Research Journal of Animal Sciences 3 (1): 1-5, 2009
ISSN: 1993-5269

Effect of Substitution of Corn Grain and Soybean Meal with Corn Gluten Feed or Corn Distiller Dried Grains and Soluble in Ruminants

N. Moujahed, A. Moujahed-Raach, M. Jlali, T. Najar and Ch. Kayouly
Institut National Agronomique de Tunisie, 43 Av. Ch. Nicole, 1082, Tunisia

Abstract: Four Barbarine breed sheep (initial average BW and age 58 kg and 18 month, respectively), receiving a basal diet composed of oat hay, were used in a Latin square design (4×4) to study the effect of the total substitution of soybean meal (D1: Sb: 23.5% of concentrate) by corn distillers dried grains with soluble (D2: DDGS: 45%) or corn gluten feed (D3: CGF: 65%) or a mixture of the 2 ingredients (D4: CGF+DDGS, respectively 23 and 26%) on intake, digestibility and nitrogen balance. The proportion of concentrate in diet was adjusted at a level of 25% of the total dry matter intake. Each experimental period lasted 28 days (21 and 7 days, respectively for adaptation and measurements). The compound feeds were approximatively iso-nitrogenous and iso-energetic. The obtained results showed that the studied corn co-products were characterized by a high quality of crude protein. The voluntary intake of hay and total diet DM were not affected by the applied substitution (average value 53.2 g DMkg$^{-0.75}$ day^{-1}). No effect of substitution was noted on DM, OM and CP digestibility or N balance. In contrast, an improvement of the digestibility of crude fiber was observed ($p<0.05$), mainly in diet containing DDGS. The biological quality of N expressed as the ratio: Retained N/Absorbed N, seamed to be higher in SBM, DDGS and GDDS diets (averaged 30.5%) than in CGF one (26.6%). It was concluded that substituting soybean with corn co-products in concentrate supplied at a rate of 25% of DM total intake did not affect nutritive value of oat hay based ration and the studied diets were nutritionally similar.

Key words: Substitution, soybean, corn, gluten feed, distillers dried grain and soluble, ruminants

INTRODUCTION

In Tunisia, breeding intensification based on high producing-potential animals requires the use of high energy and protein feeds. Consequently, the most of manufactured compound concentrates are based mainly on corn (energy) and soybean (energy and protein). However, these ingredients are completely imported and their prices in the international markets frequently fluctuate. Since concentrate accounts for 60-70% of the feeding cost in ruminants and 100% in poultry, these variations are reflected directly on commercial prices of animal products. To face this dependence, it is imperative, in the short and the medium term, to widen the list of the imported raw materials. Nutritionally, partial and some times total substitution of corn and soybean is possible, but the substituting product must be included taking into account the limits of their incorporation in connection with the requirements of the different categories of animals.

Corn Gluten Feed (CGF) and Dried Distiller Grain and Soluble (DDCS) are the most important co-products, respectively from dry and wet milling processes (Stock *et al*., 1999). They have mainly high digestible fibre and degradable protein which represent important sources of energy and protein for rumen microbes especially in forage-based diets (Ham *et al*., 1994), in addition to their reducing-acidosis effects (Krehbiel *et al*., 1995). These substrates used to be included mainly in ruminants (Trankle, 1997; Vander Pol *et al*., 2006; Kononoff and Erickson, 2006) and poultry diets (Owings, 1985) to substitute partially or totally corn grain and/or Soybean (Sb). Moreover, due to their nutritional profiles and synergistic effects in feeding, combination of them is also investigated (Loza *et al*., 2004).

The most studies on corn grain co-products were carried out in high quality based died conditions (Morris *et al*., 2005), such as those based on alfalfa hay (Sindt *et al*., 2001; Loza *et al*., 2004) and they were rarely associated with low quality roughages witch are frequently produced in southern countries. In connection with this, in Tunisia ruminant feeding is based on low quality hay and silage mainly from oat and the current study aimed to investigate the possibilities to substitute

Corresponding Author: N. Moujahed, Institut National Agronomique de Tunisie, 43 Av. Ch. Nicole, 1082, Tunisia

corn grain and soybean with CGF or DDGS or both of them and their effects on oat hay based diet intake, digestion and nitrogen use in ruminants.

MATERIALS AND METHODS

Animals, diets and experimental design: Four Barbarine breed sheep (average initial weight and age: 58 and 18 month, respectively) were used in a Latin square design (4×4) to study the effect of partially and fully substituting, respectively corn and soybean with CGF, or DDGS or a mixture of them. They received a basal diet composed of oat hay supplemented with concentrate containing 23.5% Sb (C_{Sb}: D1) or 45% DDGS (C_{DDGS}: D2) or 65% CGF (C_{CGF}: D3) or a mixture of 23% CGF and 26% DDGS (D4: $C_{CGF+DDGS}$). Composition of the 4 compound concentrates is presented in Table 1. Hay was produced in the north of Tunisia in 2006 and was shopped (about 10 cm) in order to facilitate weighing and to avoid lost from mangers. Sheep were housed in metabolic cages and before the beginning of the experiment, they received preventive treatments anti-parasites (IVOMEC) and against enterotoxaemia (Coglavax). Animals have free access to fresh water and were weighed at the commencement and at the end of each measurement period. Experiment lasted 28 days (21 for adaptation 7 measurements).

Measurements: Amounts of offered and refused hay was weighed daily during the measurement period. Daily samples of hay refusals (20%) and concentrate were taken and bulked. Total daily fecal output for each animal, collected before the morning meal, was weighed, sampled (10%) and pooled for the 7 day collection period. Fecal samples were stored at -10°C. A daily collection of urine was practiced. About 100 mL of 10% H_2SO_4 solution was added to the urine container. A 10% urine aliquot collected daily from each animal was stored at -10°C pending N analysis. Portions of individual pooled samples of refusals and faeces were dried in a forced-air oven (50°C), ground through a 1 mm screen and stored for later analysis. Drinking water consumption was recorded daily during the 7 day measurement period.

Laboratory analysis: Dry Matter (DM) content of feed, refusals and faeces was determined by drying in a forced-air oven at 105°C for 24 h. Feed, refusals and faeces were analyzed for ash (550°C, 6 h), CF using the Weende procedure and CP by the Kjeldahl method as 6.25× N and fat was determined only in feed using Soxhlet method (AOAC, 1984). Soluble N (Ns) was analyzed as described by Vérité and Demarquilly (1978). Non Protein Nitrogen (NPN) was determined using the method of precipitation by Trichloroacetic Acid (TCAA) as described by Licitria (1996). Non PN is precipitated by TCAA and residual N is analyzed using Kjeldahl procedure. Non PN is calculated by difference between total and residual N. Acid Detergent Fiber (ADF) was analyzed in offered feeds as described by Van Soest *et al.* (1991). Urinary N was determined by the Kjeldahl method.

Table 1: Compound feed composition (%)

Row material	C_{Sb}	C_{DDGS}	C_{CGF}	$C_{CGF+DDGS}$
Soybean 48	23.5	0	0	0
Corn gluten feed	0	0	65	23
Dried distiller grain	0	45	0	26
Corn grain	50	28	30	21
Wheat bran	21.5	22	0	25
MVS	05	05	05	05

C_{sb}: Concentrate including soybean; C_{DDGS}: Concentrate including DDGS; C_{CGF}: Concentrate including CGF; $C_{CGF+DDGS}$: Concentrate including CGF and DDGS; MVS: Mineral and Vitamin Supplement

Statistical analysis: The General Linear Model procedure (GLM) of SAS (1990) was used to analyze data. Model included effects of diet, animal and period. Duncan multiple range test was used to compare treatment means.

RESULTS AND DISCUSSION

Chemical composition: Chemical composition of feed and concentrates is presented in Table 2. Soybean was high in CP content (48.7% of DM). This value is slightly higher than which presented by INRA (2004). The CGF was relatively high in CP (27.8% DM). The found value is relatively higher comparatively to some values reported in the literature (Allen and Grant, 2000; Schroeder, 2003; Macken *et al*., 2004). The substrate DDGS was relatively higher in CP than the studied CGF (29.9% DM) and approximatively similar to the values observed by Al-Suwaiegh *et al*. (2002) for DDG (28.9% DM) and humid DG (30.5% DM). The compound concentrates were approximatively iso-nitrogenous (CP averaged 19.5% DM).

Among the studied substrates, the DDGS was the highest in Fat (13.6% DM). This result is in the range of the values noted by Al-Suwaiegh *et al.* (2002) and Larson *et al.* (1993). While, the 3 other substrates are low in Fat (averaged 3.36% DM). Wheat bran, CGF and DDCS are particularly high in cell wall (NDF averaged 49.6% DM), which was lowly lignified (ADF averaged 11.2% DM). On the bases of cell-wall component contents, it's worthy to note that compound concentrates containing CGF, DDGS or a mixture of them are of cell wall type, while soybean concentrate is of starch one.

Non PN and Ns results are presented in Table 3. Soybean had the lowest NPN content relative to Nt, since

Table 2: Chemical composition of feeds and concentrates

Aliments	DM (%)	Ash	OM	CP	CF	Fat	ADF	NDF
Wheat bran	85.4	6.7	93.3	16.15	10.7	2.7	11.6	49.5
Corn grains	87.1	1.5	98.5	8.10	2.9	3.9	2.4	20.4
CGF	89.2	5.8	94.2	27.80	9.3	3.5	11.3	48.0
DDGS	88.1	4.7	95.3	29.90	9.9	13.6	10.6	51.2
Sb	88.6	7.3	92.7	48.70	4.6	1.2	4.7	13.3
C_{Sb}	88.3	8.6	91.4	18.80	4.7	3.1	4.9	25.2
C_{DDGS}	88.5	7.5	92.5	19.20	5.8	7.3	6.8	40.3
C_{CGF}	89.2	7.5	92.5	19.90	6.2	3.8	6.9	35.6
$C_{DDGS+CGF}$	88.2	7.3	92.7	20.00	6.8	6.7	7.5	36.6
Oat hay	91.2	9.4	90.6	5.30	38.1	2.0	42.0	65.0

Table 3: Non protein and soluble nitrogen in used row materials and experimental concentrates

Aliments	NPN (DM%)	NPN/Nt (%)	Ns (DM%)	Ns/Nt (%)
Wheat barn	0.53	20.5	0.43	16.6
Corn grains	0.27	20.8	0.22	17.0
CGF	1.52	34.2	0.64	14.4
DDGS	0.54	11.3	0.18	3.8
Sb	0.45	5.8	1.23	15.8
C_{Sb}	0.30	10.0	0.20	6.7
C_{DDGS}	0.60	19.4	0.20	6.5
C_{CGF}	1.10	34.4	0.60	18.8
$C_{DDGS+CGF}$	0.70	21.9	0.30	9.4

Nt: Total nitrogen, NPN: Non Protein Nitrogen, Ns: Soluble Nitrogen

Table 4: Intake, digestibility, feeding value and N balance of the diets

Parameters	D1	D2	D3	D4	SEM
Intake (g DM day^{-1})					
Total diet	1653.6	1622.9	1566.4	1596.9	108.2
Hay	1225.7	1198.5	1143.1	1173.5	107.4
Concentrate	427.9	424.5	423.3	423.3	1.7
Digestibilty (%)					
OM	61.5	61.5	62.6	60.6	0.4
CP	53.1	52.5	53.3	52.1	0.8
CF*	49.5b	59.1a	48.7b	49.9b	1.5
Nutritive value (g day^{-1})					
DOMi	931.1	906.8	889.1	878.3	46.8
DCPi	82.8	79.2	78.3	78.9	7.2
Nitrogen balance (g day^{-1})					
Ni	25.0	24.3	23.3	24.5	0.2
Na	13.3	12.8	12.4	12.8	0.51
Nr	4.2	3.9	3.3	3.8	0.2
Nr/Na*	41.5a	38.7ab	26.7b	36.5ab	3.7

D1: hay + C_{SB}; D2: hay + C_{DDGS}; D3: Hay + C_{CGF} ; D4: hay + $C_{(CGF+DDGS)}$.. a, b: Values with different letters in the same line are statistically different: *$p<0.05$; SEM: Standard Error of the Mean

its proportion represented only 5.8% of Nt. This result is equivalent to which found by Licitra *et al.* (1996). The value of Ns (15.8% Nt) is relatively lower than which found by Moujahed *et al.* (1993). However, DDGS presented the lowest N solubility. The found value is higher that which reported by Vérité and Demarquilly (1979). It's worthy to note that DDGS crude protein seemed to be of a higher quality comparatively to wheat bran and CGF (lower proportion of NPN and Ns). Among the studied compound concentrates C_{CGF} seemed to present the lowest CP quality since it's characterised with the highest proportions of NPN and Ns relative to Nt (34.2 and 18.8% Nt, respectively).

Intake: Dry matter voluntary intake of feed and total diets results are presented in Table 4. Including CGF or DDGS or both of them in concentrate did not result in any change in DM intake of hay or total diet (averaged 1185 and 1610 g day^{-1}, respectively). This may be related to the low and equivalent rate of concentrate used in the diets, since hay is high in lignocelluloses which could result in low intake in all the diets (Sauvant and Van Mildgen, 1995). Our finding agrees with several studies dealt with total substitution of soybean with corn co-products or other N sources (Irshaid *et al.*, 2003; Froidmont and Bartiaux-Thill, 2004; Ponnampalam *et al.*, 2005). However, it's not in line with results of Hejazi *et al.* (1999), who suggested that DM intake is higher in diets containing high-fiber by products. The including rates of these substrates could explain result divergences.

Digestibility and feeding value of diets: No effect of including CGF or/and DDGS was observed on OM and CP digestibility of oat hay basal diet (Table 4). This result agree with those of Birkelo *et al.* (2004) when substituting soybean with DDG in a basal diet composed of corn silage and Lucerne hay, mainly for CP digestibility. It could be related to the relatively low rate of concentrate in the diets (25% of DM). In contrast, CF digestibility in DDGS was higher ($p<0.05$) than the other diets, which were similar (mean value 59.1%). The same trend was found by Ham *et al.* (1994) and Birkelo *et al.* (2004) with corn co-products. Including lowly lignified (Table 2) and highly digestible fiber from DDGS may be at the origin of this effect (Grings *et al.*, 1992; Larson *et al.*, 1993). In addition, the transformation process of corn when manufacturing methanol likely resulted in a partial delignification of the substrate, thereby increasing their rumen digestion level (Jaster *et al.*, 1984).

No differences were observed in DOMi between the 4 diets (averaged 901 g day^{-1}, Table 4). When expressed as g kg$^{-0.75}$ the noted values are in the range of results found by several authors in hay and concentrate composed diets (Ben Salem *et al.*, 2004; Irshaid *et al.*, 2003 and Salisbury *et al.*, 2004). For all the diets values are higher than 23 g kg$^{-0.75}$, minimum level recommended by INRA (1978) to cover maintenance requirements of sheep. Similar trend was obtained for DCPi (averaged 79.8 g day^{-1}, Table 4). These results indicated that at feeding level higher than maintenance needs of sheep the studied substitution had no effect on feeding value of oat hay based diet.

Nitrogen balance: The studied substituting strategy had no significant effect neither on absorbed nor on retained N (averaged 12.8 and 3.8 g day^{-1}, respectively, Table 4).

However, substituting soybean with CGF or/and DDGS have a significant ($p<0.05$) effect on N Biological Value (NBV) expressed as (Retained N)/(Absorbed N) ratio, comparatively to Soybean diet (D1). In deed, the observed value was the highest in soybean diets (31.6% Na), comparatively with CGF one (26.7% Na) witch was the lowest. The two other diets presented intermediate values. This may indicate that retained N from soybean diets was of a higher quality. Indeed, soybean concentrate presented the highest proportion of true protein N (90% of Nt), calculated as (Nt-NPN)/Nt; while CGF concentrate presented the lowest one (65.6% of Nt).

CONCLUSION

It was concluded, that the strategy to substitute soybean and a part of corn grain with corn co-products in concentrates supplied at a rate of 25% of DM total intake did not affect intake, digestion and N use of poor ration composed of oat hay as basal diet and that the studied diets were nutritionally similar. Such alternatives should lead to reduce animal feeding cost and to moderate the economic impact related to row material importation, mainly in developing countries. Higher rates of corn co-product concentrates are currently investigated in our laboratory.

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