Nutritive value and energy content of the straw of selected Vicia L. taxa from Tunisia

Riccardo Fortina,1, Aziza Gasmi-Boubaker,2, Carola Lussiana,1 Vanda Malfatto,1 Sonia Tassone,1, Manuela Renna1
1Dipartimento di Scienze Agrarie, Forestali e Alimentari, Università degli studi di Torino, Grugliasco (TO), Italy
2Institut National Agronomique de Tunisie, Tunis Mahrajène, Tunisia

Abstract

The chemical composition and energy value of straws of Vicia sativa L. (varieties Languedoc and Mghila, and subspecies amphicarpa) and Vicia villosa Roth. (variety Sejenane and accession 2565) were investigated. The plants were grown in a Mediterranean environment, under identical environmental conditions. Total digestible nutrients (TDN) and energy values (digestible energy, metabolisable energy, and net energy for lactation) were estimated according to the equations developed by the 2001 Dairy National Research Council. Both ether extract (EE) or total fatty acids (FA) amounts, and digestible neutral detergent fibre (dNDF) calculated from chemical analysis or measured using an in vitro digestibility assay were considered for calculation. Significant differences were observed in the chemical composition and energy value of the straws of the considered V. sativa and V. villosa varieties. Within the same variety, the TDN was similar using either EE or FA values for calculation. The energy resulted largely dependent on the dNDF values. Energy was higher when in vitro dNDF was used for calculation in low-NDF straw samples, while the opposite occurred for high-NDF samples.

Introduction

Common vetch (Vicia sativa L.) is a multipurpose, cool season, annual and erect growth habit legume grown for livestock feed and soil fertility improvement in Mediterranean environments, where average annual rainfall ranges from 250 to 350 mm. The forage can either be grazed, or cut for hay or straw production (Larbi et al., 2011a).

Hairy vetch (Vicia villosa Roth) is a cool season and creeping growth habit legume grown for pasture, hay, silage, and grain production for livestock feed, as well as green manure and cover crop for weed control and soil productivity improvement. Hairy vetch tolerates colder than common vetch and it is also more suitable for grazing because of its low vegetative growth, high forage production, and low harvest index (Larbi et al., 2011b).

Despite the importance of common and hairy vetches as feed resources in dryland mixed farming systems, little information exists on intra- and inter-species variations in quality determinants of straw. Moreover, very few energy values of individual V. sativa and V. villosa varieties are currently available.

This study is part of a research aimed to evaluate the nutritive value of straw and seeds of different species and varieties of the genus Vicia growing in Mediterranean areas. In this paper, straw samples of five varieties, subspecies or accessions of V. villosa and V. sativa, grown in identical climate and soil conditions in North Tunisia, were analysed for their chemical characteristics. Total digestible nutrients (TDN) and energy values were determined according to the National Research Council (2001) using two different approaches [chemical and biological (from an in vitro assay)] for the assessment of neutral detergent fibre (NDF) digestibility. Fatty acids (FA) were also measured as an alternative approach to the National Research Council equation for the estimation of TDN and energy of feeds with less than 1% of ether extract (EE). The differences among results were used to suggest the most accurate and precise predictive approach for high fibre-low fat feedstuffs such as vetch straws.

Materials and methods

Biological material

The biological material consisted of straw samples of two species of the genus Vicia L.: i) V. sativa L., represented by two Tunisian varieties (Languedoc and Mghila) and one subspecies [amphiparca (Dortheas) Asch.]; ii) V. villosa Roth, represented by a Tunisian variety (Sejenane) and one accession (2563) introduced from and provided by the International Center for Agricultural Research in the Dry Areas (ICARDA) in the frame of a germplasm exchange.

Corresponding author: Prof. Riccardo Fortina, Dipartimento di Scienze Agrarie, Forestali e Alimentari, Università degli Studi di Torino, largo Paolo Braccini 2, 10095 Grugliasco (TO), Italy.
Tel. +39.011.6708580 - Fax: +39.011.6708563.
E-mail: riccardo.fortina@unito.it

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Each variety/subspecies/accession was sown on ten 20 x 2 m plots at the experimental station of the National Institute of Agronomy of Tunisia (INRAT), Tunis, Tunisia (latitude: 36°50’37” N; longitude: 10° 11’28” E) on 1 November 2011. The seedling rate was 100 viable seeds/m²; the plots were not fertilised and the soil texture was clay-loam. Straw harvesting occurred 230 days after sowing; total precipitation during the period was 516 mm (data recorded at the meteorological station of INRAT). The straw was harvested cutting the plants manually; after separation of the seeds by threshing, the stalks were mixed and sampled for chemical analysis.

Chemical analysis and calculations

Straws samples were ground in a 1-mm sieve Pulverisette 15 (Fritsch GmbH, Idar-Oberstein, Germany) and analysed in duplicate.

AOAC (2000) procedures were used to determine dry matter (DM) (method no. 930.15), ash (method no. 942.05), and crude protein (CP) (nitrogen x6.25; method no. 984.13). Ether extract was determined following method no. 920.39 of AOAC (2003). Soluble protein (SoP) and rumen undegradable protein (RUP) were measured according to Licitira...
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et al. (1998).

The Ankom 200 Fibre Analyzer (Ankom Technology, Macedon, NY, USA) was used to determine NDF, acid detergent fibre (ADF) and acid detergent lignin (ADL), following the procedure of Mertens (2002) for NDF and Van Soest et al. (1991) for ADF and ADL. For NDF, the detergent solution contained sodium sulphite and a heat-stable bacterial α-amylase (activity=17,400 Liqefun units/mL; Ankom Technology). The NDF, ADF and ADL were corrected for residual ash content. The neutral detergent insoluble protein (NDIP) and the acid detergent insoluble protein (ADIP) were determined as residual nitrogen (N×6.25) in Ankom fibre bags after extraction with neutral detergent or acid detergent solution.

The non-fibrous carbohydrates (NFCc) content was corrected for NDIP and calculated as follows: NFCc = 100 – [CP + ash + EE + (NDF – NDIP) and the detergent solution contained sodium sulphite (Soest procedure of Mertens (2002) for NDF and Van Soest et al. (1991) for ADF and ADL). For NDF, the detergent solution contained sodium sulphite and a heat-stable bacterial α-amylase (activity=17,400 Liqefun units/mL; Ankom Technology). The NDF, ADF and ADL were corrected for residual ash content. The neutral detergent insoluble protein (NDIP) and the acid detergent insoluble protein (ADIP) were determined as residual nitrogen (N×6.25) in Ankom fibre bags after extraction with neutral detergent or acid detergent solution.

The non-fibrous carbohydrates (NFCc) content was corrected for NDIP and calculated as follows: NFCc = 100 – [CP + ash + EE + (NDF – NDIP)].

Estimated TDN of straws was calculated with the equation 2-5 of the National Research Council (2001) as sum of digestible non-fibrous carbohydrates (dNFCc: equation 2-4a), digestible protein (dCP: equation 2-4b), digestible fatty acids (dFA: equation 2-4d) and digestible neutral detergent fibre (dNDFc: equation 2-4e).

Total FA were determined using a combined direct transesterification and solid-phase extraction method (Alves et al., 2008) and quantified by gas chromatography as described by Renna et al. (2014). The dNDF was either calculated from the lignin content of NDF (dNDFc: chemical approach), or measured from a 48-hour in vitro assay (dNDFm: biological approach) by the Ankom DaisyII incubator (Ankom Technology) following Robinson et al. (1999). For each sample, 2 bags (Ankom F57) were filled with ground material (1-mm sieve, 250 mg) and sealed. Filtered rumen fluid was collected at a slaughterhouse from beef cattle fed mixed grass hay (ad libitum) and a concentrate (400 g d⁻¹) containing ground corn (62%), soybean meal (10%), barley (20%), sunflower meal (5%), minerals and vitamins (3%). After 48 h of incubation, the bags were removed from jars, rinsed thoroughly with cold tap water and immediately analysed for NDF content using the Ankom200 Fibre Analyzer. After incineration and correction for the ash, the residual NDF was used to calculate NDF digestibility as percentage of DM. The TDN of straw samples were estimated using dFA and dNDFc (TDNc) or dFA and dNDFm (TDNm) in equation 2-5 of the National Research Council (2001) for the chemical and biological approach, respectively.

As proposed by the National Research Council (2001) for the calculation of the digestible energy (DE) of straw samples, equation 2-8a instead of equation 2-1 was used. Metabolisable energy (ME) and net energy for lactation (NEL) were calculated using equations 2-2 and 2-11 (National Research Council, 2001). All energy values were calculated using both the dNDFc (DEc, MEc and NELc) and the dNDFm (DEm, MEm and NELm) values in the equations.

**Statistical analysis**

The statistical analysis of data was performed using IBM SPSS Statistics v.20 for Windows (SPSS Inc., Chicago, IL, USA). Differences in the chemical composition, total FA concentration, dNDFc, dNDFm, TDN and energy values (DE, ME, NEL) of straws were subjected to one-way analysis of variance according to the following model:

\[
X_{ij} = \mu + \alpha_i + \epsilon_{ij}
\]

where: \(X_{ij}\) is observation; \(\mu\) is overall mean; \(\alpha_i\) is effect of variety/subspecies/accession; \(\epsilon_{ij}\) is residual error. Pairwise multiple comparisons (Tukey’s test) were performed to test the difference between each pair of means. A paired-samples Student’s t-test was used to compare the energy values calculated using dNDFc or dNDFm. Significance was declared at P≤0.05.

**Results**

**Chemical composition of the analysed vetch straws**

The chemical composition of *V. sativa* and *V. villosa* L.

| Variety | Languedoc | Mghila | Subspecies ampicarpica | Variety | Sejenane | Accession | SEM | P |
|---------|-----------|--------|------------------------|---------|----------|-----------|-----|---|
| DM, %   | 91.3b    | 91.7a  | 91.9a                  |         | 91.4c   | 91.5e     | 6.67 | * |
| Ash, g 100g⁻¹ DM | 11.6c | 7.3d | 14.8c                 |         | 7.5c   | 7.9d     | 0.91 | *** |
| CP, g 100g⁻¹ DM | 13.4a | 7.5c | 9.3a                  |         | 7.4c   | 7.0d     | 0.78 | *** |
| SoIP, %CP | 38.3c | 37.4a | 42.2c                |         | 28.9a | 36.3c     | 1.35 | *** |
| RUP, %CP | 40.7c | 43.1c | 40.0c                |         | 45.2c | 44.2c     | 0.67 | *** |
| EE, g 100g⁻¹ DM | 0.7e | 0.7c | 0.5c                  |         | 0.5c   | 0.6c     | 0.03 | *** |
| FA, g 100g⁻¹ DM | 0.4a | 0.3c | 0.3c                  |         | 0.3c   | 0.3c     | 0.01 | ns |
| NDF, g 100g⁻¹ DM | 55.5c | 77.4a | 55.5c             |         | 72.4c | 75.9c     | 3.25 | *** |
| ADF, g 100g⁻¹ DM | 43.4a | 57.1a | 39.6c                |         | 56.3c | 56.6c     | 2.51 | *** |
| ADL, g 100g⁻¹ DM | 9.2c | 12.3c | 7.7c                  |         | 11.4c | 11.5c     | 0.57 | *** |
| NDIP, g 100g⁻¹ DM | 4.0a | 4.0a | 4.2c                 |         | 2.7c | 3.1c     | 0.20 | *** |
| ADIP, g 100g⁻¹ DM | 2.2c | 2.1b | 2.0b               |         | 1.8c | 1.8c     | 0.05 | ** |
| NFCc, g 100g⁻¹ DM | 22.7a | 11.2a | 24.8c              |         | 14.9c | 11.5c     | 1.90 | *** |
| dNDFc, g 100g⁻¹ DM | 21.7a | 31.9a | 23.5c              |         | 30.7c | 32.5c     | 1.51 | *** |
| dNDFm, g 100g⁻¹ DM | 25.0 | 25.0 | 26.4               |         | 27.3c | 28.5c     | 5.17 | ns |
| TDNc, g 100g⁻¹ DM | 48.8c | 41.9a | 48.6c              |         | 44.6c | 42.9c     | 0.96 | *** |
| TDNm, g 100g⁻¹ DM | 52.1c | 35.3a | 51.5c              |         | 41.2c | 38.9c     | 2.28 | *** |

DM, dry matter; CP, crude protein; SoIP, soluble protein; RUP, rumen undegradable protein; EE, ether extract; FA, total fatty acids; NDF, neutral detergent fibre; ADF, acid detergent fibre; ADL, acid detergent lignin; NDIP, neutral detergent insoluble protein; ADIP, acid detergent insoluble protein; NFCc, non-fibre carbohydrate (corrected); dNDFc, digestible neutral detergent fibre (calculated); dNDFm, digestible neutral detergent fibre (Ankom measured); TDNc, total digestible nutrients (calculated); TDNm, total digestible nutrients (Ankom measured). *Means within a row with different letters differ significantly. *P<0.05; **P<0.01; ***P<0.001; ns, not significant (P>0.05).
vicia straws is presented in Table 1. In gen-
teral, the differences observed among
varieties of V. sativa were more consistent
than those observed for varieties of V. villosa.

In the current study, CP values ranged from
7.0 (V. villosa acc. 2565) to 13.4% of DM (V.
sativa var. Languedoc). The CP and ash values
of V. villosa samples were significantly lower
than those of V. sativa var. Languedoc and
subsp. amphicarpa (P<0.001), but similar to
those of V. sativa var. Mghila. The soluble pro-
tein (SollP) and the rumen degradable fraction
(RDF) of CP were always higher in V. sativa
than V. villosa, the latter being characterized
by a significantly higher amount of rumen
undegradable protein (RUP) (P<0.001).

Significant differences between varieties
were observed for their EE content (P<0.001),
which was lower than 1% of DM in all samples.
Total FA of straws resulted similar in both
species and all analysed varieties (P>0.05)
and approximately equal to 50% of EE.

Regarding NDF, the values for V. sativa
ranged from 55.5 (var. Languedoc and subsp.
amphicarpa) to 77.4% of DM (var. Mghila),
while those for V. villosa ranged from 72.4 to
75.9%. The samples of V. sativa var. Mghila
showed the highest amounts of NDF and ADL
within and between species (P<0.001). The
ADF of V. sativa var. Mghila did not differ
significantly from the ADF of V. villosa varieties
(56.3 to 57.1% of DM), but was significantly
higher if compared to that of V. sativa var.
Languedoc and subsp. amphicarpa (43.4 and
39.6% of DM, respectively; P<0.001).

Significant differences were observed among
species and varieties in their NFCc
(P<0.001). V. sativa var. Mghila and V. villosa
acc. 2565 showed the lowest values of NFCc
(about 11% of DM) due to their high amount of
NDF, as previously described.

The digestible NDF (dNDFc) calculated from
the chemical analysis values of NDF and ADL
(equation 2-4e of National Research Council)
showed differences among varieties of both
species of Vicia (P<0.001); the highest values
were observed, as expected, in V. sativa var.
Mghila and V. villosa acc. 2565 (31.9 and 32.5%
of DM, respectively). The digestible NDF from
the in vitro assay (dNDFm) did not show
significant differences within and between
species. The dNDFc values of V. villosa were
always lower than dNDFc in V. sativa, only
dNDFm of var. Mghila showed the same trend
as observed for V. villosa.

Total digestible nutrients (calculated and
TDNm of V. sativa var. Mghila were always
lower and significantly different from var.
Languedoc and subsp. amphicarpa (P<0.001).
For V. villosa, only TDNe values were signifi-
cantly different between varieties.

With the exception of var. Mghila, V. sativa
samples always showed higher TDNe and
TDNm values than V. villosa samples
(P<0.001). Var. Mghila resulted the least
digestible variety among the 5 studied due to
the high amounts of NDF and lignin.

Energy content of the analysed
vetch straws

The energy values (DE, ME, NEc) of straw
samples are shown in Table 2. The energy
values calculated from dNDFc (DEc, MEc and
NEc) were always significantly different with-
in and between species (P<0.001). In accor-
dance with the chemical composition of straws,
DEc, MEc and NEc values ranked in the
following order: V. sativa var. Languedoc> V.
sativa subsp. amphicarpa> V. villosa var.
Sejenane> V. villosa acc. 2565> V. sativa var.
Mghila. In V. sativa, NEc ranged from 0.79
Mcal kg⁻¹ DM of var. Mghila to 1.05 Mcal kg⁻¹
DM of var. Languedoc; NEc of V. villosa straws
was comprised between 0.82 and 0.87 Mcal kg⁻¹
DM (in acc. 2565 and var. Sejenane, respec-
tively).

Using measured dNDFc values (dNDFm), the
estimated DEc, MEc and NEc resulted lower
than DEc, MEc and NEc only in straw samples
characterised by high NDF and ADF amounts
(i.e., V. sativa var. Mghila and V. villosa var-
ieties); less fibrous samples (V. sativa var.
Languedoc and subsp. amphicarpa) showed
higher energy amounts.

No statistical difference was observed when
the energy values were calculated using
dNDFm or dNDFc in the National Research
Council equations (Table 3).

Discussion

The chemical composition of vetch straws
may significantly differ according to species
and varieties, as previously observed by Larbi
et al. (2011a, 2011b). These authors revealed
significant intra-species variations in 45
accessions of V. sativa and 25 accessions of V.
villosa ssp. dasycarpa in days to flowering, pod
maturity and harvest index, as well as yields
and quality determinants of hay, grains and straw. More recently, Kebede et al. (2014) evaluated the forage nutritive values of 20 accessions of different vetch species; their nutritional value varied across testing sites and harvesting stage. Intermediate maturing and erect growth habit vetch species had better ash and CP, and lower NDF, than early maturing and creeping growth habit species. Such results seem to be in accordance with those obtained in the current trial, with the exception of V. sativa var. Mghila.

In our study, the straw of V. sativa var. Languedoc and subsp. amphicarpa showed higher amounts of CP than the average range values (7.0 to 8.9% of DM) reported for common vetch by other authors (Hadjipanayiotou et al., 1985; Bruno-Soares et al., 2000; Haddad and Husein, 2000). Bruno-Soares et al. (2000) also reported – for V. villosa cv. Amoreiras – higher CP values (10.9% of DM) than those observed for hairy vetch in our trial.

According to some authors (Hadjipanayiotou et al., 1985; Bruno-Soares et al., 2000; Haddad and Husein, 2000; López et al., 2005), the NDF values of Vicia spp. straws may vary between 40.2 and 64.7% of DM. Neutral detergent fibre is highly variable among the same species and varieties of the genus Vicia according to different soil types and climate conditions (Kebede et al., 2014). In the current trial, the NDF values of V. villosa varieties and of V. sativa var. Mghila were higher than the above mentioned maximum value, but the NDF values of V. sativa var. Languedoc and subsp. amphicarpa fell within the range and were similar to those observed by López et al. (2005).

According to the National Research Council (2001), if EE<1, then FA=0, and digestible FA (dFA)=0. In this study the total amount of FA and dFA were determined for a more accurate TDN calculation. Total digestible nutrients were therefore calculated using dFA and two different approaches (chemical and biological) for dNDF values, according to the equations developed by the National Research Council (2001). Both approaches require estimates of the DEc, MEc and NELc calculated with high NDF amounts (i.e., V. sativa var. Mghila and V. villosa varieties) resulted lower than the DEc, MEc and NELc calculated with the chemical approach. On the contrary, with less fibrous samples (V. sativa var. Languedoc and subsp. amphicarpa), the chemical approach resulted in higher energy amounts than the biological one. These results are partially in agreement with previous studies on other feeds such as corn, wheat, and corn or wheat distillers grain with solubles (Yu et al., 2004; Nuez-Ortín and Yu, 2011), in which the highest energy values were found when dNDF was measured with a biological approach (ruminal in situ assay).

Conclusions

This study showed that the chemical composition of straws of the considered varieties of Vicia sativa and Vicia villosa can be significantly different even if plants have grown in identical environmental conditions. The chemical composition of the two species showed differences for all the analysed parameters with the only exception of FA. Within the same species, the two varieties of V. villosa showed a more uniform chemical composition than the three varieties of V. sativa.

For feedstuffs characterized by very low amounts of EE (<1) such as straws, the National Research Council suggests that dFA=0 for the TDN calculation. The FA determination allows a more precise estimation of TDN, but the cost for the analysis may not be justified for this type of samples and the differences seem negligible.

The different approach in estimating the digestibility of NDF (chemical or biological) led to variable energy values. However, the results of the paired-samples Student’s t-test indicated that the differences are negligible. Therefore, dNDF (easier to be obtained and less expensive) can be used for predicting the energy value of low-EE and high-NDF samples such as straws.

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