Journal of Agricultural Science; Vol. 5, No. 2; 2013
ISSN 1916-9752 E-ISSN 1916-9760
Published by Canadian Center of Science and Education

Forage Yield, Chemical Composition and *In Vitro* Gas Production of Triticale (*X Triticosecale wittmack*) and Barley (*Hordeum vulgare*) asociated with Common Vetch (*Vicia sativa*) Preserved as Hay or Silage

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Received: September 26, 2012 Accepted: October 16, 2012 Online Published: January 15, 2013
doi:10.5539/jas.v5n2p227 URL: http://dx.doi.org/10.5539/jas.v5n2p227

Abstract

Forage cereals are deficient in protein, but legumes are acceptable in protein quality; the association of both forages can increase their nutritional value and biomass production. The objectives were to evaluate forage yield, chemical composition, energy content and *In Vitro* gas production of varieties of triticale (UAEMex and Siglo XXI), barley (Doña Josefa) and its association with common vetch, harvested at 145 days (milky-dough stage); a portion was ensiled and the other was hayed. Data were analyzed by a completely randomized design, and by using non-orthogonal contrasts to compare means of barley against triticale, common vetch and unicrops *vs.* associations. There were differences ($P < 0.001$) in DM (dry matter) production, being higher triticale Siglo XXI and associated with common vetch (6.50 and 5.4 ton DM/ha respectively), the highest CP content ($P < 0.001$) was for common vetch (234 g/kg DM) and their associations (187±2 g/kg DM). NDF content showed no differences between varieties and their associations ($P > 0.302$). Doña Josefa Barley showed a higher content ($P < 0.05$) of TDN (65%), NE_l 1.4, and NE_g0.8 Mcal/kg DM in both methods of preservation. Total gas production (ml/g DM), was higher for the association of Doña Josefa barley to common vetch ($P < 0.05$) (127±6 ml gas/g DM) compared to the rest (117±3 ml gas/g DM). As a conclusion, associations of barley or triticale to Siglo XXI with common vetch as hay or silage, allows us to consider them as an option to incorporate into the processes of production of livestock feed in high valleys.

Keywords: barley, triticale, common vetch, hay, silage, *In Vitro* gas production.

1. Introduction

Forages are an important resource for animal feed in the world because they provide energy and protein for livestock (Ghanbari, 2000). Due to adaptation of highlands (located in altitudes of 2200 to 2600 meters above sea level), where the productivity of other forage is limited by low temperatures, an alternative to forage production are small grains such as wheat (*Triticum aestivum*), barley (*Hordeum vulgare*), oats (*Avena sativa L.)* and triticale (*X Triticosecale wittmack*) (Anil et al., 1998; Lema et al., 2004; Ross, King, O'Donovan, & Spaner, 2004). They are commonly used in winter forage by grazing (Lema et al., 2004) or conserved silage or hay (Haj-Ayed, González, Caballero, & Alvir, 2000).

Intercropping is defined as the growth of two or more crop species simultaneously in the same field during the growing season (Ofori & Stern, 1987). These intercropping fields are important for the development of production systems that depend little on external inputs (Adesogan et al., 2002). This may be due to the potential benefits of intercropping such as high productivity and profitability (Yildirim & Guvence, 2005); improved soil fertility by added nitrogen-fixing legumes (Hauggaard-Nielsen et al., 2001); efficient use of resources; and reduced damage caused by pests, diseases, and weeds (Banik et al., 2006). But their most important use is for the production of quality forage through the complementary effects of two or more crops simultaneously in the same area (Ross et al., 2004; Bingol et al., 2007; Lithourgidis et al., 2007).

Forage conservation from hay or silage; maintain the nutritional qualities for long periods of time (Givens & Rulquin, 2004; Scharenberg et al., 2007). In recent years, commercial varieties of triticale and barley have been released, counting on a wide range of advanced lines with specific adaptation to conditions in the highlands of Mexico. Such varieties are not available due to their potential as forage, nutritional quality or associations with common vetch, and use to establish feeding programs in ruminants. Except for some reports of forage yield and chemical composition, the technique of *In Vitro* gas production (Menke & Stengass, 1988; Theodorou, Williams, Dhanoa, Mc Allan, & France, 1994) is a parameter of importance to know fermentation patterns and degradation, depending on the availability of nutrients from the feed. The objectives of this study were to evaluate the forage yield, chemical composition and *In Vitro* gas production of two varieties of triticale and barley associated with common vetch as silage or hay.

2. Materials and Methods

2.1 Crop Establishment

The study took place in the valley of Toluca, Mexico State, located at coordinates 19° 17' north latitude and 99º 39' west longitudes at an altitude of 2675 meters above sea level. The climate is of type C (w2) (w) b (i'), corresponding with subhumid climate with summer rains, with little temperature variation between 5 and 7°C. Average annual rainfall is 1000 mm and mean annual temperature is 14°C. The predominant soil type is vertisol pelvic volcanic (INEGI, 2000).

The evaluation consisted in two varieties of spring triticale (UAEMex and Siglo XXI) and barley (Doña Josefa) as unicrop and associated with common vetch, which were provided by the Institute of Agricultural Research and Training in Mexico State (ICAMEX) in coordination with the International Maize and Wheat Improvement (CIMMYT) and the Faculty of Agricultural Sciences at the Autonomous University State of Mexico. The trial was established on April 24, 2010 (three replicates for each of the varieties). The experimental unit consisted in seven rows, each 50 linear meters by 30 cm wide (with two lines of planting and spaced at 80 cm), leaving a meter on each side to protect the experimental area. The planting density was 80,000 plants/ha, which was fertilized with 60-90-70 – N-P-K, respectively (130.4 kg of urea, 195.6 kg triple superphosphate, and 116.7 kg potassium chloride/ha), and irrigation was applied after sowing.

2.2 Sampling, Forage Conservation and Chemical Analysis

Each sample of dry matter (DM) and fresh matter (FM) was performed by cutting the crop at an approximate height of 2 cm from the soil surface, when the grain was in the milky-dough stage (145 days); random sampling for the collection of varieties, taking 1.0 m linear from areas of the central rows forming the experimental unit, obtaining three samples of each variety, and determininged the DM content (60°C for 48 h) and moisture for forage yield (ton/ha).

Of the selected forage samples, a part was hayed (three samples of each variety and association were sun-dried for seven days to reach approximately 85% DM), and the other part was prepared freshly chopped for micro-silages by triplicate, in 20 x 10 cm tubes of polyvinyl chloride, with a capacity of 1.5 kg (Cobos et al., 1997), and compacting and sealing them well with plastic bags and tape to prevent the entrance of air. At 60 days the samples were opened from micro-silages (200 g), dried in a forced air oven (60°C, 48 h), and ground in a Willey mill with a sieve of 2 mm.

Forage samples were analyzed for DM (#934.01), ash (#942.05), and N (#954.01) according to (AOAC, 1997). The neutral detergent fiber (NDFom, Van Soest et al., 1991), acid detergent fiber (ADFom), and lignin (AOAC, 1997; #973.18) analyses used an ANKOM200 Fiber Analyzer Unit (ANKOM Technology Corporation, Macedon, NY, USA). NDFom was assayed without use of an alpha amylase but with sodium sulfite in the NDFom. Both NDFom and ADFom are expressed without residual ash. Moisture content of the silages was determined through distillation with toluene (Haigh & Hopkins, 1977).

2.3 In Vitro Gas Production

For the *in vitro* gas production technique, we used three rumen fistulated dairy cattle (LW 450 ± 20 kg) as donors of rumen fluid. The animals received a diet of oat hay and alfalfa hay (50:50), formulated to meet all of their nutrient requirements (NRC, 2001), and was supplied twice a day (8:00 and 16:00 hours). Fresh drinking water was available to the cows at all times.

Gas production was determined in 125 ml amber flask and three series of incubation for each sample of forage conservation method, using the technique proposed by Theodorou et al. (1994). In each flask was introduced 0.8g DM of each of the samples, then we added 90 ml of buffer solution (Menke & Steingass, 1998) gassed with CO_2 and stored (4°C for 12 h); until the next day when we took 700 ml of ruminal fluid and 300g of solid rumen contents of each cattle donor, and filtered the homogenized mixture through four layers of gauze and glass wool subsequently, maintaining the rumen fluid at 39°C, then was gassed with CO_2, and subsequently added to each flask 10 ml of ruminal fluid. Finally, the flasks were introduced into a water bath at 39°C and initiated gas production record using a pressure transducer (DELTA OHM, Manometer, 8804). The volume of gas produced was recorded at 3, 6, 9, 12, 24, 36, 48, 72 and 96 h of incubation. For corrections were used two flasks without substrate as blank and barley straw as standard.

2.4 Calculations and Statistical Analysis

After the incubation period (96 h), the accumulated gas was released and the fermentation residues of each flask were dried (60°C, 48 h) to calculate the proportion of dry mater disappeared (DMd) and relative gas production (RGP, ml gas g DMd) according to Gonzalez Ronquillo et al. (1998).

The kinetics of gas production were determined by adjusting the model,

$$GP = b\ (1\text{-}e^{-ct}) \tag{1}$$

Proposed by Krishnamoorthy et al. (1991); according to the model, *b* represents the total production of gas (ml gas/g initial DM); *c* the rate of degradation in relation to time (h^{-1}), and *t* time (h^{-1}).

The values of net energy for lactation (NE_l) and net energy gain (NE_g) of forages were obtained through determining the content of total digestible nutrients (TDN) from chemical composition (NRC, 2001):

Total digestible nutrients (TDN)

$$TDN\ (\%) = 81.38+(CP*0.36)-(ADF*0.77) \tag{2}$$

Where CP and ADF are expressed in g/100g DM

Net energy of lactation (NE_l)

$$NE_l\ (Mcal\ kg^{-1}) = [(0.0245*TDN)-0.12] \tag{3}$$

Net energy gain (NE_g)

$$NE_g\ (Mcal\ kg^{-1}) = [(0.029*TDN)-1.01] \tag{4}$$

Data were analyzed by GLM procedure of SAS (1999) by a completely randomized design

$$Y = \mu + Txi + \varepsilon ij \tag{5}$$

Were Y is the variable, Txi is the effect duo to the treatment, and εij is the experimental error.

We used non-orthogonal contrasts to compare: C1, barley against triticale; C2, barley-common vetch *vs.* triticale associated with common vetch; C3, common vetch *vs.* barley and triticale associated with common vetch; C4, unicrops (barley and triticale) *vs.* barley and triticale associated with common vetch. The comparison of measures of each variable was carried out through the Tukey method (Steel et al., 1997).

3. Results

3.1 Forage Yield, Chemical Composition and Energy Content

Table 1 shows the forage yield (ton/ha) for the varieties of barley and triticale, as well as its association with common vetch; differences were observed ($P < 0.001$) between forages, being higher (C2, $P < 0.020$), common vetch when compared to their associations (C3, $P < 0.013$), when comparing forage associations was higher (C4, $P < 0.001$) than unicrops. Except triticale, S XXI was higher than barley Doña Josefa and triticale UAMex.

Table 1 shows forages conserved as hay; CP content was higher for barley (C1, $P < 0.009$) *vs.* triticale's, and its association with common vetch (C2, $P < 0.005$); when comparing C3 ($P < 0.001$), common vetch was higher with respect to their association; C4 with the unicrops were lower ($P < 0.001$) with respect to associations with common vetch. NDF content were not different between forage varieties and their associations ($P < 0.302$), but ADF content was higher ($P < 0.001$) for triticale's *vs.* barley, and its association with common vetch (C2, $P < 0.05$). Likewise, common vetch was lower when compared with their associations (C3, $P < 0.019$); associations with common vetch were higher (C4, $P < 0.001$) compared with unicrops. There were differences for TDN content, NE_l and NE_g ($P < 0.001$) between varieties and their associations ($P < 0.001$). NE_l and NE_g were higher (C1, $P < 0.001$) for barley compared with triticale's and their association with common vetch (C2, $P < 0.02$). Common vetch was higher in terms of TDN content, $NE_{l,}$ and NE_g (C3, $P < 0.005$) when compared with their associations.

Table 1. Forage yield (ton/ha), chemical composition (g/kg DM), total digestible nutrients (TDN, %), net energy for lactation (NE_l) and gain (NE_g, Mcal/kg DM) of barley, triticale, common vetch and their associations, preserved by hay

FORAGE	Yield	DM	OM	CP	NDF	ADF	Lignin	TDN	NE_l	NE_g
UNICROP										
BDJ	2.0	931.5	895.3	176.1	520.1	280.4	64.3	66.1	1.5	0.9
TUAEMex	2.3	935.1	917.0	160.5	518.8	336.7	69.7	61.2	1.3	0.7
TS-XXI	5.4	890.5	878.9	159.5	531.9	349.5	76.7	60.2	1.3	0.7
ASOCIATION										
BDJ - CVetch	3.1	925.5	851.0	199.2	563.0	316.9	72.7	64.3	1.4	0.8
TUAEMex-CVetch	4.0	871.3	891.3	174.8	560.8	315.5	69.3	60.6	1.3	0.7
TS-XXI-CVetch	6.5	894.9	874.1	186.5	578.0	376.6	64.0	59.0	1.3	0.7
CVetch	5.0	935.5	808.6	234.2	517.6	315.4	105.1	65.5	1.4	0.8
SEM	0.2	10.8	4.8	2.4	20.5	6.7	3.9	0.4	0.01	0.01
P value	0.001	0.019	0.001	0.001	0.302	0.001	0.002	0.001	0.001	0.001
C1	0.249	0.401	0.887	0.009	0.852	0.001	0.050	0.001	0.001	0.001
C2	0.020	0.023	0.195	0.006	0.815	0.050	0.606	0.023	0.015	0.029
C3	0.013	0.012	0.090	0.001	0.227	0.019	0.016	0.004	0.002	0.006
C4	0.002	0.001	0.037	0.0002	0.381	0.001	0.331	0.001	0.001	0.001

DM, Dry matter; OM, Organic matter; CP, Crude protein; NDF, Neutral detergent fiber, ADF, Acid detergent fiber; TDN, Total digestible nutrients (%); NE_l = Net energy of lactation (Mcal/kg DM), NE_g = Net energy of gain (Mcal/kg DM).

Barley Doña Josefa (BDJ), Triticale UAEMex (TUAEMex), Triticale Siglo XXI (TSXXI), Common Vetch (CVetch)

Contrast: C1, Barley *vs.* Triticales; C2, Barley-CVetch. Triticale asociated with CVetch; C3, CVetch *vs.* Barley and Triticale asociates with CVetch; C4, unicrops (Barley and Triticales) *vs.* Barley and Triticale associated with CVetch.

Table 2 presents the chemical composition of forage silage; CP content was higher (C1, $P < 0.010$) for barley *vs.* triticales. Common vetch (C3, $P < 0.007$) was higher with respect to their association; when compared to unicrops it was lower (C4, $P < 0.001$) compared with their associations. There were no differences for C1 ($P < 0.304$) and C2 ($P < 0.104$); NDF content was higher for varieties associated with common vetch (C3, $P < 0.025$), the association barley and triticales associated with common vetch was higher (C4, $P < 0.022$) compared with the unicrops. ADF content was no different for C1 ($P < 0.187$) and C4 ($P > 0.614$), ADF content was higher (C2, $P < 0.023$) for triticale compared with barley associated with common vetch; common vetch was higher (C3, $P < 0.015$) when compared with their associations. TDN, NE_g and NE_l show differences ($P < 0.001$) between varieties and their associations. TDN, NE_l, and NE_g were higher (C1, $P < 0.001$) for barley compared to triticale, and their association with common vetch (C2, $P < 0.02$). Common vetch was lower (C3, $P < 0.015$) compared with their associations with barley and triticale's, TDN, NE_l and NE_g content were higher for associations (C4, $P < 0.001$) compared with unicrops.

Table 2. Chemical composition (g/kg DM), total digestible nutrients (TDN,%), net energy for lactation and gain (Mcal/kg DM) of barley, triticale, common vetch and their associations, preserved as silage

FORAGE	DM	OM	CP	NDF	ADF	Lignin	TDN	NE_l	NE_g
UNICROP									
BDJ	226.1	907.9	178.0	418.3	274.8	49.9	66.6	1.5	0.9
TUAEMex	226.9	895.6	152.7	487.7	343.1	57.2	60.4	1.3	0.7
TS-XXI	255.0	903.8	140.9	430.0	357.0	67.17	58.9	1.3	0.7
ASOCIATION									
BDJ-CVetch	267.3	845.9	195.3	473.6	270.9	62.6	67.5	1.5	0.9
TUAEMex-CVetch	216.7	839.6	188.9	505.3	318.6	71.2	63.6	1.4	0.8
TS-XXI-CVetch	288.6	911.1	171.4	561.5	325.4	61.0	62.4	1.4	0.8
CVetch	233.8	848.3	217.3	436.0	335.0	94.1	63.4	1.4	0.8
SEM	14.3	1.7	4.2	19.2	57.8	6.6	0.6	0.01	0.01
P value	0.001	0.071	0.001	0.011	0.594	0.034	0.001	0.001	0.001
CONTRAST									
C1	0.113	0.388	0.010	0.302	0.964	0.129	0.003	0.003	0.003
C2	0.001	0.008	0.081	0.104	0.024	0.689	0.017	0.021	0.020
C3	0.001	0.131	0.007	0.025	0.015	0.115	0.015	0.016	0.017
C4	0.001	0.003	0.001	0.022	0.614	0.399	0.001	0.001	0.001

DM, Dry matter; OM, Organic matter; CP, Crude protein; NDF, Neutral detergent fiber, ADF, Acid detergent fiber; TDN, Total digestible nutrients (%); NE_l = Net energy of lactation (Mcal/kg DM), NE_g = Net energy of gain (Mcal/kg DM).

Barley Doña Josefa (BDJ), Triticale UAEMex (TUAEMex),Triticale Siglo XXI (TSXXI), Common Vetch (CVetch)

Contrast: C1, Barley *vs.* Triticale; C2, Barley-CVetch *vs*Triticale associated with CVetch; C3, CVetch *vs.* Barley and Triticale associated with CVetch; C4, unicrops (Barley and Triticale) *vs.* Barley and Triticale associated with CVetch.

3.2 In Vitro Gas Production

There were differences ($P < 0.001$) for the total gas production (b) for the different forages evaluated as hay (Table 3); barley was higher (C1, $P < 0.001$) compared with triticale's (Figure 1), and there was a trend ($P < 0.092$) when compared with common vetch-barley *vs.* common vetch-triticales. Common vetch was lower (C3, $P < 0.003$) when compared with their associations (Figure 2), and unicrops were lower (C4, $P < 0.001$) compared with their association. There were no differences for the fermentation rate for C2 ($P < 0.116$) and C3 ($P < 0.433$). Fermentation rate (c), shows differences ($P < 0.001$) between treatments, being higher (C1, $P < 0.001$) triticale's compared with barley; and associations were higher (C4, $P < 0.004$) respect to unicrops. There were no differences for lag time in C2 ($P < 0.117$); lag time in barley was higher (C1, $P < 0.001$) compared with triticale, and common vetch was higher (C3, $P < 0.001$) compared with their associations. Unicrops were lower (C4, $P < 0.028$) compared with their associations. There were no differences ($P > 0.1$) for DMd between forages and their associations. Significant differences were observed ($P < 0.003$) in RGP, being higher in barley (C1, $P < 0.044$) compared with triticale,, and associated with common vetch (C2, $P < 0.022$). Common vetch was lower (C3, $P < 0.008$) compared with their associations, and common vetch associated with barley and triticale's was higher (C4, $P < 0.006$) compared with unicrops.

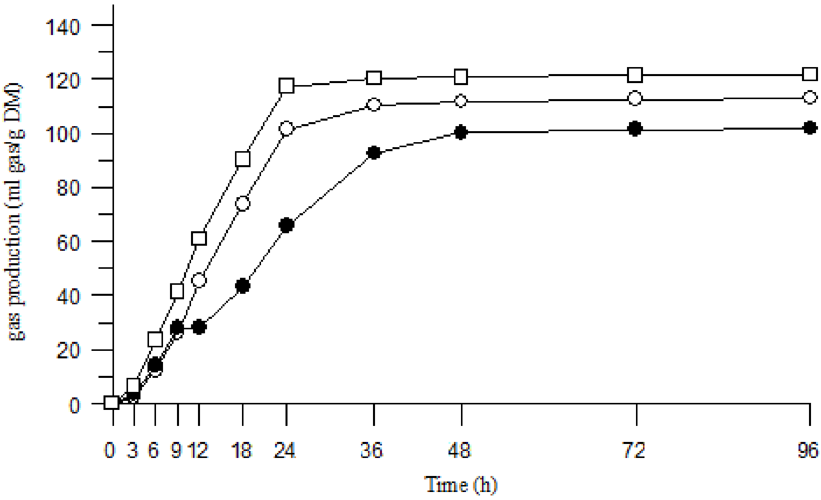

Figure 1. Cumulative gas production at 96 h (ml gas / g DM) of triticale varieties: UAEMex (○), Siglo XXI (●) and barley Doña Josefa (□), preserved by hay

Table 3. Parameters of *In Vitro* gas production (ml gas/g DM) obtained from the adjustment of incubation and digestibility of barley, triticale, and common vetch and their associations, preserved by hay

FORAGE	b	c	Lag time	DMd	RGP
UNICROP					
BDJ	116.6	0.0914	4.3	66.4	185.9
TUAEMex	101.4	0.1035	3.6	64.8	171.5
TS-XXI	92.4	0.0844	4.2	66.4	129.8
ASOCIATION					
BDJ – CVetch	139.0	0.1158	3.7	58.2	231.0
TUAEMex-CVetch	128.9	0.0952	4.6	65.9	163.6
TS-XXI-CVetch	124.9	0.1009	4.0	68.3	157.0
CVetch	54.1	0.0930	4.5	55.3	96.9
SEM	2.5	0.2	0.1	2.2	11.2
P value	0.001	0.442	0.001	0.395	0.003
CONTRAST					
C1	0.001	0.001	0.001	0.869	0.044
C2	0.092	0.118	0.116	0.197	0.022
C3	0.001	0.433	0.001	0.196	0.008
C4	0.001	0.004	0.028	0.396	0.006

b = total gas production (ml gas/g DM initial), c = degradation rate *vs.* time (h), lag time (h); DMd = dry matter disappeared at 96h (mg/100 mg), RGP = relative gas production (ml gas 96h/g DMd 96h).

Barley Doña Josefa (BDJ), Triticale UAEMex (TUAEMex),Triticale Siglo XXI(TSXXI), Common Vetch (CVetch)

Contrast: C1, Barley *vs*Triticale; C2, Barley-CVetch *vs.* Triticale associated with CVetch;C3, CVetch *vs.* Barley and Triticale associates with CVetch; C4, unicrops (Barley and Triticale) *vs*. Barley and Triticale associated with Cvetch.

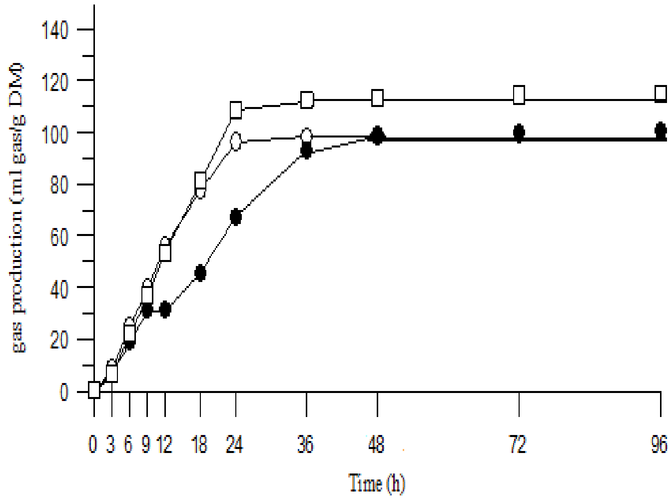

Figure 2. Cumulative gas production at 96 h (ml gas/g DM) of triticale varieties: UAEMex (○), Siglo XXI (●) and barley Doña Josefa (□), preserved as silage

Table 4. Parameters of *in vitro* gas production (ml gas / g DM) obtained from the adjustment of incubation and digestibility of of barley, triticale, common vetch and their associations, preserved as silage

FORAGE	b	c	Lag time	DMd	RGP
UNICROP					
BDJ	123.7	0.1002	4.3	68.3	178.1
TUAEMex	115.4	0.0855	5.3	66.4	170.3
TS-XXI	90.7	0.0804	4.8	61.9	144.3
ASOCIATION					
BDJ – CVetch	116.0	0.1115	4.2	63.8	179.5
TUAEMex-CVetch	108.7	0.1002	4.3	58.7	168.0
TS-XXI-CVetch	106.1	0.0994	3.7	62.4	179.5
CVetch	101.8	0.8004	2.1	66.7	155.4
SEM	2.5	0.003	0.1	2.4	8.5
P value	0.001	0.001	0.001	0.020	0.001
C1	0.001	0.001	0.001	0.045	0.001
C2	0.092	0.118	0.118	0.197	0.022
C3	0.001	0.056	0.062	0.065	0.001
C4	0.001	0.001	0.001	0.108	0.001

b = Total gas production (ml gas / g DM initial), c = degradation rate versus time (h); Lag time (h); DMd = dry matter disappeared at 96h (mg /100 mg), RGP = relative gas production (ml gas 96h / g DMd 96h).

Barley Doña Josefa (BDJ),Triticale UAEMex (TUAEMex),Triticale Siglo XXI(TSXXI), Common Vetch (CVetch)

Contrast: C1, Barley *vs*Triticales; C2, Barley-CVetch *vs*Triticale associated with CVetch;C3, CVetch *vs* Barley and Triticale associates with CVetch; C4, unicrops (Barley and Triticale) *vs* Barley and Triticale associated with CVetch

There were differences ($P < 0.001$) for the total gas production (b) for the different forages evaluated as silage (Table 3); barley was higher (C1, $P < 0.001$) compared with triticale (Figure 3), and there was a trend ($P < 0.092$) when compared common vetch-barley *vs.* common vetch-triticale. Common vetch was lower (C3, $P < 0.001$) when compared with their associations (Figure 4), and unicrops were lower (C4, $P < 0.001$) compared with their association. There were no differences for the fermentation rate for C2 (P > 0.118); fermentation rate was higher for barley (C1, P < 0.001) compared with triticale; and common vetch was lower (C3, P < 0.056) compared with their association with barley and triticale; common vetch associations were higher (C4, P < 0.001) compared with unicrops. The lag time in barley was lower (C1, P < 0.001) compared with triticale's, and there was a trend for common vetch (C3, P < 0.061) compared with their associations. Unicrops were higher (C4, P < 0.001) compared with their associations. DMd were different between forages (P < 0.021); barley was higher (C1, P < 0.045) compared with triticale, but there are no differences when comparing barley-common vetch (C2, P > 0.118) *vs.* triticale-common vetch, and unicrops *vs.* associations (C4, P > 0.109). There was a trend (C3, P < 0.065) when comparing common vetch *vs.* barley and triticale associated with common vetch. RGP was different between forages (P < 0.001); barley was higher (C1, P < 0.001) compared with triticale, and barley associated with common vetch was higher (C2, P < 0.002) compared with triticale's associated with common vetch. Common vetch was lower (C3, P < 0.001) compared with their associations, and unicrops were lower (C4, P < 0.001) compared with associations.

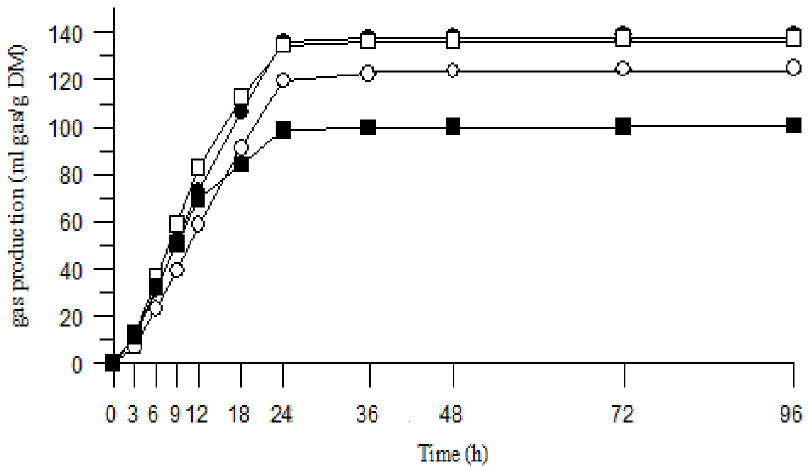

Figure 3. Cumulative gas production at 96 h (ml gas / g DM) of triticale varieties: UAEMex (○), Siglo XXI (●) and barley Doña Josefa (□), associated with common vetch(■) preserved as hay

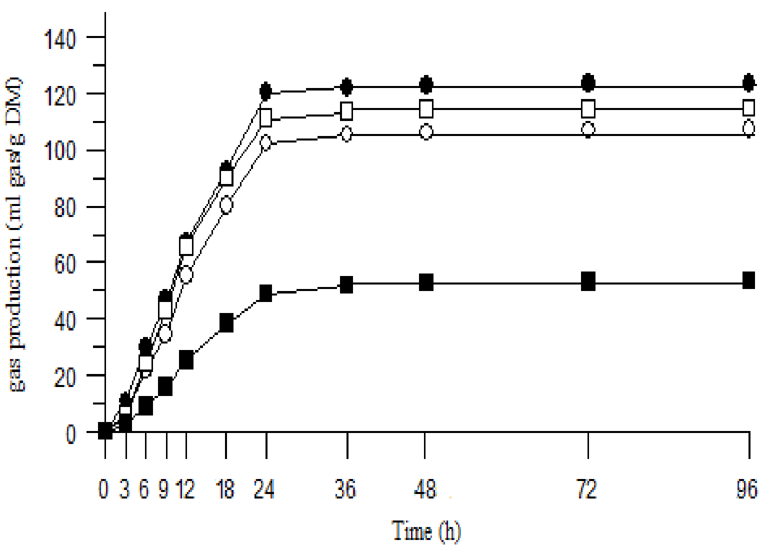

Figure 4. Cumulative gas production at 96 h (ml gas / g DM) of triticale varieties: UAEMex (○), Siglo XXI (●) and barley Doña Josefa (□), associated with common vetch(■) and preserved as silage

4. Discussion

4.1 Forage yield, Chemical Composition and Energy Content

Carr et al. (2004) indicates that the cultivation of barley and oats associated with pea (*Pisum sativum*) increased forage yield (0.63 and 0.72 ton/ha) compared with unicrops. However, Gonzalez et al. (2007), evaluated genotypes of triticale, oats, and barley and observed a differential behavior in unicrops and their association with common vetch, since triticale had lower performance in unicrop and their association; however, oats and barley increased their forage yields in association with common vetch, reaching total forage yields of 4.80 and 3.99 ton/ha. Fernandez et al. (2007) associated triticale with pea, with yields of 4.8 and 6.6 ton/ha, coinciding with the results of the present study. This shows an effect on the species, considering that the cereals were harvested when the grain was in the milky-dough stage and common vetch at the end of the flowering stage; the amount of forage yield was higher compared to that obtained by associating common vetch with triticale and barley. This coincides with Lauriault et al. (2002) where common vetch had similar forage yield to that observed in the present study; and similarly by associating common vetch with cereals, this legume crop provided the least amount of DM to the total amount of forage produced, due to the effect of competition by cereals over legumes.

Anil et al. (1998) founded that when associating cereal with a legume forage, their quality gets better; these results agree with other studies (Khorasani et al., 1997; Carr, Horsley, & Poland, 2004) conducted in temperate zones, and similar to those in North America. Cereals in general are low in protein, however, the values of protein may reach 19% prior to ear emergence for barley, diminishing rapidly to plant maturity (Hargreaves, 1994), but this can vary depending on the species, variety and weather conditions. The present study highlights the barley Doña Josefa associated with common vetch with a higher protein content; similar data have been reported in other studies that have included a legume associated with forage cereals, and found that in these systems significantly increased the CP content in barley as the present study (Caballero, & García, 1996; Haj-Ayed et al., 2000; Assefa & Ledin, 2001; Kuusela, 2004; Carr et al., 2004).

NDFom and ADFom content increase in barley and triticale compared with their associations. Contrary to Ross et al. (2004), showing an effect of the legume on the reduction in NDF content in intercrops than in unicrops (Ghanbari & Lee, 2002), so the benefits of the association reflected an increased intake and digestibility of forage. Garduño et al. (2008), studied oats in association with common vetch and founded lower values in NDF compared to cereals evaluated in the present study, but similar in ADF. Lignin content for intercropping increased, probably due to the contribution of common vetch. Ghanbari-By Lee (2002) and Haj-Ayed et al. (2000) report that in association with legumes, the lignin content increased; this is because those legumes have lower cell wall content and higher lignin content (Parra et al., 1972). The nutritional value of associated varieties is directly related to the cutting age, showing a positive response in associated systems (intercrops). Combining the growth of forage-grain crops (cereals) with crops that are able to increase the protein content of them as legumes, it is possible to obtain a higher forage production and acceptable quality (Ghanbari, 2000).

The percentage of TDN was different ($P < 0.01$) for all forages tested, with values ranging from 59 to 67%, in both methods of conservation; similar results were reported by Carr et al. (2004), who evaluated barley and oats associated with peas, reporting values of 51 and 57% TDN. NE_l and NE_g values were differents for the forages evaluated, highlighting barley Doña Josefa and their association with common vetch, with the highest energy content with respect to triticale and their associations in both methods of preservation. This coincides with Gonzalez et al. (2007), who highlight barley and their association with common vetch, with higher averages in both (1.2 NE_l and 0.5 NE_g). Quiroz (2006), report a higher energy content of triticale compared to other commercial varieties of triticale and oats; Elizalde & Gallardo (2003), found a lower NE value for barley, contrary to the present study.

4.2 In Vitro Gas Production

Lara Fuentes & Valdez Arciniega (2010), founded values ranged from 305 and 275 ml gas/g DM in barley varieties with different levels of N fertilization. Moreover, evaluating different varieties of whole corn plant, Antolin et al. (2009) reported mean values of 217 and 202 ml gas/g DM for silage and hay, respectively. This indicates that varieties of triticale and barley fermented less compared to whole-plant corn and other barley varieties. Catrileo et al. (2003) evaluated the *in vitro* degradation of barley with clover (*Trifolium repens* and *Trifolium pratense*) silage, noting a decrease with the increasing maturity of the association, but there was not an influence of the species that were associated with barley. This is contrary to the present study, which indicates that common vetch had a positive influence on gas production of the cereals evaluated.

5. Conclusions

Both barley and triticale associated with common vetch showed a higher fermentation compared with our association; considering its nutritional quality and energy content, forage cereals associations with common vetch is an option with higher forage yield and improved nutritional content for feeding livestock, both preserved as hay or silage.

Acknowledgments

At the Autonomous University of Mexico State for allowing the project Foundation PRODUCE (Mexico State) ID: 2750/2009. And the National Council of Science and Technology (CONACyT) for the grant received Esmeralda Yunuen Aguilar. The authors would like to thank Miss Liz Hopper from the University of North Texas Dept. of Linguistics and Technical Communication for the critical review of this manuscript.

References

Adesogan, A. T., Salawu, M. B., & Deaville, E. (2002). The effect on voluntary feed intake, *in vivo* digestibility and nitrogen balance in sheep of feeding grass silage or pea-wheat intercrops differing in pea to wheat ratio and maturity. *Animal Feed Science and Technology, 96*, 161-173. http://dx.doi.org/10.1016/S0377-8401(01)00336-4

Anil, L., Park, J., Phipps, R. H., & Miller, F. A. (1988). Temperate intercropping of cereals for forage: a review of the potential for growth and utilization with particular reference to the UK. *Grass and Forage Science, 53*, 301-317. http://dx.doi.org/10.1046/j.1365-2494.1998.00144.x

Antolín, D. M., González, R. M., Goñi, C. S, Domínguez, V. I. A., & Ariciaga, G. C. (2009). Rendimiento y producción de gas in vitro de maíces conservados por ensilaje o henificado. *Técnica Pecuaria México, 4*, 413-423.

AOAC. (1997). Official Methods of Analysis (15th Ed). INC. VA, USA: Association of Official Analytical Chemists.

Asselfa, G., & Leding, I. (2001). Effect of variety, soil type and fertilizer on the establishment, growth, forage yield, quality and voluntary in take by cattle of oats and vetches cultivated in pure stands and mixtures. *Animal Feed Science and Technology, 92*, 95-11. http://dx.doi.org/10.1016/S0377-8401(01)00242-5

Banik, P., Ghosal, P. K., Sasmal, T. K., Bhattacharya, S., Sarkar, B. K., & Bagchi, D. K. (2006). Effect of organic and inorganic nutrients for soil quality conservation and yield of rainfed low land rice in sub-tropical plateau region. *Journal Agronomy Crop Science, 192*, 331-343. http://dx.doi.org/10.1111/j.1439-037X.2006.00219.x

Bingol, N. T., Karsli, M. A., Yilmaz, I. H., & Bolat, D. (2007). The effects of planting time and combination on the nutrient composition and digestible dry matter yield of four mixtures of vetch varieties intercropped with barley. *Journal of Veterinary Animal Science, 31*, 297-302

Caballero, G. R., & García, R. C. (1996). Cultivo y utilización de la asociación veza-cereal en Castilla-La Mancha. Ed.CSIC, Centro de Ciencias Medioambientales. *Consejería de Agricultura y medio Ambiente. Madrid, España.*, 46-50

Carr, P. M., Horsley, R. D., & Poland, W. W. (2004). Barley, oat, and cereal-pea mixtures as dry land forages in the Northern Great Plaints. *Agronomy Journal, 96*, 677-684. http://dx.doi.org/10.2134/agronj2004.0677

Catrileo, S. A., Rojas, C. G., & Matus, C. J. (2003). Evaluación de la producción y calidad de cebada sembrada sola y asociada a especies forrajeras para la producción de ensilaje. *Agricultura Técnica, 63*(2), 135-145.

Cobos, P. M., González, S. M., Mendoza, G. D. M., García, C. B., & Barcena, R. G. (1997). Nutritional evaluation of cattle manure, molasses and corn stover silage for lambs. *Small Ruminant Research, 25*, 33-38. http://dx.doi.org/10.1016/S0921-4488(96)00966-2

Elizalde, V. H. F., & Gallardo, C. M. (2003). Evaluación de ensilajes de avena y cebada en la ganancia de peso de vaquillas en crecimiento. *Agricultura Técnica, 63*, 380-386. http://dx.doi.org/10.4067/S0365-28072003000400006

Fernández, L. B. C., Flores, A., González, A. J., Valladares, & Castro, P. (2007). Comparación de las rotaciones forrajeras guisante-triticale/Maíz y Ryegrass italiano/maíz. *Producción Vegetal, 90*, 97

Garduño, C. Y., Espinoza, O. A., González, E. C. E., Mateo, S. B., & Arriaga, J. C. M. (2008). Intercropped oats (*Avena sativa*)-common vetch (*Vicia Sativa*) silage in the dry season for small-scale dairy system in the

Highlands of central Mexico. *Tropical Animal Health and Production, 41*, 827-834. http://dx.doi.org/10.1007/s11250-008-9258-7

Ghanbari-Bonjar, A. (2000). *Intercropped wheat (Triticum aestivum) and bean (Viciafaba) as a low-input forage*. PhD thesis, Wye College, University of London.

Ghanbari-By, L. (2002). Intercropped field beans (*Viciafaba*) and wheat (*Triticum aestivum*) for whole crop forage yield and quality. *Journal of Agriculture Science, 138*, 311-315. http://dx.doi.org/10.1017/S0021859602002149

Givens, D. I., & Rulquin, H. (2004). Utilization by ruminants of nitrogen compounds in silage-based diets. *Animal Feed Science and Technology. 114*, 1-18. http://dx.doi.org/10.1016/j.anifeedsci.2003.09.005

González, R. E. B., & Martínez, R. C. G. (2007). Producción y calidad de forraje en avena (*Avena sativa*), cebada (*Hodeum vulgare*) y triticale (*X triticosecalewittmack*) en asociación con ebo (*Vicia sativa*), en el valle de Toluca, México. Tesis de Licenciatura. Facultad de Ciencias Agrícolas. *Universidad Autónoma del Estado de México,* 54-68. http://dx.doi.org/10.1016/S0377-8401(97)00181-8

González, Ronquillo, M., Fondevilla, M., Barrios, U. A., & Newman, Y. (1998). *In vitro* gasproduction from buffel grass (*Cenchrusciliaris L*). Fermentation in relation to the cutting invernal, the level of nitrogen fertilization and the season of growth. *Animal Feed Science and Technology, 72*, 19-32

Haigh, P. M., & Hopkins, J. R. (1977). Relationship between oven and toluene dry matter in grass silage. *Journal of Science Food Agricultural, 28*(6), 477-480. http://dx.doi.org/10.1002/jsfa.2740280602

Haj-Ayed, M., González, J., Caballero, R., & Alvir, M. R. (2000). Nutritive value of on-farm common vetch-oat hays. II Ruminal degradation of dry matter and crude protein. *Animal Zootechnie, 49*, 391-398. http://dx.doi.org/10.1051/animres:2000130

Hargreaves, A., & Leaver, J. D. (1994). Efectodel tiempo de acceso al ensilaje de planta complete de cebada sobre la producción de leche de vacas en pastoreo. XIX Reunión Anual Sociedad Chilena de Producción Animal, Temuco, Chile (pp. 65-66). 19-21 de octubre.

Hauggaard-Nielsen, H., Ambus, P., & Jensen, E. S. (2001). Interspecific competition, N use and interference with weeds in pea-barley intercropping. *Field Crops Research, 70*, 101-109. http://dx.doi.org/10.1016/S0378-4290(01)00126-5

INEGI. (2000). Síntesis geográfica, nomenclatura y anexo cartográfico del Estado de México. Instituto Nacional de Estadística, Geografía e Informática, México. DF. Retrieved from www.inegi.org.mx

Khorasani, G. R., Jedel, P. G., Helm, J. H., & Kennelly, J. J. (1997). Influence of stage of maturity on yield components and chemical composition of cereal grain silages. *Canadian Journal Animal Science, 148*, 259-267. http://dx.doi.org/10.4141/A96-034

Krishnamoorthy, V., Soller, H., Steingass, H., & Menke, K. H. (1991). A comparative study on rumen fermentation of energy supplements *in vitro*. *Journal Animal Physiology Animal Nutrition, 65*, 28-35. http://dx.doi.org/10.1111/j.1439-0396.1991.tb00237.x

Kuusela, E. (2004). Annual and seasonal changes in production and composition of grazed clover-grass mixtures in organic farming. *Agriculture and Food Science, 13*, 309-325. http://dx.doi.org/10.2137/1239099042643071

Lara Fuentes, L. A., & Valdez Arciniega, J. A. (2010). Rendimiento, composición química y producción de gas in vitro de cuatro variedades de cebada (*Hordeum vulgare*) con la aplicación de diferentes niveles de fertilizacion nitrogenada. Tesis de Licenciatura. Facultad de Medicina Veterinaria y Zootecnia. *Universidad Autonoma del Estado de Mexico,* 58-59.

Lauriault, L. M., Kirssey, R. E., & Donart, G. B. (2002). Irrigation and nitrogen effects on tall wheatgrass yield in the southern high plains. *Agronomy Journal, 94*, 792-797. http://dx.doi.org/10.2134/agronj2002.0792

Lema, M., Cebert, E., & Sapra, V. (2004). Evaluation of Small Grain Cultivars for Forage in North Alabama. Tennessee State University, Tennessee, USA. *Journal of Sustainable Agriculture, 23*, 133-145. http://dx.doi.org/10.1300/J064v23n04_10

Lithourgidis, A. S., Vasilakoglou, I. B., Dhima, K. V., Dordas, C. A., & Yiakoulaki, M. D. (2006). Forage yield and quality of common vetch mixtures with oat and triticale in two seeding ratio. *Field Crops Research, 99*, 106-113. http://dx.doi.org/10.1016/j.fcr.2006.03.008

Menke, K. H., & Steingass, H. (1998). Estimation of energetic feed value obtained from chemical analyses and *in vitro* gas production using rumen fluid. *Animal Research, 28*, 7-5

NRC. (2001). Nutrient Requirement of Dairy Cattle; 2001 Seventh revised edition; National Research Council; National Academy Press; Washington, D.C., USA

Ofori, F., & Stern, W. R. (1987). Cereal-legume intercropping system. *Advance in Agronomy, 41*, 41-90. http://dx.doi.org/10.1016/S0065-2113(08)60802-0

Parra, R., Combellas, J., & González, E. (1972). Composición y valor nutritivo de forrajes producidos en el trópico. 2. fracciones químicas que afectan la disponibilidad de los componentes fibrosos. *Agronomía Tropical, 22*, 219-230.

Quiroz, M. J. (2006). Potencial de rendimiento y calidad nutricional del forraje en líneas de triticale (*X triticosecalewittmack*) de ciclo largo para condiciones de temporal en Toluca, México. Tesis Ingeniero Agrónomo. *Universidad Autónoma del Estadode México, Toluca, México*, 54-56.

Ross, S. M., King, J. R., O'Donovan, J. T., & Spaner, D. (2004). Intercropping berseem clover with barley and oat cultivars for forage. *Agronomy Journal, 96*, 1719-1729. http://dx.doi.org/10.2134/agronj2004.1719

SAS, Statistical Analysis System Institute. (1999). Statistical Analysis System Institute Inc. SAS/STAT User's Guide, Cary, North Carolina, USA.

Scharenberg, A., Arrigo, Y., Gutzwiller, A., Soliva, C. R., Wyss, U., Krevzer, M., … Dohme, F. (2007). Palatability in sheep and *in vitro* nutritional value of dried and ensiled sainfoin (*Onobrychisvicifolia*) birdsfoot trefoil (*Lotus corniculatus*) and chicory (*Cichoriumintybus*). *Archives of Animal Nutrition, 61*, 481-496. http://dx.doi.org/10.1080/17450390701664355

Steel, R. G. D., Torrie, J. H., & Dickey, D. A. (1997). Principles and Procedures of Statistics: A Biometrical Approach (pp. 1-600) (3rd Edn). McGraw-Hill Series in Probability and Statistics, NewYork.

Theodorou, M. K., Williams, B. A., Dhanoa, M. S., Mc Allan, A. B., & France, J. (1994). A simple gas production method using a pressure transducer to determine the fermentation kinetics of ruminant feeds. *Animal Feed Science and Technology, 48*, 185-197. http://dx.doi.org/10.1016/0377-8401(94)90171-6

Van Soest, P. J., Robertson, J. B., & Lewis, B. A. (1991). Methods for dietary fiber neutral detergent fiber and nonstarch polysaccharides in relation to animal nutrition. *Journal of Dairy Science, 74*, 3583-3597. http://dx.doi.org/10.3168/jds.S0022-0302(91)78551-2

Yildirim, E., & Guvence, I. (2005). Intercropping based on cauliflower: more productivity, profitable and highly sustainable. *European Journal of Agronomy, 22*, 11-18. http://dx.doi.org/10.1016/j.eja.2003.11.003