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Nutritive value of on-farm vetch-oat hays. I. Voluntary intake and nutrient digestibility

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Abstract — Forage hay from the common vetch-oat intercrop has the potential to meet the forage deficit and integrate crop and livestock production in Mediterranean cereal-sheep systems. Groups of three wethers (1–2 year-old) were randomly allocated to individual on-farm hays of a sample size of 12 with the aim of assessing variability of botanical and chemical fractions, digestibility of nutrients, and DM intake. Vetch content (g·kg^{-1} DM) of hays (mean value = 557) ranged from 125 to 917. Mean contents (g·kg^{-1} DM) of crude protein (CP), neutral detergent fibre (NDF) and acid detergent lignin (ADL) were 126, 486, and 45 respectively. Variations of chemical composition between hays, and especially those of CP and ADL were partially explained by vetch proportion. Voluntary intake (g DM·kg^{-1}·BW$^{0.75}$) had a mean value of 64.2 and ranged from 49.0 to 78.9. Organic matter digestibility (mean value = 68.8%) ranged from 59.9 to 72.6%. The digestibility coefficient of nutrients and voluntary intake showed lower variability than that of chemical fractions, which, in turn, had a lower variability than that of botanical composition. The mean digestible energy (DE) concentration of the study sample was 11.72 MJ DE·kg^{-1} DM. Low variability of this value (CV = 5.9%) indicated a compensatory effect between vetch and oat. Vetch proportion in hay gave a better explanation of the variation of CP intake (r^2 = 0.63) than of the variation of DE intake (r^2 = 0.37). On-farm hays with at least 50% of vetch contribution may be considered as a production objective. This criterion may contribute to standardisation and marketing operations at the farm level.

forage quality / vetch-oat hay / digestibility / sheep / Mediterranean agriculture

Résumé — **Valeur nutritive des foins de vesce-avoine pour les ovins. I. Quantités ingérées et digestibilité.** Les foins des associations de vesce-avoine peuvent être employés pour combler le déficit fourrager et intégrer les activités agricoles et d'élevage dans les systèmes céréale-ovin méditerranéens.

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On a étudié un total de 12 foins sur des lots de trois moutons, distribués au hasard, pour établir la variation de la composition chimique et botanique, la digestibilité et la quantité de MS ingérée. La teneur (g·kg^{-1} MS) en vesce dans le foin (valeur moyenne = 557) a varié de 125 à 917. Les concentrations moyennes en matières azotées totales (MAT), en parois (NDF) et en lignine (ADL) ont été de 126, 486 et 45 g·kg^{-1} MS, respectivement. Les variations de la composition chimique entre foins sont partiellement expliquées par la teneur en vesce du foin, en particulier pour les valeurs de MAT et ADL. L'ingestibilité (g MS·kg^{-1}·P^{0,75}) a été en moyenne de 64,2 et a varié de 49,0 à 78,9. La digestibilité de la matière organique (valeur moyenne = 68,8 %) a varié de 59,9 à 72,6 %. La variabilité de la digestibilité et de l'ingestibilité a été plus faible que celle des fractions chimiques, lesquelles, à leur tour, ont eu une plus faible variabilité que celle de la composition botanique. La concentration énergétique moyenne des foins a été de 11,72 MJ d'énergie digestible par kilogramme de MS. La faible variabilité de cette valeur (CV = 5,9 %) est indicative d'un effet de compensation entre la vesce et l'avoine. La teneur en vesce du foin permet de mieux expliquer la variation de la quantité de matières azotées ingérée (r^2 = 0,63) que la variation de la quantité d'énergie digestible ingérée (r^2 = 0,37). L'obtention de foins avec une teneur minimale de 50 % de vesce peut être considérée comme un objectif de production. Ce simple critère pourrait aider aux opérations de standardisation et de marketing au niveau de la ferme.

qualité des fourrages / vesce-avoine / digestibilité / ovins / agriculture méditerranéenne

1. INTRODUCTION

In the Mediterranean basin the diversification of the dominant cereal-fallow system by rotating small grains with a non-irrigated leguminous hay crop would increase available forage to cover the seasonality of natural resources available for ruminant production [4].

Common vetch (*Vicia sativa* L.) is the annual forage legume most extensively sown in the Mediterranean basin. Its prostrate growing habit makes it advisable to intercrop vetch with oat (*Avena sativa* L.) to preclude forage rotting and harvesting difficulties. Oat acts as a support for the climbing ability of vetch. Hay producers intend to cover the summer and winter periods of forage deficit for small ruminants by feeding vetch-oat hay on its own or by combining it with small grains (mainly barley grain). Since climatic and crop conditions are variable, variation of the quality of hay can be expected and thus animal response may differ widely among hay producers. The most recent data compiled in Mediterranean conditions [1] lack quantitative intake measurements of mixed hays harvested in on-farming conditions. Animal response cannot be derived from data which is available and a standard of hay quality based on factors affecting daily production per animal is not currently available.

A sample of on-farm vetch-oat hays was selected with the aim of assessing forage quality factors. Intake of digestible energy (DE) and intake of crude protein (CP) were selected as the major indices of forage quality. The main objective of this work was to test if there was a wide difference among hays of different farms in forage quality factors and if this was related to the proportion of vetch in the hays.

2. MATERIALS AND METHODS

2.1. Study sample

Common vetch-oat hays were collected in 1991 from collaborative farmers of the Castile-La Mancha region (central plateau of the Iberian Peninsula). The vetch-oat intercrop was sown in October-November 1990, taking advantage of the first autumn rainfall and harvested as hay in May-June of the following year. The vetch and oat seeds were mixed and distributed with winter cereal seeders.

The botanical and chemical characteristics of the whole study sample (n = 32) have been previously reported [5]. Botanical composition of vetch-oat hays was determined by sampling with a core sampler. Three aliquots (approximately 100 g each) were taken from each of the four bales from each hay and combined. Vetch, oat, and adventitious species were separated by hand. Individual species were oven-dried at 80 °C for 24 h and botanical composition was expressed on a dry matter (DM) basis. The whole hay sample was divided into two subsamples (1–50 and 51–100% of vetch DM contribution), and 6 random samples were selected within each of the two subsample groups for a total of 12 samples. The cultural practices of the vetch-oat intercrop and botanical composition for these 12 hays are shown in Table I, with samples displayed in increasing order of vetch proportion in the hay.

2.2. Digestion experiments

Vetch-oat hays were chopped at 3–4 cm with a blade-cutting machine. Groups of three randomly-selected castrated male sheep were fed to each hay. The sheep belonged to the Manchega breed (1–2 year-olds and 54.8–61.7 kg body weight (BW)). The feeding period for each hay was 19 days, with intake measured over the last 10 days and digestibility over the last 7 days. Animals had continuously free access to drinking water and a mineral-vitamin block supplement (Nantasal, Nanta, Madrid, Spain). Hays were administered adjusting the forage offered to obtain 5–10% of refusal. The composition of the refusals did not provide evidence of selection. During digestibility periods, daily collection of hay forage (100 g), refusal (10% by weight), and faeces (10% by weight) were carried out. These last samples were frozen at –20 °C until analysis. After the evaluation period was completed, daily samples of forage, refusal, and faeces were mixed and homogenised and composite samples for each animal were grounded a 1 mm screen prior to chemical analysis. Previously, samples of faeces were oven dried at 60 °C for 48 h. Dry matter (DM), organic matter (OM), and crude fibre (CF) of hay forage,

Table I. Culture practices of the hay forage sample and botanical composition of hays.

Hay sample[a]	Seeding rate (kg seed·ha^{-1})		Stage of maturity at harvest[b]		Botanical composition (g·kg^{-1} DM)		
	Vetch	Oat	Vetch	Oat	Vetch	Oat	Weed
H1	75	25	MP	MG	125	874	0.5
H2	150	30	MP	MG	285	711	4.0
H3	150	30	MP	B	298	692	10
H4	150	30	MP	B	337	603	60
H5	80	20	MP	B	460	540	0
H6	90	30	FP	B	518	420	61
H7	80	20	MP	MG	553	426	21
H8	125	20	FP	MG	586	404	10
H9	100	40	B	MG	840	146	14
H10	120	15	MP	MG	882	65	52
H11	140	40	FP	MG	883	108	9.0
H12	120	16	MP	B	917	61	22

[a] The vetch-oat intercrop was sown in November, 1990 and harvested in May–June 1991.
[b] Vetch: B = Bloom; MP = Mid-Pod; FP = Full-Pod; Oat: B = Bloom; MG = Milk-Grain.

refusal and faeces were determined according to AOAC procedures [3]. Crude protein (CP) estimation was obtained by multiplying the Kjeldahl nitrogen (N) [3] by 6.25. Neutral and acid-detergent fibres (NDF and ADF), and acid-detergent lignin (ADL) were determined by methods described by Robertson and Van Soest [16]. Hemicellulose and cellulose contents were estimated as NDF-ADF and ADF-ADL, respectively. In addition, neutral and acid-detergent insoluble N (NDIN and ADIN) were determined. Analysis of forage hay were done in triplicate and those of refusal and faeces were done in duplicate. The digestible energy was calculated in the same way by determining the heat of combustion of hay feeds, refusals and faeces in a calorimeter Adiabatic bomb (IKA, C-400, Staufen, Germany). The digestible energy intake (DEI) was chosen as the main index of forage quality: DEI = Observed DM intake × DE concentration. Observed DM intake was expressed in kg DM·kg^{-1}·BW$^{0.75}$ and DE concentration in MJ DE·kg^{-1} DM.

2.3. Statistical analysis

Multivariate regression equations for nutrient digestibility were obtained by the stepwise procedure. The main indices of forage quality (intake of DE and intake of CP) were then linearly regressed on the vetch proportion of hay. All statistical analyses were performed with the Statistical Analysis System for window software, version 6.08 [18].

3. RESULTS

The chemical composition of hay samples is presented in Table II. Mean values of botanical composition (g·kg^{-1} DM) were: 557 vetch, 421 oat, and 22 weed. The

Table II. Chemical composition of the common vetch-oat hays.

Hay	DM[a]	OM	CP	CF	NDF	ADF	ADL	GE	NDIN	ADIN
	g.kg^{-1}	g·kg^{-1} DM						MJ·kg^{-1}DM	% total N	
H1	875	942	88.6	265	537	283	38.3	18.42	14.2	6.3
H2	904	877	126	316	602	342	36.3	17.20	27.7	8.6
H3	874	914	113	240	444	278	38.8	17.52	11.7	5.0
H4	874	941	102	262	515	278	28.9	18.35	19.5	5.5
H5	868	929	144	251	466	249	40.6	18.44	12.0	4.0
H6	883	916	128	245	534	324	61.2	18.00	21.9	7.2
H7	900	868	127	219	449	279	36.2	16.88	14.5	5.3
H8	807	910	102	317	562	302	46.7	17.88	14.3	7.8
H9	869	863	154	220	375	243	47.7	17.10	13.7	5.6
H10	886	915	118	310	502	314	61.3	17.78	19.6	9.0
H11	881	941	147	208	497	241	46.8	17.97	11.3	5.4
H12	889	901	167	228	351	236	55.6	17.87	10.4	5.6
Mean		910	126	256	486	279	45	17.88	15.9	6.2
CV(%)		3.1	18.2	15.6	15.0	12.5	22.2	2.93	32.8	24.2

[a] DM = dry matter; OM = organic matter; CP = crude protein; CF = crude fibre; NDF = neutral-detergent fibre; GE = gross energy; ADF = acid-detergent fibre; NDIN = neutral detergent insoluble nitrogen; ADIN = acid detergent insoluble nitrogen.

coefficient of variation of botanical components (48.6 and 65.6% for vetch and oat, respectively) showed higher values than those shown in the chemical composition. The vetch content ($g\cdot kg^{-1}$ DM) in the hay study sample varied from 125 to 917. Since most hays showed weed content lower than 25 $g\cdot kg^{-1}$ DM (Tab. I), the vetch and oat proportions were complementary ($r = 0.997$, $P < 0.001$). The vetch content may thus represent the botanical composition of each hay sample.

The lower range of variation observed for quality components than for botanical components was related to individual species composition of vetch and oat. Differences in botanical composition partially contributed to the explanation of variations of CP and fibre fractions and their components. Concentration of CP and ADL in common vetch is usually higher than in oat. Conversely, concentration of fibre fractions and their components is higher in oat than in vetch. Therefore, correlation studies show (Tab. III) that some 50% of variation in CP concentration of the study sample of vetch-oat hays can be attributed to differences in vetch proportion. Variations of fibre fractions and lignin also reflected individual species composition; but, in this case, differences in botanical composition contributed less to variations than in CP concentration. Vetch content, however, explained 69% of variation in ADL when this constituent was expressed as a proportion over ADF. Between the chemical fractions, the proportions of ADIN and specially of NDIN showed the highest relative variation. Nevertheless, both constituents were not related to the botanical composition of hays (Tab. III).

Table III. Correlation coefficients of chemical fractions upon proportion of common vetch in vetch-oat hays (n = 12).

Item	r	Probability
OM	–0.234	0.464
CP	0.702	0.011
CF	–0.275	0.387
NDF	–0.538	0.071
ADF	–0.414	0.181
ADL	0.675	0.016
HCEL	–0.498	0.099
CEL	–0.606	0.037
ADL/ADF	0.831	0.001
ADIN[1]	–0.320	0.311
NDIN[1]	0.048	0.882

[1] Expressed as % on total N.

Mean values of voluntary intake and digestibility coefficient of nutrients of the common vetch-oat study sample are presented in Table IV. Voluntary intake of individual hays ($g\ DM\cdot kg^{-1}\cdot BW^{0.75}$) varied from 49 to 79 with a mean value of 64.2. The variability between samples for digestibility coefficients was lower than that exhibited in DM intake and much less than in chemical and botanical composition. Variation between hays of digestibility coefficients of OM and gross energy (GE) was lower than that shown in individual fractions (Tab. IV).

The mean digestible energy concentration of the study sample was 11.72 MJ $DE\cdot kg^{-1}$ DM (CV = 5.9%). The gross energy digestibility (GED,%) can be estimated from the OM digestibility (OMD, %) by the equation: $GED = -1.46 + 0.975 \times OMD$ ($r^2 = 0.8$; rsd = 2.06; $P < 0.001$). Digestibility coefficients were regressed on voluntary intake and chemical component concentrations by a step-wise procedure (Tab. V). Two independent variables (CP and ADL contents) explained 52% of the variation in GED. For OM digestibility, these same variables in addition to CF content explained 61% of the total variation.

Voluntary intake of DE (DEI) and CP (CPI) were regressed on the proportion of vetch (V). The equations obtained were: DEI ($MJ\cdot kg^{-1}\cdot BW^{0.75}$) = 0.645 + 0.215 V ($r^2 = 0.37$; rsd = 0.0787, $P = 0.034$). CPI ($g\cdot kg^{-1}\cdot BW^{0.75}$) = 5.36 + 5.32 V ($r^2 = 0.64$; rsd = 1.14; $P = 0.0018$). The independent variable explained 37% of the variation in

Table IV. Voluntary intake (g·kg^{-1}·BW$^{0.75}$) and digestion coefficients (%) of nutrients in the common vetch-oat hays.

Hay	DM intake[a]	Digestion coefficients[a] OM	GE	CP	CF	NDF	ADF
H1	58.8	65.1	61.7	56.7	57.2	55.8	52.2
H2	49.0	70.5	66.9	69.6	72.4	70.3	67.9
H3	67.4	69.7	64.6	68.1	51.5	54.0	54.9
H4	67.3	72.6	69.3	62.9	65.2	66.1	57.2
H5	66.6	70.2	66.8	70.4	62.1	58.0	54.5
H6	59.0	65.1	62.3	67.1	55.1	60.0	60.7
H7	73.5	71.6	66.9	70.5	50.5	59.8	57.3
H8	62.4	59.9	57.1	57.1	51.7	50.5	40.4
H9	52.6	71.8	72.0	76.0	57.9	57.9	54.6
H10	78.9	65.9	62.9	62.0	58.9	56.2	54.5
H11	69.9	71.8	68.8	75.2	52.1	63.9	50.9
H12	65.0	71.1	68.1	77.1	53.5	50.0	49.8
Mean	64.2	68.8	65.6	67.7	57.3	58.5	54.9
CV (%)	13.2	5.7	6.2	10.2	11.5	10.3	12.1

[a] Mean values of three caged sheep.
For abbreviations see Table II.

Table V. Prediction equations of digestibility (%) of organic matter (OMD), gross energy (GED), and crude protein (CPD) of vetch-oat hays.

Equation[a]	RSD	R^2
Organic matter		
1) OMD = 84.1–0.060 CF	3.53	0.307
2) OMD = 90.0–0.058 CF–0.138 ADL	3.29	0.417
3) OMD = 71.3–0.022 CF–0.243 ADL + 0.111 CP	2.72	0.612
Gross energy		
1) GED = 51.7 + 0.110 CP	3.87	0.288
2) GED = 57.1 + 0.150 CP–0.234 ADL	3.25	0.522
Crude Protein		
1) CPD = 33.0 + 0.275 CP	3.60	0.755
2) CPD = 41.8 + 0.272 CP–0.013 IL	3.25	0.806
3) CPD = 62.2 + 0.225 CP–0.015 IL–0.051 CF	2.80	0.859

[a] All regressions are significant at $P < 0.001$. All independent variables, except IL (g DM·kg^{-1}·BW$^{0.75}$), are expressed in g·kg^{-1} DM.
IL = intake level. For other abbreviations see Table II.

voluntary intake of DE. Conversely, 64% of the variation in voluntary intake of CP can be attributed to the vetch proportion in hay. The residual standard deviation (rsd) for DE intake was equivalent to 10% of the mean (0.753), which is about what would be expected for variation among animals fed alike.

4. DISCUSSION

Production and utilisation of forage crops and their integration into profitable livestock systems is linked to the development of quality standards and predicted animal response, either as single or in mixed diets. Whole-crop hay of vetch-winter cereal mixed stands is the major special-purpose forage in the Mediterranean area [4], although there is a lack of standards for the cultivation and utilisation on the farm level. Alibes and Tisserand [1] revised the nutrition value of major Mediterranean forages but voluntary intake and nutrient concentration of specific vetch-cereal mixed stands remain unreported.

A vetch-cereal hay of 13% CP would meet most protein sheep requirements except for early weaned lambs and ewes suckling twins in the first 6-8 weeks of lactation, which is in agreement with the NRC nutrient concentration standards [14]. Mean CP concentration of our study sample (12.6%) was near this limiting value. Mean voluntary intake (64.2 g $DM \cdot kg^{-1} \cdot BW^{0.75}$) would represent 1.38 kg $DM \cdot day^{-1}$ for a 60 kg BW ewe. This level of intake furnishes 16.24 MJ $DE \cdot day^{-1}$ and 175 g $CP \cdot day^{-1}$ (Tabs. III and IV). This mean-quality common vetch-oat hay would only meet energy requirements for maintenance and would almost cover those of the first 15 weeks of gestation, in agreement with NRC standards [14]. Conversely, daily intake of CP would oversupply protein requirements in both production stages.

Taking into account the mean nutrient concentration of our study sample and considering that fibre fraction concentrations is the main limiting factor of intake [21], the following chemical ideotype ($g \cdot kg^{-1}$ DM) for vetch-oat hay forage can be proposed: NDF < 500, ADF < 300, and CP > 130. Only 33% of vetch-oat hays accomplished the three chemical criteria combined. However, when only those hays with vetch proportions over 50% were considered, the percentage of hays accomplishing the three combined criteria was 67%. Ready chemical analysis, however, is not always available to farmers specially in marketing operations at the farm level. These results illustrate that the objective of obtaining vetch-oat hay with a vetch proportion over 50% is a suitable criterion for managing cropping practices and day-to-day marketing operations.

Nutritive value of hays also depends on the composition of each botanical component, and therefore, on their stage of maturity. Individual composition of common vetch and oat under the Mediterranean environment has been reported by Rebole et al. [15] and Alzueta et al. [2]. The stage of maturity of common vetch and oat influenced the chemical composition of each component. Based on data recorded for yield components and forage quality, Caballero et al. [5] recommended harvesting common vetch during pod-filling (50% of DM content in the seed). The common vetch-oat intercrop is harvested based on the stage of maturity of the vetch component and early-maturating varieties of oat should be avoided, so that the oat component does not surpass the milk-grain stage. Competition between common vetch and oat and cultivation practices (seed ratio and seeding rates of vetch) aimed to obtain a determined vetch contribution have been reported [5].

Lower dispersion of energy or OM digestibility relative to the variation of botanical and chemical components was the result of individual chemical differences between vetch and oat. So, the two independent variables selected in the predictive equation for GED (Tab. V) represent the highest individual variation between vetch and oat. Higher vetch proportions in hays represent higher CP and ADL concentrations and higher cell contents. Since both the effects of CP or cell contents and ADL are set against each other, the net result is a lower variation of OM and energy digestibility in a sample that showed higher variation of chemical components and a much higher botanical composition. Moreover, digestibility determinations were carried out at a voluntary intake level, which contribute to reduce their variability, since forage characteristics that could increase digestibility also have a positive effect on voluntary intake, which in turn reduces the digestibility values [8]. Our results also suggest that in an on-farm low-homogeneous study sample, lignin turned out to be a good predictor of digestion coefficients as indicated by regression between "in vivo" data and chemical composition, although its main effect was over cell wall digestibility [20]. The results of other works [10, 11] show similar conclusions.

The relationship observed between CPD and CP content is due in part to the reduction of the proportion of endogenous faecal CP with increasing CP intake. Also, the positive and negative effects on CP digestibility observed, respectively, for CP and CF contents (Tab. V) were in agreement with correlation studies between rumen degradability of CP and chemical composition, presented in the second part of this study [9], in which we also observed that nitrogenous components of these hays were mainly digested in the rumen.

Minson and Wilson [13] indicated that voluntary intake of forages can be related to many forage attributes but a significant correlation only indicates a potential factor controlling the intake that can be intercorrelated with some digestion characteristics. Higher cell wall content has been traditionally correlated with lower intake [19] because this chemical attribute is linked to higher ruminal retention time [12]. In our study sample, the presence of two individual species (common vetch and oat) with different physical and chemical attributes makes it difficult to discriminate any single forage attribute that may influence intake. In any case, our results illustrate that voluntary intake of digestible energy and, even more so, the voluntary intake of CP are positively related to vetch proportion in hays. A lower cell wall concentration in common vetch than in oat may indicate a lower ruminal retention time [17] and a corresponding higher voluntary intake. On the contrary, the lower ruminal retention time reported for vetch by this author, was derived from the reduction of the time required for forage breakdown. This in turn is one of the main factors determining voluntary intake [7]. Also, voluntary intake of hays is improved by increased degradation rate of hay DM [6], which in turn shows a close correlation with vetch proportion in hay [9].

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