Variety effect on composition, kinetics of fermentation and *in vitro* digestibility of oat (*Avena sativa* L.) straw and its neutral detergent fibre

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Abstract

Yield, chemical composition, *in vitro* digestibility and kinetics of fermentation of straw from 18 varieties of oats (*Avena sativa* L.) were studied. All the straw varieties were grown in three replicates under the same agronomic conditions. Significance differences were observed in the yield of straw (4.4 to 7.5 ton dry matter (DM)/ha) from different varieties. The proportion of seed/straw from these varieties varied from 0.28 to 1.02. Crude protein (CP), neutral detergent fibre (NDF), acid detergent fibre (ADF) and acid detergent lignin (ADL) content varied from 24.2 to 48.1, 626 to 708, 437 to 533 and 52.0 to 92.4 g/kg DM, respectively in the straws. *In vitro* organic matter digestibility (IVOMD) differed among varieties and varied from 400 to 539 g/kg DM. The mean value of digestible organic matter yield (DOM) was 2.34 ton/ha. A significant difference was observed in the potential gas production *(A)* and lag time *(L)* among varieties. The fractional rate of gas production (*c*, /h) ranged from 0.030 to 0.034. The results emphasized that in any evaluation of oat varieties, kinetics of digestion or fermentation should be taken into consideration as well as yield and digestibility.

Keywords: Oats, straw yield, composition, digestibility, gas production kinetics
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Introduction

Cereals are cultivated to obtain grain for human consumption or for animal feed. Straw as the residue of cereals after harvesting can represent a substantial amount of biomass. Despite its abundance, straw has generally been overlooked as animal feed, in many cases owing to insufficient knowledge of its potential feeding value. Under severe shortage of hay, straw can become valuable low-cost forage that can be used effectively, especially in extensive ruminant production systems based on low inputs (López *et al*., 2005). It has been estimated (Kossila, 1984) that the amount of straw produced for each unit of grain is 0.6 for wheat, 0.72 for barley, 0.78 for oats and 1.2 for rye. Oats (*Avena sativa* L.) ranks around sixth in the world cereal production, producing in excess of 23 million tons annually worldwide (FAO, 2011) leaving about 20 million tons of straw. To provide balanced diets that include straw, it is important to know the nutritive value of this roughage and its variability, as straw sources vary in their nutrient content and digestibility. Crude protein (CP) content of cereal straw varies from 24 up to 54 g/kg dry matter (DM) (Theander & Aman, 1984). Capper (1988) and Capper *et al*. (1988) reported that *in vitro* DM digestibility for wheat, barley and oats straw were 360, 400, 450 g/kg, respectively. Mulholland *et al*. (1994) showed DM intake for oats, wheat and barley straw with sheep to be 660, 450 and 320 g/day, which indicates a large variability in the nutritive value of cereal crop residues. Cuddeford (1995) suggested that oat straw has higher digestible organic matter (OM) and metabolizable energy (ME) contents than other cereals in terms of available energy. He also suggested that oat straw is the most palatable and nutritious, followed by barley straw, wheat straw and rye straw. Varietal differences have also been reported in the nutritive value of the residues from wheat (White *et al*., 1981; Kernan *et al*., 1984; Tolera *et al*., 2008), barley (Bediye *et al*., 1998) and corn (Harika & Sharma, 1994; Tolera *et al*., 1999).

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The objective of this study was to evaluate the nutritive value of straw from 18 oat varieties in terms of composition, digestibility and kinetics of fermentation for better understanding of varietal differences for ruminant nutritionists and crop breeders.

Material and Methods

Straw from 18 varieties (Table 1) of oats provided by the South Australian Research and Development Institute (SARDI) was used in the study. They were grown under similar agronomic condition in three replicates in a randomized complete block design at the Research Farm of the School of Agriculture, Razi University, Kermanshah, Iran. The blocks were designed based on the non-uniformity of the field (in vertical to non-uniformity slope). Each experimental unit consisted of five rows by 2 m. Straw was obtained after harvesting the oat grain. The plants were cut by hand at about 10 cm above soil surface. The weight of grain and straw of each plot was determined. A subsample of approximately 450 g was randomly taken from the harvested portion of each plot and dried at 60 ºC for further analysis and at 100 ºC for 24 h to determine DM yield per hectare.

Table 1 Origin and codes of varieties of oats used in the experiment

Variety code	Origin	Name
V1	SARDI (SA, AUS)	94046-57
V2	Wisconsin (USA)	Dalyup
V3	SARDI (SA, AUS)	Echidna
V4	SARDI (AUS)	Euro
V5	Georgia (USA)	GA-Mitchell
V6	France	Grise Dhiver
V7	Illionis (USA)	IL92-6745
V8	USSR	LGorskij 1026
V9	WADA (Aus)	Mortlock
V10	New Zealand	NZ2742
V11	Ohio (USA)	OH 1022
V12	SARDI (SA, AUS)	Possum
V13	SARDI (SA, AUS)	Potoroo
V14	SA (AUS)	Quall
V15	Brazil	UPF775456
V16	SA (AUS)	Wallaroo
V17	WADA (Aus)	Wandering
V18	SARDI (SA, AUS)	Wintaroo

The straw samples were ground with a laboratory mill to pass a 1-mm screen. Standard methods as described in AOAC (1990) were used to determine DM, ash and CP levels. The neutral detergent fibre (NDF), acid detergent fibre (ADF) and acid detergent lignin (ADL) levels were determined according to Van Soest *et al*. (1991).

In vitro digestibility was determined as described by Tilley & Terry (1963). Rumen liquid was collected from three rumen cannulated sheep (receiving a mixture of lucerne hay and straw) before the morning feeding. The rumen liquid from the sheep was mixed on a volume basis, and filtered through four layers of cheesecloth.

The incubation inoculum was prepared by diluting the rumen liquid with a buffer solution (Tilley & Terry, 1963) in a 1 : 4 (vol/vol) ratio. Mixed inoculum was stirred in a water bath at 39 ºC with purging CO_2 until used (10 to 15 min later). About 250 mg (1 mm ground) of each sample was placed into 50-mL sterile

tubes, and 20 mL of the incubation inoculum was added. The tube was stoppered with a Bunsen valve and incubated for 48 h at 39 ºC. The tubes were gently swirled by hand every 8 h. Each sample was incubated in three replicates. At the end of the 48 h of incubation, the tube contents were acidified using 6 M HCl to reach a final pH of 1.3 to 1.5. After a few seconds, when the foam subsided, pepsin (EC 3.4.23.1) powder was added to a final concentration of 0.2% (wt/vol). The tubes were re-incubated for an additional 48 hours. The tubes were then centrifuged at 2500 rpm for 15 min, and the supernatant was discarded. The tubes containing the pellets were dried in a forced air oven at 60 ºC for 48 h to determine the residual DM weights. *In vitro* DM and OM digestibility were calculated respectively as the DM and OM that disappeared from the initial weight inserted into the tube.

The method used for gas production measurements was as described by Theodorou *et al*. (1994). All samples were ground to pass a 1-mm screen. About 125 mg of each sample were weighed into tubes kept at approximately 39 ºC and flushed with CO_2 before use. Each sample was incubated in three replicates. Fifteen mL of buffered rumen fluid (20% rumen fluid + 80% buffer solution) were prepared (as described in *in vitro* digestibility section) and were anaerobically dispensed in each tube at 39 ºC. All the tubes were flushed with CO_2, crimped with rubber stoppers and aluminium seals, placed in an incubator at 39 ºC, and shaken at regular intervals. The pressure of gas produced in each tube was recorded using a pressure transducer (Testo 512 digital manometer) at 2, 4, 6, 8, 12, 18, 24, 48, 72, 96 and 120 h after the start of incubation. To estimate the kinetics of gas production, data on cumulative gas volume produced, were fitted using the generalized Mitscherlich model proposed by France *et al*. (1993):

$$G = A\,(1-e^{-c\,(t-L)-d\,(\sqrt{t}\,-\sqrt{L}\,)})$$

where *G* (mL) denotes cumulative gas production at time *t*, *A* (mL) is asymptotic gas production, *c* (/h) and *d* (/h) are rate constants and *L* (h) is lag time. The half-life ($t_{1/2}$, h) of the fermentable fraction of each substrate was calculated as the time taken for gas accumulation to reach 50% of its asymptotic value. All gas volumes were adjusted to a common sample weight of 200 mg DM (Lopez *et al*., 2007). The volume of gas produced (GP) (mL/200 mg) after 24 h incubation was used with CP content to estimate metabolizable energy (ME) concentration (MJ/kg DM), based on the following equation reported by Menke & Steingass (1988) for roughage feeds:

$$ME = 2.2 + 0.1357\,GP + 0.057\,XP + 0.002859\,XP^2 \quad (R^2 = 94\%;\ n = 200)$$

where:
ME = metabolizable energy (MJ/kg DM); GP = gas production after 24 h (mL/200 mg DM);
XP = crude protein (%).

A shorter gas production test was done to determine *in vitro* true DM degradability (IVTDMD) and NDF degradability (NDFD). Rumen digesta collection, sample and buffer preparations, and incubation techniques were as described above. Incubation was stopped at 30 h after recording the gas volume and the entire residue in the incubation tubes was drained into 600 mL spotless beakers and refluxed with neutral detergent solution to determine IVTDMD and NDFD. This determination is the Goering & Van Soest (1970) modification of Tilley & Terry (1963), as described by Blummel & Becker (1997). The partitioning factor (PF) was calculated as the ratio of mg substrate truly degraded/mL gas produced by it, according to Blummel *et al*. (1997).

Data of gas production parameters and *in vitro* dry matter digestibility (IVDMD) were analysed using multi-observational data analysis with three replicates and three samples each. Since there were no significant differences among samples, the mean of three samples of each replicate was analysed, based on RCBD with three replicates such as the other agronomical traits. Analysis of variance was carried out using SAS (2000) and significant differences between treatments were identified using Duncan multiple-range test (Duncan, 1955).

Results and Discussion

Yield of straw, grain, grain/straw ratio and total biomass from the 18 varieties of oats are shown in Table 2. Yield of grain from these varieties varied from 2.1 to 5.8 ton DM/ha. Tamm (2003) reported that yield of grain from different varieties of oats ranged from 3.3 to 5.8 ton DM/ ha. There was a difference (P <0.01) in the yield of straw from different varieties. Maximum straw yield was obtained from V8 and minimum yield was recorded for V12. A positive correlation was observed between grain yield and total biomass produced (r = 0.83, P <0.01). The grain/straw ratio varied from 0.28 to 1.02, indicating a wide variation in the proportion of straw to grain produced.

Table 2 Yield (ton/ha) of seed, straw and total biomass from different oat varieties

Oat varieties	Yield (ton/ ha)			
	Seed	Straw	Total biomass	Seed/ straw
V1	4.46^{abcd}	4.57^{hi}	9.03^{abcd}	0.98^{ab}
V2	4.17^{abcd}	4.50^{i}	8.67^{bcd}	0.93^{ab}
V3	4.42^{abcd}	4.92^{ghi}	9.35^{abcd}	0.90^{abcd}
V4	5.11^{ab}	5.89^{defg}	10.99^{abc}	0.87^{abcde}
V5	3.49^{bcde}	5.10^{fghi}	8.58^{bcd}	0.68^{defgh}
V6	2.74^{de}	5.77^{efg}	8.51^{cd}	0.47^{hi}
V7	4.50^{abcd}	6.89^{abcd}	11.40^{ab}	0.65^{efgh}
V8	2.09^{e}	7.48^{a}	9.58^{abcd}	0.28^{i}
V9	4.46^{abcd}	5.74^{efg}	10.19^{abcd}	0.77^{bcdefg}
V10	4.37^{abcd}	7.42^{ab}	11.79^{a}	0.59^{fgh}
V11	3.13^{cde}	5.61^{efgh}	8.74^{bcd}	0.56^{gh}
V12	3.57^{bcde}	4.42^{i}	7.99^{d}	0.80^{abcdef}
V13	5.80^{a}	5.64^{efgh}	11.44^{ab}	1.02^{a}
V14	5.04^{abc}	5.37^{efghi}	10.41^{abcd}	0.91^{abc}
V15	4.30^{abcd}	7.08^{abc}	11.38^{abc}	0.58^{fgh}
V16	4.22^{abcd}	6.36^{bcde}	10.58^{abcd}	0.66^{efgh}
V17	4.29^{abcd}	6.12^{cdef}	10.41^{abcd}	0.70^{cdefgh}
V18	4.99^{abc}	6.35^{bcde}	11.34^{abc}	0.78^{bcdefg}
Mean	4.18	5.85	10.02	0.73
P-value	0.009	<0.001	0.029	<0.001
SEM	0.176	0.148	0.256	0.030

$^{a,b,\ldots,i}$ Column means with different superscripts differ significantly at $P < 0.05$.

The chemical composition of different varieties of oats is presented in Table 2. There were significant ($P < 0.01$) differences between varieties in terms of CP, NDF, ADF and ADL levels. Crude protein level (ranging from 24 to 48.1 g/kg DM) of the oat varieties used in the present experiment were similar to those reported by Pearson *et al*. (2001), Lopez *et al.* (2005) and Anderson & Hoffman (2006).

The mean NDF, ADF and ADL levels in the oat straw were 659, 490 and 76.1 g/kg DM, respectively. The greatest difference between the highest and the lowest value in cell wall fractions was observed in lignin levels (92.4 vs. 51.9 g/kg DM), followed by hemicellulose (217.9 vs. 135.3 g/kg DM) and cellulose (445.2 vs. 334.6 g/kg DM). The NDF levels of the oat varieties in the present study were lower than the values reported by Pearson *et al.* (2001) and Lopez *et al.* (2005), but the obtained ADF and ADL levels were consistent with their values.

The result of *in vitro* digestibility (Table 3) showed that there were differences ($P < 0.01$) between DM and OM digestibility of straws from the different varieties. The IVOMD ranged from 400 to 539 g/kg DM. The *in vitro* DM digestibility of oat straws (from 397 to 529 g/kg DM) was similar to the values reported by Lopez *et al*. (2005) and higher than the values reported by Brown & Almodares (1976) and Jung *et al*. (1992). Differences in the digestibility of straws from different varieties may be due, not only to the chemical composition (Dias-da-silva & Guedes, 1990) but also to stem, leaf and seed ratios (Bhargava *et al*., 1988). Crude protein was positively correlated to IVOMD ($r = 0.33$, $P < 0.05$). There were significant negative correlations between IVOMD and cell wall fractions, particularly ADL ($r = -0.77$, $P < 0.001$). Variety 16 with the highest ADL had the lowest IVOMD, while V2 with the lowest ADL had the highest IVOMD. It is accepted that forage degradation in the rumen is affected mainly by the cell wall content and its lignification, as lignin is an indigestible fraction and acts as a barrier, limiting the access of microbial

enzymes to the structural polysaccharides of the cell wall. Ammar (2002) reported that NDF, ADF and ADL levels were negatively correlated with *in vitro* digestibility. The mean value of digestible OM yield (DOM) was 2.3 ton/ha. Varieties 7 and 8 had the highest yield of DOM (2.9 ton/ha) while V12 produced the lowest DOM yield (1.9 ton/ha). Other factors known to affect the composition and digestibility of straw are variety and cultivar (Mould *et al*., 2001; Kafilzadeh & Maleki, 2011), environmental and seasonal effects (Mathison *et al*., 1999) and proportion of morphological fractions of the straw (Agbagla *et al*., 2001).

Table 3 Chemical composition (g/kg DM) of straw from 18 varieties of oats

	Nutrients					
Variety	DM	OM	CP	NDF	ADF	ADL
V1	956^{abc}	884^{cdefg}	26.1^{fghi}	652^{defg}	490^{abc}	69.7^{g}
V2	962^{a}	875^{fg}	34.2^{b}	628^{fg}	465^{bc}	51.9^{i}
V3	960^{ab}	884^{cdefg}	31.0^{cd}	708^{a}	490^{abc}	72.9^{fg}
V4	945^{ef}	903^{abcd}	48.1^{a}	649^{defg}	485^{abc}	80de
V5	961^{ab}	885^{cdefg}	24.2^{i}	647^{defg}	505^{ab}	64.1^{h}
V6	956^{abc}	886^{cdefg}	28.4^{defg}	645^{defg}	500^{ab}	59.3^{h}
V7	954^{abcde}	907^{ab}	32.2^{bc}	667^{bcde}	489^{abc}	64.3^{h}
V8	962^{a}	897^{abcde}	29.7^{cde}	656^{defg}	510^{ab}	82.1^{cd}
V9	937^{f}	916^{a}	26.9^{efghi}	626^{g}	461^{bc}	92.2^{a}
V10	947^{cdef}	914^{ab}	25.5^{ghi}	669^{bcde}	533^{a}	88.2^{ab}
V11	945^{def}	904^{abc}	28.3^{defgh}	662^{cdef}	526^{a}	85.1^{bc}
V12	955^{abcd}	871^{g}	45.8^{a}	650^{defg}	456^{bc}	70.9^{g}
V13	961^{ab}	894^{bcdef}	29.8^{cde}	698^{ab}	505^{ab}	63.7^{h}
V14	951^{bcde}	882^{defg}	28.9^{def}	665^{bcde}	464^{bc}	70.8^{g}
V15	953^{abcde}	904^{abc}	25.4^{hi}	673^{bcd}	514^{ab}	91.5^{a}
V16	945^{def}	913^{ab}	29.2^{de}	636^{efg}	437^{c}	92.4^{a}
V17	957^{abc}	878^{efg}	27.4^{efgh}	631^{fg}	481^{abc}	76.3^{ef}
V18	962^{a}	904^{abc}	27.5^{efgh}	692^{abc}	509^{ab}	77.8^{def}
Mean	954	894	30.5	659	490	76.1
P-value	0.<0.001	0.<0.001	0.<0.001	0.<0.001	0.024	0.<0.001
SEM	1.14	2.24	0.88	3.66	4.86	1.63

$^{a,b,\ldots,i}$ Columns means with different superscripts differ significantly at $P < 0.05$.
DM: dry matter; OM: organic matter; CP: crude protein; NDF: neutral detergent fibre; ADF: acid detergent fibre; ADL: acid detergent lignin.

The ME (MJ/kg DM) levels of straw from different varieties were calculated from the amount of gas produced at 24 h incubation with the supplementary analysis of CP. There were significant ($P < 0.01$) differences among ME of straw from these varieties. Metabolizable energy was negatively correlated with ADL concentrations (r = -0.51, $P < 0.01$) and positively correlated with the CP level (r = 0.79, $P < 0.01$).

Gas production kinetic parameters of straw from oat varieties are presented in Table 5. There were differences ($P < 0.01$) among varieties in asymptotic gas production (A) and lag time (L). Potential gas production (A) ranged from 53.8 to 56.0 mL/200 mg. The constant rate (c) was also different ($P < 0.05$) among varieties. The differences in gas production characteristics may partly be due to differences in CP,

Table 4 *In vitro* digestibility of dry and organic matter (IVDMD and IVOMD, g/kg DM) and digestible DM and OM yield (DDM and DOM, ton/ha) and metabolizable energy (ME, MJ/kg DM) of straw from 18 varieties of oats

Variety	IVDMD	IVOMD	DDM	DOM	ME
V1	463^{bc}	480^{bc}	2.11^{g}	1.94^{ef}	5.21^{cde}
V2	529^{a}	539^{a}	2.38^{efg}	2.13^{def}	5.38^{b}
V3	440^{def}	460de	2.17f^{g}	2.00^{ef}	5.21^{cd}
V4	444^{cde}	450^{ef}	2.62^{cdef}	2.39^{bcde}	5.36^{b}
V5	428^{efg}	443^{ef}	2.18f^{g}	2.00^{ef}	5.17^{defg}
V6	456^{bcd}	452^{ef}	2.63^{cdef}	2.30^{bcdef}	5.21^{cde}
V7	465^{b}	476^{bcd}	3.20^{a}	2.97^{a}	5.25^{c}
V8	422^{fg}	434^{f}	3.16^{ab}	2.91^{a}	5.19^{def}
V9	404^{h}	410^{g}	2.32^{efg}	2.15^{def}	5.08^{hi}
V10	400^{h}	402^{g}	2.97^{abcd}	2.73^{ab}	5.04^{i}
V11	414^{gh}	414^{g}	2.32^{efg}	2.10^{def}	5.15^{fg}
V12	466^{b}	483^{b}	2.06^{g}	1.87^{f}	5.47^{a}
V13	445^{cde}	462^{cde}	2.51^{defg}	2.33^{bcdef}	5.16^{efg}
V14	452^{bcd}	460de	2.42^{efg}	2.18^{cdef}	5.24^{c}
V15	431^{efg}	448^{ef}	3.05^{abc}	2.67^{abc}	5.12^{gh}
V16	397^{h}	400^{g}	2.52^{defg}	2.33^{bcdef}	5.14^{fg}
V17	460^{bc}	472^{bcd}	2.82^{abcde}	2.54^{abcd}	5.25^{c}
V18	428^{efg}	444^{ef}	2.72^{bcde}	2.54^{abcd}	5.15^{fg}
Mean	441	450	2.56	2.34	5.21
P-value	<0.001	<0.001	<0.001	<0.001	<0.001
SEM	4.33	4.66	0.058	0.055	0.015

$^{a,b,\ldots,i}$ Column means with different superscripts differ significantly at P <0.05.

NDF and ADF concentrations. Nsahlai *et al*. (1994) and Larbi *et al*. (1998) reported that there was a positive correlation between CP and the rate of gas production, and negative correlations between NDF and ADF with the rate and extent of gas production. Asymptotic gas production (*A*) was lowest in V16 and highest in V2. These findings were in line with the *in vitro* digestibility results in which V16 and V2 showed the lowest and the highest IVOMD, respectively (r = 0.53, P <0.01). The rate at which gas was produced (*c*) was not altered much in different varieties. Therefore, it appeared that the rate of gas production was not responsible for the differences in the total gas production. Varieties with higher gas production had a shorter half time ($t_{1/2}$). The negative correlation found between asymptotic gas production (*A*) with either NDF and ADF (r = -0.47, r = -0.50, P <0.01) is consistent with the results of Haddi *et al*. (2003). The negative effect of cell wall content on gas production could be the result of a reduction of microbial activity through increasing the adverse environmental conditions as incubation time progresses. The values of potential gas production and fractional rate of gas production (*c*) of experimental varieties of oats were consistent with those (56.6 mL/200 mg DM and 0.031/h, respectively) reported by Lopez *et al*. (2005).

Digestibility of NDF is an important component of forage quality. Increased NDF digestibility (NDFD) may result in reduced physical fill in the rumen over time, and allows greater voluntary feed intake (Dado & Allen, 1995). Oba & Allen (1999) reported that one unit increase in forage NDFD *in vitro* or *in situ* was associated with a 0.17 kg increase in dry matter intake (DMI). *In vitro* true DM degradability (IVTDMD) and NDFD were determined after terminating the incubation at 30 h and were calculated from the truly undegraded substrate. The IVTDMD varied from 44.9% to 57.2%, while NDFD varied from 17.3% to 31.9%. The partitioning factor (PF), an index of the substrate dependent variation, is the ratio of substrate

degraded to gas volume produced by it at 30 h incubation. This ratio is reported to be valuable in improving the accuracy of voluntary DMI prediction of temperate, tropical crop residues and Mediterranean hays (Blummel *et al*., 1997), and forages with high PF had high DMI (Blummel *et al*., 2005). Blummel *et al*. (1997) noted that in forage fermentation, PF values between 2.75 and 4.41 mg/mL do correspond to Y_{ATP}'s from 10 to 32 mg, and a Y_{ATP} of 32 mg is considered maximum microbial efficiency. Calculated PF from varieties in the present experiment ranged from 2.77 to 3.23. Blummel *et al*. (2005) reported 37.6% and 2.90 mg/mL for IVTDMD and PF (24 h) in oat straw, respectively, and forages with high PF had high DMI.

Table 5 Cumulative gas production and kinetic parameters for different varieties of oat straw incubated with rumen fluid *in vitro*

Variety	Gas parameters			
	A (mL/200 mg)[1]	*c* (/h)[2]	*L* (h)[3]	$t_{1/2}$ (h)[4]
V1	55.0^{bc}	0.032^{ab}	1.59^{bcdef}	34.9^{bcd}
V2	56.1^{a}	0.032^{ab}	1.59^{bcdef}	33.8^{d}
V3	55.3^{abc}	0.030^{c}	1.50^{efg}	34.9^{bcd}
V4	55.6^{ab}	0.031^{bc}	1.46^{g}	34.5^{bcd}
V5	55.3^{abc}	0.032^{ab}	1.55^{defg}	34. 8^{bcd}
V6	54.9^{bcd}	0.032^{ab}	1.61^{abcde}	35.1^{bc}
V7	55.5^{ab}	0.031^{abc}	1.49f^{g}	34.9^{bcd}
V8	54.5^{cde}	0.033^{a}	1.62^{abcd}	34.9^{bcd}
V9	54.0^{e}	0.032^{ab}	1.62^{abcd}	36.7^{a}
V10	53.9^{e}	0.032^{ab}	1.71^{a}	36.5^{a}
V11	53.8^{e}	0.032^{ab}	1.70^{ab}	36.5^{a}
V12	56.0^{a}	0.032^{ab}	1.58^{cdef}	33.8^{d}
V13	54.5^{cde}	0.031^{abc}	1.47^{g}	34.0^{cd}
V14	55.1^{bc}	0.032^{ab}	1.47^{g}	34.5^{bcd}
V15	55.0^{bc}	0.031^{abc}	1.46^{g}	34.0^{cd}
V16	53.8^{e}	0.032^{ab}	1.68^{abc}	36.8^{a}
V17	55.7^{ab}	0.031^{bc}	1.45^{g}	35.0^{bcd}
V18	54.1^{de}	0.031^{abc}	1.60^{bcdef}	35.3^{b}
Mean	54. 9	0.032	1.56	35.1
P-value	<0.001	0.026	<0.001	<0.001
SEM	0.099	0.000	0.012	0.276

$^{a,b...,g}$ Column means with different superscripts differ significantly at P <0.05.
[1]*A*- potential gas production; [2]*c* - rate constant; [3]*L*- lag time; [4]$t_{1/2}$, time to half asymptote.

Conclusion

Considering the importance of straw in diets for ruminants in the world, it is suggested that selection of new oat varieties should take into consideration the nutritive value of the straw as well as the quantities of seed and straw produced. The study showed the presence of considerable varietal differences in nutritive value of straw from 18 varieties of oats. Cell wall content, digestibility and potential gas production of fermentation of straws were affected by variety. There were significant negative correlations between IVOMD, gas production and cell wall fractions. These variations indicate that in any evaluation of oat varieties, not only yield, but digestible OM yield of straw and partitioning factor as index of intake, as well

as the digestibility of straw, should be taken into consideration, particularly in areas where straw from these grasses is considered an important feedstuff for ruminants.

Table 6 *In vitro* true dry matter degradability (IVTDMD, g/kg DM), NDF degradability (NDFD, g/kg DM) at 30 h incubation and the partitioning factor, PF (IVTDMD: 30 h gas production, mg/mL)

Variety	NDFD	IVTDMD	PF
V1	306^{a}	547^{b}	3.18^{a}
V2	319^{a}	572^{a}	3.23^{a}
V3	242^{bc}	463^{gh}	2.77^{f}
V4	225^{cde}	498^{e}	2.87^{de}
V5	220^{defg}	495^{e}	2.97^{bc}
V6	227^{cde}	501^{de}	2.93^{cd}
V7	253^{b}	502^{de}	2.95^{bc}
V8	206^{efgh}	479^{f}	2.91^{cd}
V9	203^{fgh}	500^{de}	2.80^{ef}
V10	191^{hi}	459^{hi}	2.77^{f}
V11	197^{h}	469^{fgh}	2.92^{cd}
V12	254^{b}	516^{c}	3.02^{b}
V13	210^{defgh}	449^{i}	2.77^{f}
V14	201^{gh}	468^{fgh}	2.89^{cd}
V15	224^{cdef}	477^{fg}	2.91^{cd}
V16	173^{i}	475^{fg}	2.77^{f}
V17	231^{cd}	515^{cd}	2.97^{bc}
V18	229^{cd}	467^{fgh}	2.91^{cd}
Mean	228	491	2.92
P-value	<0.001	<0.001	<0.001
SEM	0.514	0.432	0.018

$^{a,b\ldots,i}$ Column means with different superscripts differ significantly at P <0.05.

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