Utilization of Fungal Treated Wheat Straw in the Diet of Late Lactating Cow*

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ABSTRACT : Eight primiparous Holstein cows, in late lactation (255±10 days in milk) and yielding 10.3±1.3 kg/d of 4% fat corrected milk (FCM) were allocated into two groups randomly. Two diets containing 30% wheat straw either untreated (UWS) or treated with *Pleurotus ostreatus* (FTWS) were offered as total mixed ration (TMR). *In vivo* digestibility of the diets was determined, using acid insoluble ash as a marker. Daily milk production was recorded and milk samples were collected and analysed. Diet FTWS resulted in significantly ($p<0.05$) higher dry matter intake (DMI) (12.2±0.86 vs. 10.6±1.3), DM digestibility (58.8 vs. 52.3) and milk yield (9 vs. 7.5 kg). Milk fat contents were 34.2 and 35.6 g/liter that did not differ between cows fed treated or untreated straw. However, the concentrations of lactose, solid non fat, total solids and milk protein for diets UWS and FTWS were 57.3 and 54.9, 98.9 and 93.2, 134.5 and 127.4, 35.7 and 32.3 g/l, respectively, which differed significantly ($p<0.05$). The average body weights gain (BWG) for UWS and FTWS were 272 and 743 g/d, respectively ($p<0.05$). The FCM yield per kg of DMI was similar (0.68 and 0.67 liter) for the two groups, but BWG/kgDMI was higher in the FTWS diet. ***(Asian-Aust. J. Anim. Sci. 2004. Vol 17, No. 4 : 467-472)***

Key Words : Fungal Treatment, Wheat Straw, Lactating Cow

INTRODUCTION

Lactating cows require sufficient neutral detergent fibre (NDF) in the diet to maintain rumen function and maximise milk yield (Robinson and McQueen, 1992; Feng et al., 1993; Dado and Allen, 1996). It is important to provide the NDF of the diet from forages because the forage is closely related to chewing activity and the determinant of rumen pH of dairy cows (Ruiz et al., 1995; Oba and Allen, 1999). Therefore, a considerable part of the diet must be supplied, using high quality forages. However, the availability of forages is limited and expensive in many parts of the world. Utilization of fibrous crop residues such as straw, which are easily available, may be practical and economical in most cases (Hanjra et al., 1991; Poore et al., 1991). If the straws are to be more widely used and the performance of animals on such feeds enhanced, their nutritional value and palatability must be improved (Castrillo et al., 1990).

In order to improve the digestibility of straw, various chemical and physical delignification methods have been extensively researched (Moss et al., 1990; Shashi and Makkar, 1996; Zahedifar, 1997). Several workers studied the effectiveness of chemical treatment for improving the nutritive value of straw and using it in the diet of lactating cows (Cameron et al., 1990; Dutta et al., 1990). Inclusion of alkali treated wheat straw up to 20% in diets of lactating cows resulted in a similar performance comparing to the control (alfalfa hay) diet (Haddad et al., 1998). Although, various physical and chemical treatments of straw have been extensively researched, the use of these methods pose many problems, which limit their usefulness (Akin et al., 1993; Shashi and Makkar, 1996). These limitations might be avoided in biological methods for up-grading the nutritive value of such straw (Gupta et al., 1992; Jalc et al., 1996). Biological method of treating straw using white-rot fungi have shown to be a promising way of improving its nutritive value (Valmaseda et al., 1991; Arora et al., 1994; Zadrazil, 1997). Reports on the nutritive values of fungal treated straw were mostly limited to in vitro digestibility. To our knowledge, only a few studies have been reported about the effects of biologically treated wheat straw in ruminant nutrition. However, no study has looked at the utilization of fungal treated or mushroom spent wheat straw in diet of dairy cow. Therefore, this experiment was conducted to study the utilization of fungal treated wheat straw in the diet of lactating cows and compare it with untreated wheat straw.

MATERIALS AND METHODS

Treatment of wheat straw

Wheat straw was soaked in water for 24 h, in two concrete water tanks (1×8×0.6 m size). It was then packed inside steel barrels (220 litre volume) and pasteurized for one h. The wheat grain spawn of Pleurotus ostreatus (coded P.41), obtained from the Iranian culture collection center, was used to inoculate the straw. The pasteurized straw was

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Received June 21, 2002; Accepted November 8, 2003

Table 1. Formulation and chemical composition of the experimental diets (DM basis)

Ingredients	Diets		SEM
	UWS	FTWS	
Alfalfa hay	20.0	20.0	
Un-treated wheat straw	30.0	-	
Fungal treated wheat straw	-	30.0	
Ground barley	30.2	30.2	
Wheat bran	4.3	4.3	
Cotton seed meal	15.0	15.0	
Urea	0.2	0.0	
Bone meal	0.3	0.3	
Sodium bicarbonate	0.1	0.1	
Sodium chloride	0.1	0.1	
Total (kg)	100	100	
Nutrients			
OM	93.30[a]	92.90[a]	0.24
CP	12.40[a]	12.60[a]	0.27
EE	1.70[a]	1.80[a]	0.05
CF	25.40[a]	23.50[b]	0.15
NFE	54.0[b]	55.60[a]	0.53
NDF	52.0[a]	48.1[b]	0.98
ADF	35.60[a]	33.80 [b]	1.01
ADL	7.4 0[a]	6.30[b]	0.27
Ca	0.65[a]	0.69[a]	0.03
P	0.46[a]	0.48[a]	0.02
GE (Mcal/kg DM)	4.07[a]	4.09[a]	0.17

Means with the different superscripts within a row are significantly ($p<0.05$) different.
UWS =untreated wheat straw. SEM=error of mean.
FTWS=fungal treated wheat straw.

spread in a steel sheet and mixed with the spawn at the rate of 4 kg spawn per 100 kg straw (fresh weight basis) in the spawning room. Then the inoculated straw was packed in polyethylene bags (65 cm length and 40 cm diameter and 100 gauge thickness). Each bag that contained aproximately 12 kg of straw (fresh weight) was tightened up with nylon thread and transferred to the fermentation room.

The inoculated straw bags were hung inside the fermentation room, with a temperature of 25±3°C and the relative humidity of 80±5% maintained by means of electric air condition for temperature and sprinkling of water inside the room for humidity control. The solid state fermentation lasted for 50 days in which the mushroom was harvested two times.

At the end of the fermentation period, the bags were removed from the fermentation room and sun dried on a cemente yard for week. After drying, the straw was removed from the bag and chopped into 3-6 cm length, by an electric chopper machine.

Animals and diet

Eight primiparous Holstein cows, in late lactation (255±10 days in milk) yielding 10.3±1.3 kg/d of FCM were allocated to the experiment. The cows were housed in individual stalls and assigned for one of the two experimental diets (four cows per diet) randomly. The feeding trial lasted for 7 weeks, consisted of three weeks adaptation and four weeks for the measurements. The cows were milked twice a day at 07:00 and 19:00 h, by an electronic milking machine. Body weight changes were obtained by direct weighing of the animals, at the first and the end of the experiment.

Two experimental diets were formulated with a roughage: concentrate ratio of 50:50. The roughage component of the diets included 30% wheat straw either untreated (UWS) or fungal treated with Pleurotus ostreatus coded P-41 (FTWS) and 20% alfalfa (Medicago sativa) hay. The concentrate consisted of ground barley, wheat bran, cotton seed cake and minerals (Table 1). Roughage and concentrate were mixed and offered ad lib as total mixed ration (TMR) at 07:30, 13:30 and 19:30 h.

Feed intake and milk record

During the experiment, the daily voluntary feed intake of each cow was individually recorded. Feeds and faeces were sampled on two days per week and kept frozen until the end of the experiment. Daily milk production was individually recorded by a milking machine, which was equipped with a recorder. The composite milk samples were collected weekly, at the regular milking times (07:00 and 19:00 h). Milk samples were preserved with 0.025 mg potassium dichromate ($K_2Cr_2O_7$) per 50 ml sample tube, and stored at 4°C (Baker et al., 1995).

Chemical analyses and nutrient digestibility

Milk samples were analysed for fat, protein, lactose, solid non fat (SNF) and total solid (TS) concentration, using of Milkoscan 4,000 (Foss Electric). The pooled weekly-collected samples of feed and faeces were oven dried at 65°C (24 h for feed and 72 h for faeces) and ground through a 1 mm screen hammer mill before analysis. Organic matter (OM) was determined by ashing the samples at 500°C for 4 h; crude protein (CP) by Kejltec method (N×6.25), crude fibre (CF) and acid detergent lignin (ADL) according to AOAC (1990). The neutral detergent fibre (NDF) and acid detergent fibre (ADF) were determined using the methods of Van Soest et al. (1991). The apparent digestibility of the nutrients was determined using the acid-insoluble ash ratio technique as a marker (Sunvold and Cochran, 1991).

Statistical analysis

Data from feed intake, milk recording and milk components was analysed, using a complete randomised, with repeated (four week) measurement design and tested by Duncan test. Data obtained from digestibility and body weight changes was analysed according to the simple

Table 2. Total tract nutrient digestibilities (%) of the diets fed to the experimental cows

Nutrients	Diets		SEM
	UWS	FTWS	
DM	52.3 [b]	58.8 [a]	1.82
OM	51.3 [b]	58.8 [a]	1.57
CP	46.1 [b]	57.7 [a]	3.67
EE	73.8 [b]	85.1 [a]	1.81
CF	33.2 [a]	39.7 [a]	5.23
NFE	48.7 [b]	58.4 [a]	3.97
NDF	34.3 [b]	42.3 [a]	3.33
ADF	29.4 [b]	37.5 [a]	2.90
CL	30.9 [b]	43.2 [a]	4.94
HCL	42.8 [a]	57.0 [a]	6.63
TDN	51.2 [b]	57.9 [a]	3.39
GE	52.3 [b]	58.8 [a]	2.23

Means with the different superscripts within a row are significantly ($p<0.05$) different. UWS=untreated wheat straw.
SEM=standard error of mean. FTWS=fungal treated wheat straw. CL=cellulose. GE=gross energy. HCL=hemicellulose.

Table 3. Effect of diet on the nutrient intake

Items	Diets		SEM
	UWS	FTWS	
DMI:			
kg/d	10.6 [b]	12.2[a]	0.59
% of BW	1.7 [b]	2.0[a]	0.09
g/kg $W^{.75}$	86.5 [b]	100.1[a]	4.17
OMI (kg/d)	9.90 [b]	11.40[a]	0.48
DOMI:			
kg/d	5.10 [b]	6.7[a]	0.27
% of BW	0.84 [b]	1.12[a]	0.05
g/kg $W^{.75}$	41.6 [b]	55.1[a]	2.22
CPI (kg/d)	1.3 [b]	1.50[a]	0.06

Means with the different superscripts within a row are significantly ($p<0.05$) different.
UWS=untreated wheat straw. BW=body weight. FTWS=fungal treated wheat straw. CPI=crude protein intake.
SEM=standard error of mean. OMI=organic matter intake. DMI=dry matter intake. DOMI=digestible organic matter intake.

complete randomised design and tested for significance by T-test. All statistical analyses were performed using the SAS (1992) GLM procedure.

RESULTS

Diet composition and digestibility and nutrient intake

Chemical composition of the diets is presented in Table 1. The FTWS diet had significantly ($p<0.05$) lower CF, NDF, ADF and ADL than the UWS diet. Table 2 shows the nutrient digestibilities of the experimental diets. Excluding the CF and hemicellulose (HCL), digestibility of the energy and other components was significantly ($p<0.05$) higher in the diet contained FTWS compared to the UWS diet. The intake of DM (DMI), OM (OMI), DOM (DOMI) and crude protein intake (CPI) were significantly ($p<0.05$) higher for the cows fed FTWS diet than those fed UWS (Table 3).

Table 4. Effect of the diet on the milk production and composition

Items	Diets		SEM
	UWS	FTWS	
Production			
Milk (kg/d)	7.5[b]	9.0[a]	1.18
FCM (kg/d)	7.1[b]	8.2[a]	1.49
Fat (g/d)	271[b]	317[a]	3.0
Protein (g/d)	271[a]	300[a]	2.7
Milk composition (g/kg)			
Fat	35.6[a]	34.2[a]	4.84
Protein	35.7[a]	32.3[b]	2.48
Lactose	57.3[a]	54.9[b]	1.02
SNF	98.9[a]	93.2[b]	2.67
TS	135[a]	127[b]	5.42

Means with the different superscripts within a row are significantly ($p<0.05$) different.
UWS =untreated wheat straw. SNF=solid non fat. FTWS=fungal treated wheat straw. TS=total solid. SEM=standard error of mean.

Table 5. Efficiency of diets for milk production and body weight changes

Items	Diets		SEM
	UWS	FTWS	
IBW (kg)	610[a]	604[a]	11.81
$IBW^{0.75}$ (kg)	123[a]	122[a]	1.91
BW gain (g/d)	272[b]	743[a]	45.00
Efficiency:			
DMI/FCM (kg/kg)	1.60[a]	1.50[a]	0.28
FCM/DMI (kg/kg)	0.67[a]	0.68[a]	0.10
BWG/DMI (g/kg)	26.20[b]	61.2[a]	5.66

Means with the different superscripts within a row are significantly ($p<0.01$) different. UWS =untreated wheat straw. DMI=dry matter intake. FTWS=fungal treated wheat straw. IBW=initial body weight. SEM= standard error of mean. BWG=body weight gain. $IBW^{0.75}$=initial metabolic body weight.

Milk yield and composition

As it is presented in Table 4, the average daily milk and FCM yield for UWS and FTWS were respectively 7.5 and 9, 7.1 and 8.2 kg/d that were significantly ($p<0.05$) different between the diets. Milk fat concentration was similar (35.6 and 34.2 g/l), whereas the protein content was slowly higher (35.7 va. 32.3 g/l) with the UWS diet. The concentration of lactose, SNF and TS were 57.3 and 54.9, 98.9 and 93.2, 135 and 127 g/l for the UWS and FTWS diets, respectively and the differences between the two diets were significant ($p<0.05$).

Body weight change

The average body weights gain were 272 and 743 g per day for cows fed UWS and FTWS, respectively that was significantly ($p<0.05$) different between the diets. The amount of body weight gain (BWG) per kg of DMI was significantly ($p<0.05$) higher (61.2 vs. 26.2 g/d) for the cows fed FTWS than the UWS diet (Table 5).

Feed efficiency

Efficiency of the dry matter utilization in milk, which expressed as kg dry matter intake per kg of FCM production (DMI/FCM), was not affected by the type of the diets (Table 5). It was 1.6 and 1.5 kg for the UWS and FTWS, respectively. The amount of FCM yield per kg of DMI was also similar (0.67 and 0.68) for the control and treated diet, respectively that were not affected by the type of the diets. However, the amount of body weight gain per kg of DMI was significantly ($p<0.05$) higher for the cows fed fungal treated wheat straw (61.2 vs. 26.2 g/kg).

DISCUSSION

Diet composition and digestibility

The diet contained fungal treatmed wheat straw had statistically ($p<0.05$) lower NDF by 3.9% unit (48.1 vs. 52.0), ADF by 2.8% unit (33.8 vs. 35.6) and ADL by 1.1% unit (6.3 vs. 7.4) (Table 1). The above results thus suggest that fungal fermentation improved nutritive values of the straw by lowering its cell wall content as measured by its NDF, ADF and ADL contents.

In comparison with the control diet, inclusion of the fungal treated wheat straw significantly ($p<0.05$) increased the total tract digestibility of DM, OM, CP, EE, NDF, ADF, cellulose and gross energy (GE) of the diet (Table 2). The higher nutrient and GE digestibility of the treated straw diet might be explained by lower NDF, ADF and ADL content in this diet in comparison to the untreated straw diet discussed above. These results are supported by Fazaeli et al. (2002) who reported that nutrient digestibility of fungal treated wheat straw diet was as much as the the alfalfa diet when fed (up to 30% of the diet) to lactating cow.

Nutrient intake

The cows fed treated straw had significantly ($p<0.05$) higher DMI, OMI, and DOMI in comparison to those offered the control diet (Table 3). This is expected due to the fact that fungal treatment improves digestibility and or palatability of straw as discussed above. Masahiro et al. (1992) reported that treated straw by Pleurotus ostreatus, resulted in a higher in vitro digestibility and voluntary intake in sheep. Similarly an improvement in DM, OM and NDF degradability and ruminal fermented gas product was reported in the Pleurotu ostreatus treated straw (Jalc et al., 1994, Adamovc et al., 1998). Biological treatment could increase voluntary intake of lignocellulosic feeds as a result of physical changes and brittleness of the straw structure, which enhanced particle size reduction in the rumen. Destroying girder structure and collapsing of the vascular bundles of treated straw with Pleurotus sajor-caju was observed by Karunanandaa et al., (1995).

Milk production and composition

Cows fed the treated straw have produced significantly ($p<0.05$) more milk (9 vs. 7.5 kg/d) and FCM (8.2 vs. 7.1 kg/d), than those fed the untreated straw diet (Table 4). The amount of fat yield was also higher ($p<0.05$). (317 vs. 271 g/d). The higher milk and fat yield are as a result of the higher amount of nutrient intake in treated straw diet (Table 3). Level of feed intake could affect the milk yield in lactating cows (Cameron et al., 1991; Friggens et al., 1995). There are a few data in the literature regarding the lactational performance of dairy cows fed chemical and physical treated straw, but no report was available about the fungal treatment straw in dairy cattle nutrition.

Apart from the fat content, other milk composition such as protein, lactose, SNF and TS concentration were significantly ($p<0.05$) higher when cows fed untreated straw diet (Table 4). There may be an adverse relationship between the quantity of milk yield and density of the component.

Body weight change

As shown in Table 5, the average body weight gain was considerably higher in cows fed diet contained treated straw than those fed control diet (743 vs. 272 g/d). The BW gaining is normal for dairy cows in late lactation stage. The cows used in this experiment were in the late lactation stage of first lactation and they also needed to increase their BW. The FTWS diet provided a diet that contained higher energy value (57.9 vs. 51.2 of TDN), CP intake (1.5 vs. 1.3 kg/d) and higher DOMI (Table 3), which resulted in a higher BW gain, beside the higher milk yield than the UWS diet.

Feed efficiency

As it is shown in Table 5, dry matter intake per kg of fat corrected milk yield (DMI/FCM), were 1.5 and 1.6 and the amount of FCM yield per kg of DMI were 0.68 and 0.67 for FTWS and UWS diets respectively, which were not affected by the type of the diets. However, the amount of body weight gain per kg of DMI was significantly ($p<0.05$) higher (61.2 vs. 26.2 g/d) for the cows fed treated straw. In other words, cows received the FTWS diet produced 0.68 kg FCM and were gaining BW 61.2 g/kg DMI whereas those, which received UWS diet, yield 0.67 kg milk and 26.2 g BW gain/kg DMI. As energy intake rises, late-lactation cows divert proportionally more energy to body gain than milk production (McQueen and Robinson, 1996). The lower efficiency of body weight gain in animals fed the control diet could be due to the lower digestibility and availability of the nutrients.

CONCLUSION

In this experiment, two diets containing 30% of untreated or fungal treated wheat straw were fed as TMR ad lib to late lactating cows. Inclusion of fungal treated straw improved the nutrient digestibilities of the diet. The animals, which fed fungal treated straw, showed higher nutrient intake. The increase in FCM yield by cows fed treated straw averaged 13% and the daily average body weight gain was 2.7 times in the treated straw diet in contrast to the untreated straw. Such improvements in the animal performance could reflect the improvement of nutritive value of the fungal treated wheat straw.

ACKNOWLEDGMENTS

The authors greatly appreciate the financial support and facilities given by Animal Science Research Institute of Iran for the completion of this project.

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