Effect of Fungal Treated Wheat Straw on the Diet of Lactating Cows

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ABSTRACT : This study was conducted to investigate the effects of diets that contained different levels of fungal treated wheat straw on the intake, digestibility and performance of lactating cows. Eight primiparous Holstein cows, in late lactation ranging from 170±10 days in milk and yielding 14.3±1.3 kg/d of fat corrected milk (FCM) were allocated into four diets with 0, 10, 20 and 30% fungal (*Pleurotus ostreatus* coded P-41) treated wheat straw in a 4×4 Latin Square experiment. The daily intake of DM, OM, DOM, CP and TDN were not affected by substitution of alfalfa hay with fungal treated wheat straw. Inclusion of the treated straw at different levels in the diet did not affect the digestibility of nutrients, except for the ADF that was significantly ($p<0.05$) reduced in the diet contained 30% treated straw. The types of the diet did not significantly affect daily milk and FCM production. The milk composition including fat, protein, lactose, solid non-fat (SNF) and total solid (TS) were not statistically ($p>0.05$) different among the diets. All cows gained weight, but the inclusion of treated straw to the diet significantly ($p<0.05$) increased the body weight gain and the highest amount was obtained in the diet containing 20% treated. Inclusion of fungal treated wheat straw up to 30% of the diet of lactating cows supplemented with a protein source such as cottonseed meal had not affected the nutrients intake and lactation performance. ***(Asian-Aust. J. Anim. Sci. 2002. Vol 15, No. 11 : 1573-1578)***

Key Words : Fungal Treatment, Wheat Straw, Lactating Cow

INTRODUCTION

Optimal milk production by lactating cows requires adequate nutrients and energy consumption. Using of concentrate feeds is a common practice to provide high-density energy diets, but feeding of high percentage of concentrate in the diet produces negative effect such as acidosis, reduced dry matter intake (DMI), and depressed milk fat content (Robinson and McQueen, 1997). Lactating cow requires optimum amount of NDF in the diets to maintain the rumen function and to maximize milk yield (Feng et al., 1993; Allen, 1997). It is important to provide NDF from forages because it is closely related to chewing activity that optimizes the rumen pH of dairy cow (Ruiz et al., 1995). Thus, a considerable part of the diet must consist of high quality forages (Khorasani et al., 1996). However, in many parts of the world where the availability of high quality forages is limited, cereal straw is fed to ruminants as basic roughage (Poore et al., 1991).

If the lignified crop residues such as straw is to be used effectively and the performance of animals fed these residues is enhanced, its nutritional characteristics and palatability must be improved (Castrillo et al., 1990). Improvement of NDF hydrolysis could stimulate rapid disappearance of NDF from the rumen, reduce physical fill, and allow greater voluntary feed intake (Oba and Allen, 1992). One of the ways of increasing the efficiency of utilizing straw in the diet of dairy cow is to enhance the bioavailability of the nutrients in the straw. It may be accomplished through chemical or biological treatment of the straw (Zadrazil et al., 1995; Rode et al., 1997).

Several workers (Moss et al., 1990; Shashi et al., 1996) studied the effectiveness of chemical treatment for improving the nutritive value of straw and its effect on the performance of cattle and buffalo. According to Cameron et al. (1990), feeding alkaline hydrogen peroxide-treated wheat straw up to 37.5% in the diet of dairy cows did not affect the FCM yield. Haddad et al. (1998) reported that inclusion of urea and sodium hydroxide treated wheat straw up to 20% in the diets, improved the performance of lactating cows.

An alternative method to improve the nutritive value of straw is by biological treatment (Gupta et al., 1992; Jalc et al., 1996) using white-rot fungi. Culturing of fungi on the straw may be advantageous for the production of mushroom as human food while improving the quality of straw as ruminant feed. Several studies have explored this possibility, using mainly wheat straw for culturing of *Pleurotus* species fungi (Tripathi and Yadav, 1992; Zadrazil, 1997). However, few experiments have been reported on the effects of feeding biological treated wheat straw for ruminants including in the utilization of fungal treated or mushroom spent wheat straw by dairy cow. This experiment was conducted to study the utilization of fungal treated wheat straw in the diet of dairy cows and to asses

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the production performance of the lactating cows fed different levels of the treated straw.

MATERIAL AND METHODS

Treatment of wheat straw

Wheat straw was soaked in tap water for 24 h, in two concrete water pools of size 0.6×8×1 m (depth, length and width). The soaked straw was removed and packed in steel barrels (220 liter volume) for pasteurization. Each barrel contained about 20 liters of tap water at the bottom and about 60 kg of soaked straw. Straw was exposed for one hour to the steam generated by heating the barrel.

Wheat grain spawn of *Pleurotus* (coded P-41), provided by Agricultural Engineering Research Institute of Iran, was used to inoculate the straw. In the spawning room, the pasteurized straw was spread in a steel sheet and mixed with the spawn at a rate of 4 kg spawn per 100 kg straw (fresh weight basis). Then, 12 kg (fresh basis) of straw was packed in polyethylene bags (65 cm length and 40 cm diameter and 100 gauge thickness), that was immediately tied up with nylon rope and transferred into the fermentation room where maintained at a 25±3°C. The relative humidity of the room was maintained at 80±5% by daily sprinkling of water.

Solid-state fermentation was prolonged for seven weeks during which the mushroom was harvested twice. At the end of fermentation period, all the bags were removed from the fermentation room and sun dried on a concrete yard. After drying for one week (summer season) the polyethylene sheets were removed from the biomass and the treated straw was chopped into 3-6 cm length, using an electric chopper machine.

Animals and management

Eight primiparous Holstein cows, in late lactation period, ranging from 170±10 days in milk and yielding 14.3±1.3 kg/d of FCM were used in a feeding trial. The initially overall body weight and metabolic body weight ($BW^{.75}$) of the animals were 572.5±24.7 and 117±3.4 kg, respectively. The cows were housed individually and randomly assigned to one of the four treatment diets (two cows per diet). The animals were given an adaptation period of 3 weeks in a trial of 14 weeks. Cows were milked twice daily at 07:00 and 19:00 by using milking machine.

Diets and feeding

Four experimental diets were consisted of 50: 50 ratio of roughage to concentrates (DM basis). Fungal treated straw was included at 0, 10, 20 and 30% (DM basis) in the diets. The remainder portion of the roughage consisted of alfalfa (*Medicago sativa)* hay. The feedstufs used in the experiment and their compositions are presented in Table 1.

The diets were formulated to provide the nutrient allowances of lactating cows according to the NRC (1989). The formulation and chemical composition of the diets are as shown in Table 2. Concentrate ingredients were prepared and combined prior to each experimental period. Roughage and concentrate were mixed daily and offered as total mixed ration (TMR) three times daily at 07:30, 13:30 and 19:30 h in an amount to ensure 10% residual balance (Dhiman and Satter, 1997).

Experimental design

A double 4×4 Latin Square experiment was conducted in which four treatments were allocated to eight lactating cows for four periods. Each change over period consisted of a 3 week adjustment followed by a 1 week data collection. Data obtained were analyzed for parametric statistics, including analyzes of variance by GLM procedure of SAS software (1992), using the following model:

Y_{ijkl} = $\mu + S_i + P_j + T_k + C_l + E_{ijk}$,
Y_{ijkl} = Responses of cow l in treatment k of period j in square i,
μ = Overall sample mean,
S_i = Square i effect,
P_j = Period j effect,
T_k = Treatment k effect,
C_l = Cow l effect,
E_{ijk} Ordinary least squares residual error.

Measurements

Feed intake : Voluntary feed intake (VFI) for each animal was recorded individually during the last week of each experimental period and dry matter intake (DMI) was estimated from VFI×percentage of DM. Samples of concentrate and roughage were taken from daily rations. Residues were collected, weight and sampled every morning before feeding. At the end of each period, feed samples were pooled proportionately to individual daily consumption. Samples of residues were air dried daily and pooled during each period. Pooled feed and residues

Table 1. Chemical composition (% of DM) of feedstuffs used in the experimental diets

Composition	Alfalfa-hay	Fungal treated wheat straw	Barley	Wheat bran	Cottonseed-meal
OM	88.8	92.6	96.5	92.8	93.2
ASH	11.2	7.4	3.5	7.2	6.8
CP	16.1	5.0	11.0	15.5	34.0
UIP	4.7	2.5	2.97	4.65	11.9
NDF	51.8	64.8	23.0	52.3	33.0
ADF	34.8	51.8	10.4	16.4	23.0
ADL	7.2	7.9	2.2	3.2	7.0
Ca	1.35	0.54	0.08	0.15	0.26
P	0.29	0.12	0.31	1.2	1.02

Table 2. Formulation and chemical composition of the experimental diets (kg/100 kg DM basis)

Feed ingredients	Diets (% Straw)			
	I	II	III	IV
	0	10	20	30
Roughage				
Alfalfa hay	50.0	40.0	30.0	20.0
Wheat straw	-	10.0	20.0	30.0
Concentrate				
Ground barley	33.6	33.5	32.0	31.8
Wheat bran	12.0	8.0	4.0	0.0
Cotton seed meal	4.0	8.0	13.5	17.3
Urea	0.1	0.2	0.2	0.35
Bone meal	-	-	-	0.25
Sodium bicarbonate	0.2	0.2	0.2	0.2
Iodide sodium chloride	0.1	0.1	0.1	0.1
Total (kg)	100	100	100	100
Composition (DM basis)				
OM (%)	91.7	92.0	92.3	92.4
CP (%)	15.2	15.2	15.1	15.1
≠ NE_L (Mcal/kg)	1.54	1.51	1.47	1.44
NDF (%)	40.6	42.0	43.5	45.3
ADF (%)	23.8	25.7	27.9	29.8
Ca (%)	0.73	0.65	0.58	0.58
P (%)	0.43	0.41	0.40	0.40

≠ Estimated from the equations: NE_L=ME×0.62 and ME=DE×0.82.
DE was determined by digestibility trials.

samples were ground through a 1 mm-screen hammer mill and stored pending chemical analyses.

Determination of digestibility : Samples of all feed offered and residues were collected during the last week of each period and kept frozen at -20°C pending analyses. Faeces from each cow was sampled three times daily and stored as mentioned above. At the end of the fourth period, the samples of feeds and residues were dried at 65°C for 48h and faeces were dried at 65°C for 96 h. The dried samples were ground through a 1 mm screen and aliquots of each ingredient and total mixed diet from each day were composite by period for analysis.

Samples were analyzed for CP, CF, Ash, ADL and GE according to the methods represented in AOAC (1990). Neutral detergent fiber (NDF) and acid detergent fiber (ADF) were determined by using the methods of Van Soest et al. (1991). The apparent digestibility of DM, OM, CP, EE, CF, NDF and ADF was determined using the acid-insoluble ash ratio technique (Sunvold and Cochran, 1991).

Milk recording and composition : Daily milk production was recorded using milking machine equipped with a recorder. A composite of milk samples were collected twice daily at regular milking times (07:00 and 19:00) on day 18, 19, 20 and 21 during the last week of each experimental period. Milk samples were preserved with potassium dichromate (0.025 mg per 50 ml sample tube) and stored at 4C° in a refrigerator pending analysis for fat, protein, lactose, total solid (TS) and solid-non fat (SNF) concentration using Milkoscan 4000 (Foss Electric, Hillerod).

Body weight change : Body weight changes were obtained monthly by weighing the animals before the morning feeding.

RESULTS AND DISCUSION

Digestibility of the diets

Inclusion of the treated wheat straw at 0, 10, 20 and 30% in the diet did not affect the digestibility of nutrients, except for the ADF that was significantly ($p<0.05$) reduced in the diet IV (Table 3). The TDN contents were also statistically similar among the diets. Such findings could be as a result of the fungal treatment that has improved the digestibility of the straw (Jalc et al., 1998). Additionally, the associated effects of the higher digestible feeds (such as barley and cottonseed meal) used in the diets could improved the digestibility of the total diet (Atwell et al., 1991) and resulted in a relatively similar digestibility in the alfalfa or treated straw diets. The DM digestibility ranged between 68.4 to 69% that is comparable with the results of Haddad et al. (1998) who compared the effects of alkali treated wheat straw with alfalfa for lactating cow. Meanwhile, the digestibility of OM, NFE and GE slightly decreased in the diet with the highest (30%) level of treated straw. This diet contained higher level of NDF (45.3 vs 40.6%) and ADF (29.8% vs 23.8%), comparing to the control or alfalfa diet.

Nutrient intake

The daily intake of DM, OM, CP, TDN and NE_L were not affected by substitution of alfalfa hay with treated straw

Table 3. *In vivo* digestibility of the nutrients and gross energy of the diets (%)

Attribute	Diets (% Straw)				SEM n=8	SOL
	I	II	III	IV		
	0	10	20	30		
DM	68.6	69.0	68.6	68.4	1.10	ns
OM	68.4	69.2	66.9	67.3	3.10	ns
CP	62.1	62.0	62.0	60.5	3.60	ns
EE	76.3	76.7	81.3	73.4	4.70	ns
CF	33.4	33.4	33.3	35.6	3.10	ns
NFE	62.8	62.0	61.2	60.5	2.90	ns
NDF	38.0	37.6	37.6	36.7	5.14	ns
ADF	38.7^a	37.8^a	36.7^{ab}	35.4^b	3.12	*
CL	46.0	44.1	44.6	46.4	3.49	ns
HmC	44.1	42.0	46.3	42.3	3.40	ns
GE	68.0	66.8	65.9	66.2	3.21	ns
TDN	62.0	61.7	60.2	59.0	1.96	ns

Means with the different superscription within a row are significantly ($p<0.05$) different.
SEM=Standard error of mean. CL=Cellulose. SOL=Significant observed level. HmC=Hemicellulose. ns=Non significant. GE=Gross energy.
* $p<0.05$.

(Table 4). Although, the NDF concentration was higher in the treated straw diets (45.3 vs 40.6%), the DMI was similar. Inclusion of the fungal treated straw up to 30% of the total diet, which was equal to the 60% of the alfalfa hay portion in the diet, did not affect the voluntary DMI. Such improvement of intake of the treated straw could be due to the physical character (the softness of the treated straw structure) and the chemical changes (the biodegradation of its cell wall) in the straw during the biological fermentation (Arora et al., 1994; Zadrazil et al., 1995) that also improved the digestibility as discussed above. Moreover, the diets used in this experiment contained 50% of concentrate and fed as TMR. Therefore, bulkiness of the straw could not act as a limited factor of feed consumption. Feed intake in ruminants is dominated by two factors, the ingestibility of the fed forage and the intake capacity of the animal (Beever et al., 1989; McOueen and Robinson, 1996). In addition, the cows used in this experiment were in late lactation and positive energy balance and ruminal fill may have little effect on the intake (Poore et al., 1991). Several authors (McQueen and Robinson, 1996; Okine et al., 1997) reported that even for relatively high fibre diets fed to late lactating cow it might be the energetic requirement of the cow rather than rumen fill that limits the intake.

There is no information about the intake of fungal treated straw by dairy cow. When steam-treated wheat straw was included in the diet of lactating cow, as a roughage source at 20 and 30% of the ration, the DMI was similar to the intake of 30% alfalfa hay diet (Sharma et al., 1982). However, the intake of DM was reduced when NaOH+ammonia treated wheat straw was included to a level of more than 20% into the diets of mid lactating cows (Haddad et al., 1998). Cameron et al. (1990) noted that the utilization of alkaline hydrogen peroxide-treated wheat straw in the diet of early lactating cows caused a slightly lower DMI, in comparison to the alfalfa and corn silage diet.

Table 4. Nutrient intake by the cows fed different diets

Attribute	Diets (% Straw)				SEM n=8	SOL
	I	II	III	IV		
	0	10	20	30		
DMI:						
(kg/d)	13.2	12.9	12.3	12.5	1.10	ns
(% of BW)	2.25	2.22	2.1	2.1	0.19	ns
(g/kg $W^{0.75}$)	111	109	103	104	8.98	ns
OMI (kg/d)	12.0	12.0	11.4	11.4	0.99	ns
DOMI						
(kg/d)	8.3	8.2	7.5	7.6	0.67	ns
(% of BW)	1.4	11.4	1.3	1.3	0.11	ns
(g/kg $W^{0.75}$)	70	69	63	64	5.60	ns
CPI (kg/d)	2.0	1.9	1.9	1.9	0.16	ns
TDNI (kg/d)	8.12	7.91	7.40	7.44	0.74	ns
NE_LI (Mcal/d)	18.34	17.80	16.61	16.5	1.80	ns

Means within a row were compared which were not significantly (p>0.05) different.
DMI=Dry matter Intake. NE_LI=Net energy lactation intake.
OMI=Organic matter intake. SEM=Standard error of mean.
DOMI=Digestible organic matter intake. SOL=Significant observed level
CPI=Crude protein intake. ns=Non significant.
# Estimated from the equations:
$DMI \times NE_{L(Mcal/kgDM)}$, $NE_{L(Mcal/kgDM)}=ME\times0.62$ and $ME=DE\times0.82$.
DE=Digestible energy of the diets, was determined by digestibility trials.

Table 5. Effects of diets on the milk yield and composition and body weight gains

Attributes	Diets (% Straw)				SEM n=8	SOL
	I	II	III	IV		
	0	10	20	30		
Production						
Milk (kg/d)	13.1	13.0	13.3	13.4	0.72	ns
FCM (kg/d)	11.0	11.2	11.3	11.6	0.95	ns
Fat (g/d)	396	408	412	423	48.11	ns
Protein (g/d)	432	429	439	440	29.27	ns
Milk contents						
Fat (g/kg)	30.2	31.4	31.0	31.6	3.10	ns
Protein (g/kg)	33.2	33.0	33.0	32.8	1.35	ns
Lactose (g/kg)	56.7	56.9	56.7	57.2	0.97	ns
SNF (g/kg)	95.9	95.8	95.8	95.8	1.64	ns
TS (g/kg)	126.1	127.2	126.7	125.8	3.94	ns
BW gain (g/d)	501^{b}	592^{ab}	674^{a}	572^{ab}	84.0	*

Means with the different superscription within a row are significantly (p<0.05) different.
SEM=Standard error of mean. SNF=Solid non fat. SOL=Significant observed level. TS=Total solid. ns=Non significant. BW=Body weight.
* p<0.05.

Milk production and composition

Table 5 shows the average milk yield and composition by cows fed the experimental diets. When milk yield and FCM were compared among the treatments, no significant (p>0.05) differences were observed. It may be explained that the fungal treated wheat straw could provide the nutrient requirements for milk production similar to that of alfalfa diet. However, protein deficiency was compensated by cottonseed meal in the diets. In addition, cows were in a state of positive energy balance so they could consume sufficient DM and other nutrients from the treated straw diets and alfalfa to produce the same amount of milk. Haddad et al. (1998) used 3.0% $Ca(OH)_2$ and 3.0% NaOH treated straw in the diet of Holstein cows in mid lactation and found that at substitution of 20% of the dietary alfalfa with treated wheat straw maintained the same level of milk production and FCM. Cameron et al. (1991) included up to 37% alkaline hydrogen treated wheat straw in the complete mixed diets that consisted of 50% concentrate without any effect on the milk and FCM production.

Inclusion of treated straw in the diets did not statistically affect the composition of the milk. The concentration of fat, protein, lactose, SNF and TS were average 31.07, 33.0, 56.9, 95.8 and 126.5 g/kg, respectively (Table 5). These data are in agreement with the findings of Haddad et al. (1998) who studied the effect of 20% dietary inclusion of alkali (3% NaOH+3% $Ca(OH)_2$) treated wheat straw on the lactational performance of dairy cow. In contrast, Brown et al. (1990) observed an increase in fat content of milk (from 30.7 to 33.2 g/kg) when untreated or ammonia treated wheat straw was included in the diet of the lactating dairy cows. A possible explanation for that is the basal diet which was high in grain (45:55 forage to concentrate ratio) may led to a lower milk fat, so that the inclusion of the straw had led to improve the milk fat (Robinson and McQueen, 1997).

Body weight change

All cows showed daily weight gain that is normal for dairy cows in late lactation (Table 5). The average daily gains were significantly ($p<0.05$) different among the diets. Substitution of alfalfa with treated straw resulted in a higher body weight gain. When the treated straw substituted alfalfa hay, higher level of cottonseed meal was included to the diet (Table 2) to compensate the protein deficiency. It could improve the metabolism and biological values of the protein and amino acid balance (Bas et al., 1989; Moller and Atreja, 1989). These results supported by Haddad et al. (1998) who reported that when alkali treated wheat straw was included (20%) to the lactating cow and its protein deficiency was compensated by soybean meal, the average daily body weight gain increased (570 vs 314 g/d) in comparison to the alfalfa diet.

CONCLUSION

Feeding the four diets containing 0, 10, 20 and 30% fungal (*Pleurotus*, P-41.) treated wheat straw resulted in a similar intake of DM, OM, DOM, CP, TDN and NE_L. Cows consuming these diets had similar milk yield, FCM production and milk composition. This experiment showed that the fungal treated wheat straw could be included to the diet of lactating cows up to 30%.

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