Departament de Ciència Animal i dels Aliments

Intake and digestibility of a variety of hooded barley in sheep

Máster Oficial en Calidad de Alimentos de Origen Animal

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03/09/2018

Universitat Autònoma de Barcelona

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Informan que

El trabajo titulado: **“Intake and digestibility of a variety of hooded barley in sheep”** ha sido realizado por el Sr. **Oriol Ajenjo Puigderrajols** bajo nuestra tutela durante el curso académico 2017-18, como parte del módulo de Trabajo Fin de Máster del Máster Oficial de “Calidad de Alimentos de Origen Animal” de la Universitat Autònoma de Barcelona.

Y, para que así conste a los efectos oportunos, firman el presente documento en Bellaterra, a 1 de septiembre de 2018.

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AGRADECIMIENTOS

En primer lugar, me gustaría expresar el más sincero agradecimiento a la Dra. Elena Albanell y el Dr. Gerardo Caja por la transmisión de conocimientos, por su entusiasmo por el aprendizaje y la transferencia y por la acogida que me han brindado, un placer.

Agradecer al Dr. Ramón Casals, a Ali El Hadi y a Nabil Mehaba por la colaboración durante el período experimental, en laboratorio y con el análisis estadístico de los datos.

A Ramón Costa y todo el personal de la Granja Experimental por su implicación en el trabajo, la transmisión de conocimiento y los buenos momentos transcurridos a lo largo de la investigación en granja.

A Blas Sánchez y Esther Alòs por su dedicación y colaboración con los análisis de laboratorio.

Muy especialmente a mi familia, por estar ahí, por apoyarme día tras día y estar a mi lado en todo momento. Cierro una etapa académica más gracias a la oportunidad brindada. Gracias.

Y finalmente, a las ovejas, sin su consentimiento esto no sería posible.

ABSTRACT

Hooded barley, a new type of barley (*Hordeum vulgare*), is characterized by having a natural mutation that leads to develop an extra sterile flower in the spikelet, producing beardless spikes. Possible advantages of this new barley for animal feeding are related with the absence of awns, avoiding hurting oral cavity of animals and expecting to be more palatable.

Whit this aim, the ingestibility and nutritive value of the hooded barley cv. Mochona were assessed, in comparison with a triticale cv. Titania as a reference, in sheep. Twelve multiparous, dry and open Manchega ewes (80.3 ± 3.4 kg live weight) were allocated in 2 balanced groups (n = 6), housed in metabolic cages and submitted to two consecutive experiments in which hay and silage of each forage, produced in similar experimental plots, were fed *ad libitum*. Each experiment consisted of adaptation (15 days, including training to metabolic cages), measurement and sampling (5 days) and washout (7 days). Obtained results showed that, despite the preservation method, both forages showed few differences in chemical composition. Nevertheless, the ingestibility of the barley tended to be greater than that of triticale, the differences between them being greater with regard to dry matter digestibility (44.0 vs. 46.0%, respectively; $P < 0.05$).This difference was a consequence of the greater content of lignin acid detergent observed in the hooded barley when compared to triticale. Consequently, the net energy content and the nutritive value of the hooded barley were slightly lower than that of the triticale. Regarding the forage preservation method, no differences were detected in terms of ingestibility and digestibility, although the digestibility of neutral detergent fibre was greater in hays than in silages. Moreover, hays tended to show better compositional values than silages, and, as a whole, resulted more palatable and digestible.

In conclusion, under our conditions, the Mochona hooded barley showed a similar composition but a lower nutritive value than the Titania triticale. More research at medium and long terms is necessary to validate these results and to test other barley varieties and forage preservation methods (e.g. haylage) to show the effects of awn elimination.

Keywords: hooded barley, triticale, digestibility, nutritive value, hay, silage.

RESUMEN

La cebada capuchona, un nuevo tipo de cebada (*Hordeum vulgare*), se caracteriza por tener una mutación natural que conduce al desarrollo de una flor extra estéril en la espiguilla, dando lugar a espigas imberbes. Las posibles ventajas de esta nueva cebada para la alimentación animal se relacionan con la ausencia de aristas, evitando herir la cavidad oral de los animales y esperando ser más apetecibles. Con este objetivo, se evaluó la ingestibilidad y el valor nutritivo de la cebada capuchona cv. Mochona, en comparación con un triticale cv. Titania como referencia, en ovejas. Doce ovejas Manchegas multíparas, secas y abiertas (80.3 ± 3.4 kg de peso vivo) fueron distribuidas en 2 grupos balanceados (n = 6), alojadas en cajas metabólicas y sometidas a dos experimentos consecutivos en los que heno y ensilado de cada forraje, producidos en parcelas experimentales, fueron ofrecidos *ad libitum*. Cada experimento consistió en un periodo de adaptación (15 días, incluido el entrenamiento en las jaulas metabólicas), medición y muestreo (5 días) y limpieza (7días). Los resultados obtenidos mostraron que, a pesar del método de conservación, ambos forrajes mostraron pocas diferencias en la composición química. Sin embargo, la ingestibilidad de la cebada tendió a ser mayor que la del triticale, siendo mayores las diferencias entre ellos en la digestibilidad de la materia seca (44.0 vs. 46.0%, respectivamente, $P < 0.05$). Esta diferencia fue consecuencia de un mayor contenido de lignina ácido detergente en la cebada en comparación con el triticale. En consecuencia el contenido de energía neta y el valor nutritivo de la cebada capuchona fueron ligeramente inferiores a los del triticale. En cuanto al método de conservación del forraje, no se detectaron diferencias en términos de ingestibilidad y digestibilidad, aunque la digestibilidad de la fibra neutro detergente fue mayor en los henos que en los ensilados. Además los henos tendían a mostrar mejores valores de composición que los ensilados y en general, resultaron más apetecibles y digestibles.

En conclusión, en nuestras condiciones, la cebada cv. Mochona mostró una composición similar pero un valor nutritivo menor que el triticale cv. Titania. Se necesitan más investigaciones a medio y largo plazo para validar estos resultados y para probar otras variedades de cebada y otros métodos de conservación de forraje (por ejemplo, henolaje) para mostrar los efectos de la eliminación de las aristas.

Palabras clave: cebada capuchona, triticale, digestibilidad, valor nutritivo, heno, ensilado.

RESUM

L'ordi "capuchona", un nou tipus d'ordi (*Hordeum vulgare)*, es caracteritza per presentar una mutació natural que es tradueix en el desenvolupament d'una flor extra estèril en l'espigueta, produint espigues imberbes. Els possibles avantatges d'aquest nou ordi per l'alimentació animal es relacionen amb l'absència d'arestes, evitant ferir la cavitat oral dels animals i esperant ser més apetitoses. Amb aquest objectiu, es va avaluar la ingestibilitat i el valor nutritiu de l'ordi "capuchona" cv. Mochona, en comparació amb un triticale cv. Titania com a referencia, en ovelles. Dotze ovelles Manxegues multípares, seques i obertes (80.3 ± 3.4 kg de pes viu) van ser distribuïdes en 2 grups equilibrats (n = 6), allotjades en gàbies metabòliques y sotmeses a dos experiments consecutius en els que fenc i ensitjat de cada farratge, produïts en parcel·les experimentals, van ser oferts *ad libitum*. Cada experiment va consistir en un període d'adaptació (15 dies, inclòs l'entrenament en les gàbies metabòliques), mesurament i mostreig (5 dies) i neteja (7 dies). Els resultats obtinguts van mostrar que, malgrat el mètode de conservació, ambdós farratges presenten poques diferencies en la composició química. No obstant, la ingestibilitat de l'ordi tendeix a ser millor que la del triticale, essent majors les diferencies entre ells en el cas de la digestibilitat de la matèria seca (44.0 vs. 46.0%, respectivament, $P < 0.05$). Aquesta diferencia fou conseqüència de un major contingut de lignina àcid detergent en l'ordi "capuchona" en comparació amb el triticale. En conseqüència, el contingut d'energia neta i el valor nutritiu de l'ordi "capuchona" van ser lleugerament inferiors que els del triticale. En quant al mètode de conservació del farratge, no es van detectar diferencies en termes de ingestibilitat i digestibilitat, malgrat que la digestibilitat de la fibra neutre detergent fou superior en els fenc que en els ensitjats. A més a més, els fencs tendien a presentar millors valors de composició que els ensitjats, i, en general, resultaven més apetitosos i digestibles.

En conclusió, en les nostres condiciones, l'ordi cv. Mochona va presentar una composició similar però un valor nutritiu menor que el triticale cv. Titania. Son necessàries més investigacions a mitja i llarg termini per validar aquests resultats i per provar altres varietats d'ordi i mètodes de preservació del farratge (per exemple, henolatge) per mostrar els efectes de la eliminació de les arestes.

Paraules clau: ordi "capuchona", triticale, digestibilitat, valor nutritiu, fenc, ensitjat.

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List of abbreviations

ADF	Acid detergent fibre
ADL	Acid detergent lignin
CF	Crude fibre
dCF	Digestibility of crude fibre
dCP	Digestibility of crude protein
dDM	Digestibility of dry matter
dGE	Digestibility of gross energy
DE	Digestible energy
DM	Dry matter
DMI	Dry matter intake
dNDF	Digestibility of neutral detergent fibre
DOM	Digestible organic matter
dOM	Digestibility of organic matter
GE	Gross energy
ME	Metabolizable energy
N	Nitrogen
NDF	Neutral detergent fibre
NE_L	Net energy lactation
PDIA	Protein digested in the small intestine supplied by rumen undegradable protein from the feed
PDIE	Protein digested in the small intestine supplied by microbial protein from rumen-fermented organic matter
PDIN	Protein digested in the small intestine supplied by microbial protein from ruminal degradable protein
SE	Standard error of the mean
UFL	Feed units for lactation (1.7 Mcal EN_L or 1 kg barley as fed)

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1. Introduction

1.1. Barley for alternative uses: Hooded Barley

There is considerable historical and archaeological evidence documenting the role of barley (*Hordeum vulgare* L.) as a sustaining food source in the evolution of humankind. Newman and Newman (2008) determined that barley was domesticated (cultivated) approximately 10,000 years ago, and before than wheat.

According to FAO (2016), barley is one of the most important cereal crops in the world at nowadays. It is widely the 4th grown cereal and one of the top-ten crop plants produced in the world. In Spain, barley is the crop that occupies the largest number of hectares (2.9 Mha), more than duplicating those of the olive groves (MAPAMA, 2016).

Barley is such as important crop because it's wide adaptability to different climatic and soil conditions, as well as because its suitability for a wide variety of purposes. Barley grain is mainly addressed for animal feed and malt production (Srivastava, 1977). Newman and Newman (2008) estimated the barley uses as: animal feed 60%, malt 30%, seeds 7%, and human food 3%. Additionally, the barley plant may be used for forage production, if harvested in early season (spring), allowing the later yield of grain at the end of the season (summer). Barley forage is used as a feedstuff resource in the form of green forage (for grazing or direct feeding), hay or silage (Sprague, 1963). According to FEDNA (2016) the most important forms of use for barley as a forage in animal feeding, are the consumption as hay (49%), green forage (36%), and the rest as silage (15%). Both, hay and silage are feed sources of medium-low nutritive value, needing to be complemented for ruminant diets.

Barley is one of the grains with the greatest genetic diversity (Fernández *et al*., 2002; Matus and Hayes, 2002; Kumar, 2016). Among there, they are different groups of barley varieties, than can be classified as:

1) winter or spring, according to the sowing season;

2) two (forage) or six (malt) seed rows, according to the morphology of the ear and purpose;

3) hulled (common) or hulless ("nude"), depending on if the outer covers are adhered or not to the grain;

4) with (common) or without awns ("hooded").

5) waxy and non-waxy, according to the ratio of amylose-amylopectin; and finally,

6) tainted or untainted, according to the level of anthocyanin (Holtekjolen *et al.*, 2006).

The barley varieties without awns or “hooded”, are a new form of barley of special interest for animal nutrition. They present a mutation that leads to the overexpression of a gene that produces the development of an extra sterile flower in the spikelet, instead of showing the characteristic barbs or awns, giving rise to spikes apparently beardless (Roig *et al.*, 2004).

This barley without awns, should be more palatable for livestock at advanced stages of maturity, not causing injuries in the mouth or the digestive system. In addition, ensiling this barley before maturity as a forage, it might be an alternative to other cereals ensiled in spring (e.g., wheat, oat and triticale).

Consequently, there is a growing interest in the evaluation of this new material for animal nutrition. In our knowledge, there is not previous information on the nutritive value of this type of forage in sheep in Spain.

1.2. Nutritional value of ruminant feeds: ingestion and digestibility

The rumen represents the main place where the digestion of dietary constituents occurs in ruminants, which is carried out by a complex microbiota (Van Soest, 1994). The structure of the digestive tract of ruminants makes them able to consume feeds with a high content of fibre and to digest them with a greater efficiency than other animals.

Nutrition deserves special attention for animal production because it represents the way in which the animal acquires the nutrients to perform its vital and productive functions. Additionally, feeding represents approximately 60% of most animal production costs and has a great impact on the economy of the production system (da Silva Cabral *et al.*, 2005*).* For this reason, the knowledge of the nutritive value of the main ingredients that constitute the diet of the animals becomes imperative, since it can allow the optimization of the performances and the reduction of the production costs, as well as the losses of energy and nitrogen associated with the digestion and metabolism of nutrients (da Silva Cabral *et al*., 2002).

The nutritive value of a feedstuff mostly depends on the amount voluntarily ingested, the level of nutrients that it contains and the digestibility of these nutrients (da Silva Cabral *et al.*, 2005). Among other factors, the measurement of the digestibility is a key aspect of the evaluation of the nutritive value of a forage because it allows to estimate the proportion of nutrients present in a feed that can be absorbed by the digestive system and be available to the animal (Bondi, 1989; Church and Pond, 1994).

The measurement of the digestibility in sheep is the standard method for determining the nutritive value of forages in most of feeding systems for ruminants (Van Soest, 1994). On the other hand, the level of intake is the most important factor affecting animal performance (Mertens, 1994) so, the voluntary intake of a forage together with its digestibility are major determinants of the quality of a forage. Accordingly to this, the values expressed in the tables of reference of the composition and nutritive value of ruminant feeds of INRA (French system), and NRC (U.S. American system) depend on the feeding conditions at which were measured. In the case of INRA, the digestibility measurements were performed at *ad libitum* (Demarquilly *et al.,* 1995) whereas for NRC they were performed at maintenance level of feeding (Huhtanen *et al.,* 2009), both under *in vivo* conditions.

The digestibility depends mainly on the nutritional composition of the feed under study, being in turn affected by the fact that faeces contain important quantities of materials of non-dietary (endogen) origin (Merchen, 1993). The faeces constitute an important route of excretion of nitrogen, fat, minerals and non-fibrous carbohydrate compounds of endogenous origin (Church and Pond, 1994). There is not intestinal carbohydrate secretion (Bondi, 1989). For this reason, the digestibility coefficients, regardless of the method used, are called "apparent". The difficulty of accurately quantifying the quantities of endogenous origin of a certain element present in the faeces causes the underestimation of its true digestibility, so that the values of apparent digestibility are always lower than those of true digestibility.

Andueza *et al.* (2011) mentions that *in vivo* digestibility trials are not feasible on a large-scale because such type of trials are high cost and time-consuming, requiring large amounts of feed. Moreover, in diets based on forages, the *in vivo* digestibility is affected by those elements that have an effect on consumption, such as: the ability to select components according to the supply of material, the availability of water, the rate of passage through the digestive, the metabolic efficiency of the animal and even the environmental conditions. As a consequence, that the *in vitro* technique can hardly reproduce the transformations that occurred in the case of *in vivo* digestibility (Cochran *et al.,* 1986). In addition, the *in vitro* trials are based in chemical parameters and in predictive equations that are dependents on the type of food, mode of conservation, the animal species and its physiological status as well as the feeding conditions. Much effort has been invested on the development of regression equations to predict the digestibility from forage composition, but an individual analysis that gives satisfactory prediction over a wide range of forages has not yet been found (Van Soest, 1982). For this reason, when it comes to evaluate a new food, the *in vitro* conditions are uncertain and only valid for special conditions, the *in vivo* methodology being the reference conditions.

1.3. Improve the quality of the final product through animal nutrition

The current instability, in which the agri-food sector is located, added to the growing consumer demand of qualitative aspects in the feeds, has caused that the farmers must now contend with frequent changes. In most cases, this situation is translated with necessity to improved management, selection and nutrition.

The dairy sheep sector is also subject to a strong demand for the production of cheese of quality (Pulina *et al*., 2018) which is dependent on milk fat and protein concentrations and also used as routine parameters to predict cheese yield (Pellegrini *et al*., 1997). In dairy sheep, as in other ruminants, feeding is the major factor affecting the quality of milk. In contrast to breeding, nutrition allows relatively rapid changes in yield and composition of milk, and therefore provides an appropriate tool for responding to the market. Bocquier and Caja (2000) indicate that the feeding of dairy ewes must ensure healthy animals that produce large amounts of milk of high quality and health value, which then are used to produce typical Mediterranean dairy sheep products. Even so, due to the observed variation coefficients of milk fat and protein content, possibilities of altering milk composition by feeding are higher for fat than protein contents (Sutton and Morat, 1989).

Energy intake, expressed as UFL (forage units for lactation) according to the French System and which correspond to 1.7 Mcal of net energy of lactation, is the main factor affecting milk yield and milk composition in dairy ruminants (Bocquier and Caja, 2000); the milk fat content being negatively correlated to energy balance (Bocquier and Caja, 1993). Consequently, a high level of nutrition will reduce the fat percentage of milk in most cases in dairy ewes.

With regard to milk protein content, in accordance with the cow and goat conclusions, the relationship between energy intake and milk protein content is positive (Flamant and Morand-Fehr, 1982; Rémond, 1985; Morand-Fehr *et al.*, 1991; DePeters and Cant, 1992). In conclusion, high levels of nutrition generally produce slight increases in milk protein and casein contents in dairy ewes.

1.4. Objectives

Given the knowledge framework previously exposed and specially by the growing interest on the hooded varieties of barley in ruminant nutrition and the lack of information on this type of forage under Spanish conditions, the general aim of this M.Sc. thesis was to estimate the nutritive value of a hooded barley variety (cv Mochona).

The study was designed to evaluate the voluntary intake and digestibility, under *in vivo* and *ad libitum* conditions in sheep, with the forage harvested under different preservation forms (hay and silage) and compared with one commercial variety of triticale (cv Titania).

2. Material and methods

2.1. Forages

In November 2016, 0.75 ha of hooded barley (cv Mochona) and 0.75 ha of triticale (cv Titania), supplied by Semillas Batlle (Bell Lloch d'Urgell, Lleida, Spain), were sown in the experimental fields of the SGCE (Servei de Granges i Camps Experimentals) of the UAB (Universitat Autònoma de Barcelona, Bellaterra, Vallés Occidental, Barcelona, Spain).

Both species were harvested, through a single cut productive cycle, and processed for hay and silage in May 2017. The hays were cured in the sun and baling was carried out in rectangular bales (1 x 0.5 x 0.4 m) at low pressure, with a delay in the packing process of 5 days due to an occasional heavy rain. The silage was made in plastic containers of 1 m^3 (1.1 x 0.9 x 1 m) with regulated drainage. Use of all forages were after a 10-month storage period.

2.2. Animals, diets and housing

Twelve multiparous dry and open ewes of Manchega breed with similar body condition and live weight (80.3 ± 3.4 kg) were used. The trial was carried out in the experimental farm of the SGCE of the UAB, and the procedures were approved by the Ethical Committee of Animal and Human Experimental of the UAB (CEEAH reference 3871).

The experimental design consisted in two balanced blocks of six ewes each, sorted according to live weight and body condition, to who the experimental treatments (barley or triticale) were randomly applied in two experimental periods. In the first experimental period, the hays were compared, whereas the ensilages were compared in the second. All forages were fed once a day and *ad libitum* (fixed at 115% of previous day's consumption). In both experimental periods the ewes were subjected to 15-day of adaptation followed 5-day of measurement and sampling and finally 7-day to washout the digestive system to evite the contamination of the samples of the following experimental period.

With aim of minimizing the distress of the ewes during the experimental periods, they were penned indoors on a straw bedded area (3 m^2/ewe) with free access to the feeders and drinkers that were placed in metabolic boxes with plastic slats in the rear half (Caja *et al.*, unpublished). The metabolic boxes consisted of plastic containers of 1000 L (Auer, Amerang, DE; 1.12 × 0.92 m) provided of individual plastic feeders (40 × 30 × 32 mm) and water bowls, connected to water tanks of 10 L, prepared for total collection of faeces and urine of 2 sheep.

During the adaptation period (day 1 to 15), the ewes were tied to the feeders during the daytime hours (08 to 20 h) and released during the night, to ensure the adaptation to the diet and to record their individual voluntary intake. During the measuring and sampling period (days 16 to 20), the ewes were kept permanently tied in the metabolic boxes and their stalls reduced to 51 cm width by using a temporary vertical separator to avoid cross-consumption of feed and allow the collection of individual faeces and urine without mixing between animals

2.3. Measurements, sampling and analysis

Before the start of each experimental period, samples of all types of forage (hooded barley or triticale, hay or silage) were taken to determine their chemical composition.

During the days of measurement and sampling, all offers and orts, faeces and urine were individually weighted using an electronic scale (Gram K3, Gram Precision, Barcelona, ES), sampled (10% by weight) and composited by forage and period for the analysis of composition (Demarquilly *et al*., 1995). The silage and faeces samples were stored frozen (−20ºC) until analysis. Previously to the analyses the frozen samples were conditioned at 60ºC for 24 h and then ground and homogenized trough a cyclone mill (Retsch SM2000, Retsch, Haan, DE) with a mesh of 1 mm. The samples of hay were ground and homogenized directly.

All the chemical analysis was carried out in triplicate according to the official reference methods (AOAC, 2003). Dry matter (DM) was determined at 103ºC for 24 h and ashes burnt at 550ºC for 5 h. Crude protein (CP) was calculated as percentage of N × 6.25 by the Dumas method using a Leco Analyser (Leco Corporation, St. Joseph, MI, USA). Crude fibre (CF) was analysed by the Weende method. Neutral detergent fibre (NDF), acid detergent fibre (ADF) and acid detergent lignin (ADL) were determined on an ash-free basis by the method of Van Soest *et al.* (1991) using the Ankom200 Fibre Analyser (Ankom Technology, Fairport, NY, USA) adding sodium sulphite and α-amylase solutions.

At the beginning and the end of each experimental period, as well as the first day of sampling, the live weight of ewes was assessed with an electronic scale (WA 08, Meier-Brakenberg, Brakenberg, DE) in addition to body condition score according to Russel *et al*. (1969).

2.4. Calculations and statistical analysis

The voluntary intake and chemical composition of the diets and faeces were used to calculate the nutritive, energy and protein value, ingestibility and digestibility of each forage according to Demarquilly *et al*., (1995) and INRA (1988, 2007). Daily voluntary intake (g/kg $LW^{0.75}$) was expressed as DM intake (DMI), neutral detergent fibre intake (NDFI) and digestible organic matter intake (DOMI). Apparent digestibility was expressed as dry matter digestibility (dDM), organic matter digestibility (dOM), crude fibre digestibility (dCF), crude protein digestibility (dCP) and neutral detergent fibre digestibility (dNDF). To predict the energy and protein value according to INRA (2007) methodology, the following equations were used:

Energy value

- Metabolizable energy (ME, Mcal/kg): $ME = GE \times dGE \times (\frac{ME}{DE})$

Where,

GE is the gross energy of the feed

dGE is the digestibility of the gross energy

ME/DE is the energy loses because the gas formation and urine

- Net energy lactation (NE_L, kcal/kg): $NE_L = ME \times kl$

Where,

ME is the metabolizable energy

kl is the efficiency of utilization of the metabolizable energy (ME) during the lactation $kl = 0.60 + 0.24(q - 0.57)$, where q is the concentration of ME in the feed

- Feed units for lactation (UFL, units/kg): $UFL = NEL/1700$

Protein value

- Protein digestible in the intestine is limited by N (g/kg): $PDIN = PDIA + PDIMN$

- Protein digestible in the intestine is limited by energy (g/kg): $PDIE = PDIA + PDIME$

Where,

$$PDIA = CP \times (1 - pDT) \times dr$$

pDT is the theoric degradability of the CP of the feed in rumen. The values used were obtained in the INRA (2007) tables

dr is the digestibility of the amino acids from the feed in the intestine. The values used were obtained in the INRA (2007) tables

PDIM is the protein digested in the small intestine supplied by the ruminal micro biome. This can be limited by the degradable nitrogen (PDIMN) or by the fermentable energy (PDIME), being:

$$PDIMN = CP \times \left(1 - 1.11(1 - pDT)\right) \times 0.9 \times 0.8 \times 0.8$$

$PDIME = FOM \times 0.145 \times 0.8 \times 0.8$; FOM is the fermentable organic matter from the feed

Statistical analysis

Data of intake and digestibility were analysed as a 2 × 2 factorial (RStudio, v.3.5.1) with the forage specie (barley or triticale) and preservation method (hay or silage) as main effects. The statistical model was expressed according to Milton (1994) and contained the main effects, its interaction and the random error term. It was:

$$Y_{ijk} = \mu + \tau_i + \varphi_j + \tau\varphi_{ij} + \varepsilon_{ijk}$$

Being,

Y_{ijk} = dependent variable,
μ = overall mean,
τ_i = forage species effect,
φ_i = method of preservation effect,
$\tau\varphi_{ij}$ = interaction of forage species and method of preservation,
ε_{ijk} = error term

The Tukey's test was used to separate the differences between means and the significance was declared at $P < 0.05$, otherwise indicated.

3. Results and discussion

3.1. Chemical composition of the forages

The chemical compositions of the studied forages are summarized in **Table 1**. The CP content is one of the most important criteria to assess the quality of a forage (Caballero *et al*. 1995; Assefa and Ledin, 2001). Hooded barley showed a higher content of CP than triticale, both as hay (12.8%) or as silage (12.5%), the difference being greater in the case of silage most likely because the loses of soluble N. According to Olea *et al*. (1989) in natural pastures is suitable for ruminants when their CP content is greater than 8% (% expressed in dry matter). So, both forages showed enough content of CP and the hooded barley was better than the triticale with regard to CP. Nevertheless, the hooded barley showed greater ash content and, consequently, lower OM values than triticale, which will result in lower rumen fermentable and digestible matters.

Regarding CF, the obtained values were high, either in the hay as in the silage, and greater than expected for both forage species, most probably because of the increase in dry leaves content produced by the late stage of maturity of the crops at harvesting. Moreover, the differences in the chemical composition between both forage can be influence of the stage of maturity in the moment of harvesting. As the crop develops, protein concentration decreases and fibre concentration increases (Helsel and Thomas, 1987) as well as increases the DM content (Brignall *et al.* 1989). NDF and ADF contents increases as the plant progressed and decreased as head filled, with the maturity of crop. Helsel and Thomas (1987) observed only minor changes in ADL as plants progressed until the maturation stage. In our case is possible that triticale, both in hay and silage, was harvested in more advanced stage than hooded barley because the content of DM is higher as well as the content of CP is lower and the CF content higher. With regard of NDF and ADF contents the hooded barley showed higher contents that explain the differences in the stage of maturity in the moment of harvesting.

Khorasani *et al.* (1997), studied the influence of the stage of maturity on chemical composition of cereal grain silages, including barley and triticale, and obtained similar coefficients than our data as well as concluded that the ensiling process had only minor effects on the quality of cereal grain silages that this explain the lowest differences between hay and silage of the same species in our experimentation.

Table 1: Chemical composition of the hooded barley (cv Mochona) and triticale (cv Titania) according to preservation method (values are mean ± SE**).**

Item	Hay		Silage	
	Hooded barley	Triticale	Hooded barley	Triticale
DM at 60ºC, %	91.8	92.3	28.0	28.2
Silage pH	-	-	4.1	3.9
Composition, %DM				
Ash	16.2 ± 1.3	12.6 ± 1.5	17.3 ± 0.2	15.1 ± 1.5
OM	83.8 ± 1.3	87.4 ± 1.5	82.7 ± 0.2	84.9 ± 1.5
CP (N × 6.25)	12.8 ± 0.1	12.2 ± 0.0	12.5 ± 0.1	10.7 ± 0.1
CF	32.0 ± 0.3	32.2 ± 0.4	29.9 ± 0.4	31.4 ± 0.4
NFE[1]	39.0 ± 1.7	43.0 ± 1.8	40.3 ± 0.2	42.8 ± 1.7
NDF	64.5 ± 0.3	64.1 ± 0.3	52.2 ± 1.0	52.5 ± 0.4
ADF	40.0 ± 0.4	39.8 ± 0.5	31.6 ± 0.5	33.2 ± 0.3
ADL	5.5 ± 0.1	4.4 ± 0.4	4.0 ± 0.2	3.2 ± 0.0

[1]NFE (N-free extract or non-fibre carbohydrates) = OM – CP – CF.

The quality of hay, expressed as Relative Feed Value (RFV) and calculated according to Jaranyama and Garcia (2004), showed low (RFV < 100) but similar values in both species (hooded barley, RFV = 83; triticale, RFV = 84). The low quality of both hays, may have been a result of the late stage of harvesting to reach the deposition of starch in the grain.

Both forages appeared to ensile well, according to Ryser *et al*. (1997) that cited that high-quality silages must have acid pH values closer or under pH = 4.0. This was reached in both cases in our forages, with lower pH in the case of triticale, agreeing with its greater OM and NFE contents and expected fermentative potential. McCartney and Vaage (1994) compared one silage of barley and one silage of triticale and obtained similar coefficients in terms of CP, ash, NDF, ADF and ADL than obtained in our data being the triticale silage which presented greater NDF and ADF coefficients than hooded barley.

3.2. *In vivo* ingestibility and digestibility

The results of the *in vivo* nutritive evaluation study, expressed as voluntary intake and apparent digestibility of the forage of each specie according the method of preservation are shown in **Table 2.**

With regard to the composition of each forage specie, despite the values of ingestibility (i.e., DMI, DOMI and NDFI) being numerically greater for the triticale, no differences were observed by in the case of hays or silages (**Table 2**; $P > 0.05$). McCartney and Vaage (1994) obtained higher values for barley and lower values for triticale, in terms of ingestability, than our data when compared two kind of silage of this two species. This is probably a consequence of the higher contents of humidity in our hooded barley and its lower content of OM what produced a less efficient fermentation in the silage. The lower intake obtained for hooded barley in comparison to the triticale, may be related to its higher content of NDF. Horrocks and Vallentine (1999) reported that NDF content and DMI are negatively correlated; the higher the NDF the lower the quality and the DMI.

Regarding apparent digestibility, in both hays and silages, the values for hooded barley and triticale differed ($P < 0.05$) for all components measured, despite their similar chemical composition, except for dCP. The whole values of digestibility were lower in the hooded barley than in triticale (i.e., 11 to 14% for dDM; Table 2, $P < 0.05$) and, similarly to the facts reported for intake, the values were lower for barley and higher for triticale than those reported by McCartney and Vaage (1993). Lignin is a major constituent of the secondary cell wall and it is completely indigestible in ruminants. A negative relationship between forage dDM and lignin content is widely recognized (Woodman and Stewart, 1932; Mowat *et al.*, 1969; Allinson and Osbourn, 1970; Minson, 1971). In addition, Huhtanen *et al*. (2009) reported that the fibre fraction accounts for most of the variation of the diet digestibility in dairy cows.

Table 2: Ingestibility and apparent digestibility of hooded barley (cv Mochona) and triticale (cv Titania) according to the preservation method in sheep under *ad libitum* feeding conditions (values are means ± SE).

Item	Hay		Silage		Hay vs. Silage (*P* effect)	
	Hooded barley	Triticale	Hooded barley	Triticale	Hooded barley	Triticale
Ingestibility, g/kg $LW^{0.75}$						
DM	27.0 ± 1.8	38.2 ± 4.2	28.2 ± 2.5	35.0 ± 4.9	0.995	0.918
DOM	22.7 ± 1.5	33.4 ± 3.7	23.1 ± 2.1	29.7 ± 4.1	0.999	0.821
NDF	17.4 ± 1.1	24.5 ± 2.7	14.6 ± 1.3	18.4 ± 2.6	0.846	0.214
Digestibility, %						
dDM	53.3 ± 1.2[b]	60.1 ± 1.0[a]	52.6 ± 1.1[b]	61.5 ± 0.8[a]	0.972	0.796
dOM	55.6 ± 1.5[b]	64.4 ± 2.3[a]	56.6 ± 1.1[b]	64.9 ± 0.9[a]	0.971	0.994
dNDF	61.6 ± 1.0[b]	66.7 ± 1.2[a]	51.7 ± 1.4[b]	58.1 ± 1.3[a]	0.001	0.001
dCF	55.5 ± 0.9[b]	62.4 ± 1.6[a]	49.4 ± 1.0[b]	59.0 ± 1.7[a]	0.050	0.327
dCP	55.4 ± 1.3	59.8 ± 0.6	59.7 ± 1.3	63.2 ± 1.7	0.121	0.275

[a, b] Means without the same superscript for the same preservation system are different ($P < 0.05$).

The CP content of both forage species was similar, although the hooded barley showed higher numerical values than triticale. Accordingly, the in vivo dCP did not differ between forage species. Sekine *et al.* (1994) compared two hays of orchardgrass with different content of lignin, similar than in our hays, in sheep and reported similar values of intake and apparent digestibility than in our data.

Whith regard to the comparison of the preservation the method within the same forage specie**,** no statistical differences were detected ($P > 0.05$) in terms of intake and apparent digestibility except for dNDF. Both silages had lower contents of NDF than the comparable hays and, consequently, their dNDF values were also lower in the silages. In this sense, Udén (1984) reported similar values of intake and apparent digestibility when compared a hay and silage with similar chemical composition like our forages. Udén (1984) also mentioned that the hemicellulose is responsible for the major differences in NDF content and dNDF between forage preservation methods.

3.3. Nutritive value of the forages

The energy and protein values of both forages according to the preservation method are summarized in **Table 3**.

Regarding energy values, as calculated by using the INRA (2007) equations, triticale have higher values than hooded barley, both in hay and silage, as a consequence of the higher dGE, which is related to OM digestibility and dependent of the CF content, according to Demarquilly *et al.* (1995) and INRA (2007) equations. Furthermore, for the same reason, the PDIE values were higher in the triticale than hooded barley. Unlike of the PDIE values, the PDIN values were higher in hooded barley than in triticale, are related to the higher content of CP of hooded barley. However, hooded barley has higher values than triticale in terms of PDIA. Both forages were similar in GE but varied widely in the proportion of the total energy which is available for milk production. Triticale showed higher values in terms of NE_L, thus, this forage has more amount of energy available for milk production than hooded barley.

When compare the preservation methods, the hooded barley silage have similar values to hay, except in values related with the OM digestibility such as DE and $NE_{L.}$ Nevertheless the triticale hay have higher values than silage, as a consequence that the better chemical composition. For the same reason, in both species the hays have higher value of PDIA, PDIE and PDIN than silages.

When expressed the energy value as UFL, triticale have higher value than hooded barley as a consequence to have higher value of NE_L. Therefore, hooded barley silage has higher UFL value than silage. If we compare the presents values, with the INRA (2007) reference values, it's reasonable to not consider hooded barley, both in hay or silage, a good alternative for the future diets of dairy ruminants, but is possible that the effect of the spike with awn or not with this method of conservation not have effect and it is necessary that to evaluate the nutritive value as green forage.

Table 3: Energy and protein digestibility values of the hooded barley (cv Mochona) and triticale (cv Titania) forages according to the preservation method.

	Hay		Silage	
Item	Hooded barley	Triticale	Hooded barley	Triticale
Energy values				
Gross energy, Mcal/kg DM [1]	4.04 (96)	4.19 (100)	4.04 (98)	4.11 (100)
dGE[1], % [2]	53.0	61.6	53.8	62.1
DE, Mcal/kg DM [1 × 2]	2.14 (83)	2.58 (100)	2.18 (85)	2.56 (100)
Metabolicity (q = ME/GE)	0.36	0.44	0.36	0.43
NE_L, Mcal/kg DM	0.96	1.21	0.98	1.19
UFL/kg DM	0.57 (80)	0.71 (100)	0.58 (83)	0.70 (100)
Protein values				
PDIA[2], g/kg DM	40	35	27	16
PDIE[3], g/kg DM	70	79	51	54
PDIN[4], g/kg DM	81	78	77	62

[1]Digestibility of the gross energy (%); [2] protein digested in the small intestine (PDI) from the ruminal undegradable protein; [3]PDI supplied by microbial protein from rumen-fermented organic matter; [4]PDI supplied by microbial protein from ruminal degradable protein.

When compared hooded barley silage with the values registered in feed tables of INRA (2007) and FEDNA (2016) for silage barley, the results of gross energy (4.51 Mcal/kg DM), digestible energy (2.47 Mcal/kg DM) and UFL (0.69 UFL/kg DM) were higher in the feed tables of INRA (2007). The FEDNA values were higher for UFL (0.90 UFL/kg DM) but lower for the gross energy (3.82 Mcal/kg DM).

The protein digestibility values were higher in our hooded barley than in feed tables of INRA (PDIA, 18 g/kg; PDIE, 50 g/kg; PDIN, 58 g/kg)., but the FEDNA values were lower, except in the PDIE value (PDIA, 23 g/kg; PDIE, 62 g/kg; PDIN, 58 g/kg).

3. Conclusions

In accordance with objectives we can conclude that:

The chemical compositions of both species are similar but the triticale cv Titania have greater nutrient content than hooded barley cv Mochona. When comparing the two methods of preservation of forages (hay and silage) there were no notable differences between them, although the hay presents higher protein content making it more palatable.

Ingestibility values of hooded barley were similar to triticale, both hay and silage, but triticale has greater digestibility values than hooded barley. As a result, the triticale was more palatable, digestible and nutritive than hooded barley. The hay present higher digestibility values than silage.

As a general conclusion we can conclude that the nutritional value of the variety of hooded barley used, under our *in vivo* conditions in sheep, was greater than reported for conventional barley used as a forage, but slightly lower than that obtained in the triticale. Consequently, we expected differences in milk yield and composition in favour of the triticale when fed to dairy ewes.

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