	68.4±0.2^{a}	68.5±1.0^{a}	63.0±1.2^{c}	64.9±0.7^{bc}
Nutritive value (%)						
TDN	60.3±0.1^{cd}	61.1±0.0^{bc}	61.6±0.1^{ab}	62.5±0.2^{a}	57.8±0.6^{e}	59.9±0.3^{d}
DCP	6.3±0.2^{bc}	6.8±0.2^{ab}	6.6±0.2^{bc}	7.3±0.0^{a}	5.5±0.1^{d}	6.1±0.0^{c}
Nitrogen utilization						
NI, g/day	21.5±0.1^{c}	22.1±0.1^{ab}	22.3±0.1^{a}	21.6±0.2^{bc}	21.7±0.2^{bc}	21.2±0.2^{c}
ND, g/day	13.1±0.1^{b}	13.5±0.4^{b}	14.2±0.3^{a}	13.8±0.3^{ab}	12.1±0.1^{c}	13.1±0.1b
NB, g/day	5.4±0.3^{cd}	6.9±0.1^{ab}	6.2±0.3^{abc}	6.9±0.1^{a}	4.8±0.5^{d}	6.0±0.2^{bc}
NB/NI, %	24.9±1.5^{ab}	30.5±2.3^{a}	27.3±1.6^{ab}	30.5±1.2^{a}	21.9±2.4^{b}	28.2±0.5^{a}
NB/ND %	40.8±2.1^{ab}	49.4±3.6^{a}	43.9±2.3^{ab}	47.9±1.5^{a}	30.1±4.0^{b}	45.6±0.8^{ab}

^{abcde} Means within the same rows with different superscript are significantly differ (P<0.05). CFM, concentrate feed mixture, contained untreated sunflower meal, SFM; HSFM, SFM treated by heat; SFMF, SFM treated by formaldehyde; SFMHF, SFM meal treated by heat and formaldehyde, SFMP, SFM treated with polyethylene glycol; SFMPF, SFM treated by polyethylene glycol and formaldehyde. NI= nitrogen intake, ND= digestible nitrogen and NB= nitrogen balance

indicated that presence of tannins and chlorogenic, caffeic and quinic acids in SFM could be protected SFM from degradation in the rumen of sheep (Pomenta and Burns, 1971). These acids are known to react with proteins in a manner similar to that of tannins; chlorogenic acid has also been shown to decrease trypsin digestion of SFM protein (Milic *et al.*, 1968). In addition, the treatments of SFM by heating, formaldehyde, and their combination also protected SFM from the degradation in the rumen and hence increased the digestion coefficients of the diets. Molina Alcaide *et al.* (2003) reported that for supplementing SFM by products with SFM may be limited by the presence of relatively high amount of total phenol and tannins. However, the present study is in agreement with their finding as SFM had high amount of total phenol and tannins, although the present results indicated that the presence of tannins could be protected SFM from the degradation in the rumen and hence improve the digestibility of nutrients. The lowest values of digestibility coefficients of diet contained SFMP could be explained on the basis that PEG, a non-nutritive synthetic polymer, has a high affinity to tannins and makes tannins inert by forming tannin-PEG complexes (Makkar *et al.*, 1995). PEG also liberates protein from the tannin-protein complexes (Barry and Manley, 1986).

Similar trend was found in the case of total digestible nutrients (TDN) and digestible crude protein (DCP) (Table 2). The values for diet contained SFMHF were 57.75 to 62.49 for TDN and 5.5 to 7.27 % for DCP, respectively. The increase of TDN and DCP with the treatment of heating, formaldehyde and its combination may be due to the protection of SFM protein from the degradation in the rumen. The decreases of TDN and DCP with the treatment of PEG are due to the protein liberating effect of PEG from the tannin-protein complexes (Barry and Manley, 1986). Abdel-Rahman *et al.* (2005) reported that TDN was significantly increased in rations contained SFM by heat treatment of SFM, and the present study are in agreement with their findings. The increases of DCP in present study are different that of the finding of Abdel-Rahman *et al.* (2005) in respect of the heat treatment of SFM.

All diets showed positive NB values, the highest value of NB was found for diet contained SFM treated by heat and formaldehyde, and the lowest was in SFM meal treated by polyethylene glycol. The natural tannins, chlorogenic, caffeic and quinic acids in SFM could be protected its protein content from the degradation in the rumen of sheep (Pomenta and Burns, 1971), and hence improved the retention of nitrogen. In addition, the treatments of SFM by heat, formaldehyde, and its combination increased the protection of protein and hence retained more nitrogen. The decrease of NB with ration contained SFM treated by PEG could due to the mode of action of PEG to liberate SFM protein from tannin complex. Results of present study in respect of NB is the same as was found by Abdel-Rahman *et al.* (2005), while Amos *et al.* (1974) reported that SFM supplemented with formaldehyde did not affect nitrogen retention.

Dry matter intake (DMI) of CFM significantly increased as the effect of between the rations contained untreated and treated SFM and rice straw (RS) as

are shown in Table (3). The reason for increasing RS intake with treated SFM in CFM is not clear.

Ruminal fermentation

There were no significant differences among all rations for all sampling times (0, 1, 3 and 6 h after feeding) in the values of pH, NH_3-N and VFA concentrations as are presented in Table (4).

Although there were no significant differences among the rations for NH_3-N concentration, the mean values was significantly higher for ration contained SFM, and that treated with PEG, followed by SFM treated with the combination of PEG and F. The lowest NH_3-N concentration was noticed for ration contained SFM treated by H, F and their combination, without significant differences among them. The treatment of SFM with PEG liberate the protein from the tannin-protein complexes (Barry and Manley, 1986), therefore, more degraded protein in the rumen by microorganisms could hence an increase of NH_3-N concentration. The low NH_3-N concentrations as effect of heat treatment possibly caused by the cross linkages between peptide chains and in presence of carbohydrates complexes were formed between free amino and aldehyde groups through Maillard reaction. These reactions lower the protein solubility (Broderick, 1975). Formaldehyde also decreased the proteolysis by rumen bacterial enzymes and hence decreased NH_3-N in the rumen. Results of present study are in agreement with the results of Abdel-Rahman *et al.* (2005) and also with the studies of Dinius *et al.* (1976); Van Nevel and Demeyer, (1979); Wallace *et al.* (1981); Whetstone *et al.* (1981); Newbold *et al.* (1990) which showed that the lower ammonia concentrations were mainly due to reduce proteolysis, degradation of peptides and deamination of amino acids in the rumen.

There were no significant differences among the diets in VFA concentrations (Table 4). Similar results were reported by Abdel-Rahman *et al.* (2005) and Borhami *et al.* (1995). Contradictory, Demjanec *et al.* (1995) reported that the effect of heat treatment on total VFA concentrations in all ruminal samples showed significant decrease, which reflect reduction in the quantity of fermentable substrate available in the supplemented protein roasted at high temperature.

Rumen degradability measurement

Table (5) shows the degradability kinetics of CP, DM and OM in the rumen of sheep fed the experimental diets. The soluble fractions (*a*) of CP were significantly ($P<0.05$) reduced when SFM was treated by the combination of heat and formaldehyde. There were no significant differences among diets contained untreated SFM and that treated by PEG. There were significantly ($P<0.05$) lower (*a*) values for DM when SFM was treated by formaldehyde or in combination of heat and formaldehyde. There were significantly ($P<0.05$) reduced (*a*) value for OM when SFM was treated by heat, formaldehyde or the combination of heat and formaldehyde compared to diets contained untreated SFM, or treated by PEG or the combination of PEG and formaldehyde (Table 5). The ruminally degradable fraction (*b*) of CP was significantly ($P<0.05$) decreased when SFM was treated by combination of heat and formaldehyde compared to the control diet, but no significant

Table (3). Dry matter intake (DMI, g/head/day) of sheep fed the experimental diets (mean±SE)

Item	CFM-SFM	CFM-HSFM	CFM-SFMF	CFM-SFMHF	CFM-SFMP	CFM-SFMPF
CFM	978.57 ±4.12	958.86 ±6.44	960.33 ±2.19	947.67 ±8.37	951.67 ±7.48	940.95 ±8.93
Rice straw	479.05 ±31.19 [c]	534.76 ±7.48 [bc]	639.99 ±14.59 [a]	574.28 ±32.86 [ab]	596.57 ±12.45 [ab]	582.86 ±18.43 [ab]
Total DMI	1274.65 ±3.46 [c]	1350.79±2 5.25 [b]	1436.65 ±13.87 [a]	1372.62 ±28.45 [b]	1379.92 ±13.92 [ab]	1346.95 ±21.52 [b]

[abc] Means within the same rows with different superscript are significantly differ (P<0.05).
CFM, concentrate feed mixture, contained untreated sunflower meal, SFM; HSFM, SFM treated by heat; SFMF, SFM treated by formaldehyde; SFMHF, SFM meal treated by heat and formaldehyde, SFMP, SFM treated with polyethylene glycol; SFMPF, SFM treated by polyethylene glycol and formaldehyde.

Table (4). Rumen pH, ammonia nitrogen (NH_3-N) concentration and total volatile fatt acids (VFA) concentration in rumen liquor of the experimental diets and ric straw fed to sheep (Mean ± SE)

Times	SFM	HSFM	SFMF	SFMHF	SFMP	SFMPF
			pH			
0	6.74±0.57	6.75±0.55	6.78±0.12	6.76±0.13	6.76±0.05	6.73±0.12
1	6.37±0.38	6.37±0.26	6.38±0.25	6.36±0.42	6.38±0.71	6.34±0.15
3	6.16±0.31	6.17±0.62	6.19±0.06	6.17±0.56	6.15±0.14	6.13±0.32
6	6.48±0.61	6.47±0.54	6.50±0.22	6.48±0.03	6.49±0.12	6.41±0.16
Mean	6.44±0.21	6.44±0.13	6.46±0.12	6.44±0.13	6.45±0.14	6.40±0.11
			NH_3-N (mg/100 ml)			
0	16.93±0.84	14.18±0.34	14.09±0.45	13.65±0.42	16.33±0.56	15.21±0.52
1	17.75±0.36	14.68±0.17	14.36±1.19	14.16±0.19	16.88±0.17	16.27±0.42
3	20.12±1.63	17.38±0.51	17.19±0.76	16.28±0.52	18.92±0.62	18.34±0.33
6	17.23±0.77	14.47±0.44	14.18±0.67	13.86±0.74	16.56±0.82	15.96±0.17
Mean	18.01±0.72 [a]	15.18±0.53 [c]	14.96±0.75 [c]	14.49±0.61 [c]	17.17±0.58 [ab]	16.45±0.67 [b]
			Total VFA (mmol/100 ml)			
0	9.56±0.56	9.27±0.17	9.12±0.34	9.06±0.11	9.44±0.41	9.31±0.32
1	10.48±0.72	10.06±0.51	9.92±0.73	9.63±0.61	10.36±0.71	10.18±0.18
3	12.66±0.53	11.26±0.32	10.89±0.93	10.76±0.54	12.01±0.42	11.31±0.51
6	9.87±0.86	9.44±0.29	9.38±0.09	9.11(0.73	9.67±0.66	9.51±0.56
Mean	10.64±0.70	10.01±0.45	9.83±0.39	9.64±0.41	10.37±0.58	10.08±0.45

[abc] Means within the same rows with different superscript are significantly differ ($P<0.05$).
CFM, concentrate feed mixture, contained untreated sunflower meal, SFM; HSFM, SFM treated by heat; SFMF, SFM treated by formaldehyde; SFMHF, SFM meal treated by heat and formaldehyde, SFMP, SFM treated with polyethylene glycol; SFMPF, SFM treated by polyethylene glycol and formaldehyde.

Table (5). Degradability kinetics of crude protein (%), dry matter (%) and organic matter (%) in the rumen of sheep fed the experimental diets and rice straw (mean±SE)

Item	SFM	HSFM	SFMF	SFMHF	SFMP	SFMPF
			Crude protein			
a[1]	12.52±1.73^{ad}	10.65±1.11^{cd}	9.33±1.04^{c}	6.69±1.51^{e}	12.35±0.6^{ab}	11.29±0.3^{cb}
b[1]	50.54±0.98^{a}	40.14±0.95^{b}	40.23±0.7^{b}	38.44±1.2^{c}	51.08±0.6^{a}	50.24±1.42^{a}
c[1]	0.05±0.00^{b}	0.07±0.01^{a}	0.07±0.01^{a}	0.09±0.01^{a}	0.05±0.00^{b}	0.05±0.00^{b}
U	36.94±0.96^{c}	49.21±0.80^{b}	50.44±0.56^{b}	54.87±0.63^{a}	36.57±1.23^{c}	38.47±1.13^{c}
ED[1]	63.10±0.98^{a}	50.84±0.80^{b}	49.61±0.56^{b}	45.18±0.63^{c}	63.47±1.08^{a}	61.58±0.98^{a}
			Dry matter			
a[1]	56.04±0.85^{ab}	50.02±2.95^{c}	44.42±1.45^{d}	44.00±1.25^{d}	57.28±0.62^{a}	55.67±1.03^{b}
b[1]	32.61±0.26^{a}	28.11±1.52^{b}	28.06±0.66^{b}	28.84±0.63^{b}	32.13±1.44^{a}	29.47±0.89^{b}
c[1]	0.04±0.00^{b}	0.05±0.01^{ab}	0.06±0.01^{a}	0.05±0.01^{ab}	0.04±0.00^{b}	0.05±0.00^{a}
u	11.35±0.90^{d}	21.87±1.98^{b}	27.52±1.14^{a}	27.16±1.23^{a}	10.59±1.21^{d}	14.86±0.39^{c}
ED[1]	88.70±0.90^{a}	78.18±1.98^{c}	72.53±1.14^{d}	72.89±1.22^{d}	89.46±1.21^{a}	85.19±0.39^{b}
			Organic matter			
a[1]	37.52±0.88^{a}	33.97±0.64^{b}	34.90±0.74^{b}	34.59±1.41^{b}	38.03±1.06^{a}	38.20±1.14^{a}
b[1]	37.44±1.12^{b}	39.11±0.37^{a}	37.48±0.58^{b}	34.80±1.27^{c}	39.33±0.49^{a}	36.28±0.88^{b}
c[1]	0.08±0.00	0.08±0.01	0.07±0.00	0.07±0.01	0.08±0.01	0.07±0.01
u	25.04±0.26^{d}	26.92±0.59^{bc}	27.62±0.61^{b}	30.61±0.55^{a}	22.64±0.54^{e}	25.52±0.56^{cd}
ED[1]	75.00±0.26^{b}	73.13±0.59^{c}	72.43±0.61^{c}	69.44±0.55^{d}	77.41±0.54^{a}	74.53±0.56^{bc}

[1] Estimated from the equation of Ørskov and McDonald (1979)., where, ED= effective degradability, a,b and c are constants and are defined as the rapidly degraded fraction, slowly degradaed fraction and the rate of degradation, respectively. u, Undegradable fractions {u = 100- (a+b)}.

[abcde] Means within rows with different superscript are significantly differ ($P < 0.05$).

CFM, concentrate feed mixture, contained untreated sunflower meal, SFM; HSFM, SFM treated by heat; SFMF, SFM treated by formaldehyde; SFMHF, SFM meal treated by heat and formaldehyde, SFMP, SFM treated with polyethylene glycol; SFMPF, SFM treated by polyethylene glycol and formaldehyde.

differences were found among diets contained untreated SFM, SFMP or SFMPF. The lowest value of (*b*) was 34.8% for SFMHF of OM, and there were no significant differences among diets contained untreated SFM, SFMF or SFMPF. Degradation rate (*c*) of DM significantly (P<0.05) decreased in CP when untreated SFM, SFMP or SFMPF was added to the diets and there were no significant differences among the diets contained HSFM, SFMF or SFMHF. There were no significantly differences of (*c*) values among all rations for OM degradability. The highest value of undegradable fractions (*u*) of CP was 54.87% for the diet contained SFMHF, and there were no significant differences among diets contained SFM, SFMP or SFMPF. Also, there was no significantly difference between the diets contained HSFM and SFMF. The lowest value of (*u*) was 36.57% for diet contained SFMP. The same trend of for CP was detected with the (*u*) values for DM and OM. The effective degradability *(ED)* of CP, DM and OM was significantly (P<0.05) decreased when SFM was treated by the combination of heat and formaldehyde than the control. There were no significant (P<0.05) differences for CP among the diets contained SFM, SFMP and SFMPF. Degradation of dietary protein in the rumen depends on the dietary protein source and their treatments. The present study showed that there were significant decrease in the degradability of CP, DM and OM when SFM was treated by the combination of heat and formaldehyde, but not significantly when SFM was untreated, treated by PEG or in combination by PEG and formaldehyde. Boer *et al.* (1987); Sharma *et al.* (2001) found that formaldehyde or heat treatments reduced nitrogen and DM disappearance, but heat treatment was less effective than formaldehyde. The present study were in agreement with the reports of Boer *et al.* (1987) and Sharma *et al.* (2001) in the case of SFM treated by formaldehyde or heat or their combination. It may concluded that formaldehyde plus heat treatment was the most effective for reducing DM, OM and N degradability in the rumen.

Measurement of the excretion of purine derivatives

The urinary purine derivatives, such as allantion and uric acid are shown in Table (6). There were significant (P<0.05) increases in the amount of purine derivatives in the urine when SFM was treated with F and HF as compared to untreated control so in hence there was a significant increase (P<0.05) in the calculated microbial nitrogen flow from the rumen. There were several methods can be applied in order to protect dietary protein from degradation in the rumen (Walli, 2005). In addition the more UDP supply as effect of treatments increases the amount of protein and essential amino acids reaching the small intestine than absorbed and improves the efficiency of protein utilization (Chalterjee and Wali, 2003). Generally, protein, in the form of amino acids available for absorption from the small intestine of ruminants originates from microbial protein synthesized in the rumen, rumen undegradable protein (UDP) of feeds and endogenous protein secreted into the digestive tract. Although the small intestinal digestibility (SID) of microbial protein is relatively constant, at 80–85%, the digestibility of UDP can vary considerably depending on the type

Table (6). Total purine derivatives excretion and microbial nitrogen (MN) leaving the rumen of sheep fed the experimental diets and rice straw (mean±SE)

Item	SFM	HSFM	SFMF	SFMHF	SFMP	SFMPF
Allantoin, mmol/d	15.9±0.3 [b]	16.8±0.4 [ab]	17.0±0.4 [a]	17.4±0.3 [a]	16. 6±0.3 [ab]	16.8±0.5 [ab]
Uric acid, mmol/d	2.8±0.02 [b]	2.96±0.0 [ab]	3.1±0.03 [a]	3.07±0.0 [a]	2.9±0.01 [ab]	2.96±0.02 [ab]
Total mmol/d	18.7±0.3 [c]	19.8±0.3 [a b]	20.1±0.2 [a]	20.5±0.3 [a]	19.5±0.1 [b]	19.7±0.2 [b]
MN g/d	14.5±0.1 [b]	15.4±0.1 [ab]	15.6±0.1 [ab]	16.0±0.1 [a]	15.1±0.1 [ab]	15.3±0.1 [ab]

[abc] Means within rows with different superscript are significantly differ ($P < 0.05$).
CFM, concentrate feed mixture, contained untreated sunflower meal, SFM; HSFM, SFM treated by heat; SFMF, SFM treated by formaldehyde; SFMHF, SFM meal treated by heat and formaldehyde, SFMP, SFM treated with polyethylene glycol; SFMPF, SFM treated by polyethylene glycol and formaldehyde.

of feedstuff and also the treatments during processing (Hvelplund and Madsen, 1990).

CONCLUSION

The results of present study concluded that the protein content of the untreated SFM is naturally protected by tannins from the degradation of microorganisms in the rumen. However, there were no significantly differences among untreated SFM and treated SFM especially by PEG or PEG plus formaldehyde. In the meantime it may suggested that treatment with formaldehyde plus heat could be the most effective method in order to reduce DM , OM and N degradability in the rumen, and hence increase MN synthesis. However, this study illustrated that PEG is ineffective to reduce the protein degradation from SFM in the rumen.

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هدم بروتين كسب عباد الشمس نتيجة المعاملة الحرارية، الفورمالدهيد، بولىايثيلين جليكول فى كرش الأغنام وأثر ذلك على الهضم وديناميكية التخمر في الكرش

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أجريت الدراسة الحالية لتقييم تأثير المعاملة بالحرارة، فورمالدهايد أو البولي ايثيلين جليكول منفردا أو معا على هدم بروتين كسب عباد الشمس بكرش الأغنام حيث استخدم ستة من ذكور الأغنام تامة النمو مع ستة علائق باستخدام تصميم المربع اللاتينى6x6.وغذيت على العلائق الستة المركزة والمحتوية على كسب عباد الشمس غير المعامل أو المعامل بالحرارة أو بالفورمالدهايد أو بالحرارة والفورمالدهايد معا أو بالبولى ايثيلين جليكول أو بالبولى ايثيلين جليكول والفورمالدهايد معا بنسبة 2% من وزن الحيوان مع تقديم قش الأرز لحد الشبع. فى حين تم تقدير مقاييس التخمر فى الكرش وديناميكيتة باستخدام 3 نعاج مزودة بفستيولا بالكرش مع إستخدام طريقة تحضين الاكياس النايلون المحتوية على العلائق المختبرة على فترات صفر ، 3 ، 6 ، 24 ، 48 ، 72 ساعة. وتشير النتائج الى أنه ليس هناك اى اختلاف معنوى بين العلائق الستة في التحليل الكيماوى وجدر الخلايا اللبفية مع حدوث انخفاض فى المركبات الفينولية مع جميع المعاملات لكسب عباد الشمس. ليس هناك اختلافات معنوية فى معاملات الهضم بين العلائق سواء المحتوية علي كسب عباد الشمس غير المعامل والمعامل باستثناء المعامل بالبولي ايثيلين جليكول وكانت أعلى قيمة لمعاملات الهضم هي 67.17 و63.91 و65.41 و68.46 % لكل من المادة العضوية والبروتين الخام و الألياف الخام والكربوهيدرات الذائبة علي التوالي وذلك للعليقة المحتوية على كسب عباد الشمس المعامل بالحرارة والفورمالدهايد معا وكانت اقل القيم هي 62.26 و 55.97 و 61.77 و 63.03 % لكل من المادة العضوية والبروتين الخام و الألياف الخام والكربوهيدرات الذائبة علي التوالي وذلك للعليقة المحتوية على كسب عباد الشمس المعامل بالبولي ايثيلين جليكول. لا يوجد اى اختلاف معنوى بين العلائق الستة لمعامل هضم الدهن. سجلت أعلى قيمة لمجموع المواد الغذائية المهضومة 62.49 % للعليقة المحتوية علي كسب عباد الشمس المعامل حراريا والفورمالدهايد معا وأقل قيمة كانت 57.75 % للعليقة المحتوية علي كسب عباد الشمس المعامل بالبولي ايثيلين جليكول وأيضا سجلت أعلى قيمة للبروتين المهضوم (7.27 %) وأقل قيم كانت 5.5 % للعليقة المحتوية علي كسب عباد الشمس المعامل بالبولي ايثيلين جليكول. وتشير نتائج ميزان الآزوت الى أن أعلى وأقل قيمة سجلت مع العليقة المحتوية علي كسب عباد الشمس المعامل حراريا والفورمالدهايد معا والعليقة المحتوية علي كسب عباد الشمس المعامل بالبولي ايثيلين جليكول (6.94 و 4.76 جم على التوالى) . أما نتائج التخمرات في الكرش فتدل على أن أعلى قيمة لتركيز الامونيا في الكرش كانت 18.01 مجم لكل 100 مل سائل كرش وأقل قيمة 14.49 مجم لكل 100 مل سائل كرش مع العليقة المحتوية علي كسب عباد الشمس المعامل بالبولي ايثيلين جليكول و العليقة المحتوية علي كسب عباد الشمس المعامل حراريا والفورمالدهايد معا على الترتيب ولا توجد اي اختلافات معنوية في تركيز الأحماض الدهنية الطيارة بين العلائق الستة. وتشير نتائج الهدم في الكرش أن هناك انخفاض معنوي لكل من البروتين الخام والمادة الجافة والمادة العضوية للعليقة المحتوية علي كسب عباد الشمس المعامل حراريا والفورمالدهايد معا إذا قورنت بالعليقة المحتوية علي كسب عباد الشمس غير المعامل. ونتائج الهدم هي 45.18 و 72.89 و 69.44 % لكل من البروتين الخام والمادة الجافة والمادة العضوية على الترتيب ولا يوجد اى اختلاف معنوي في هدم البروتين فى الكرش لكل من العلائق المحتوية علي كسب عباد الشمس غير المعامل والمعامل بالبولي ايثيلين جليكول والمعامل بالبولي ايثيلين جليكول والفورمالدهايد معا. أما نتائج مشتقات البيورين والنيتروجين الميكروبى المار من الكرش فقد أشارت لوجود زيادة معنوية فى كليهما فى جميع المعاملات إذا قورنت بالعليقة المحتوية علي كسب عباد الشمس غير المعامل.

وتقترح هذه الدراسة أن معاملة كسب عباد الشمس بالحرارة و الفورمالدهايد تكون أكثر كفاءة في هدم كل من المادة الجافة والمادة العضوية والبروتين الخام مما يساهم فى زيادة مرور البروتين الكلي الي المعدة الخلفية. كما خلصت النتائج الى انة ليس هناك حاجة للمعاملة بالبولىايثلين جليكول لزيادة بروتين عباد الشمس المار للمعدة الخلفية مما يقلل من تكلفة المعاملة فى حالة عدم استخدامة.