Chemical composition, organic matter digestibility and gas production of nine legume grains

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Abstract

Nine legume grains (*Pisum sativum*, *Cicer arietinum*, *Vicia sativa*, *Vicia faba*, *Lathyrus ochrus*, *Lathyrus cicera*, *Lupinus angustifolius* and *Lupinus luteus*) were studied with respect to their chemical composition, organic matter digestibility (OMD) and digestible energy (DE) using rams in metabolic cages. Gas production by grains was evaluated using rumen inoculum. The majority of these legume grains showed values of: crude protein (CP) — 21 to 24%, ether extract (EE) — 1.5 to 5%, neutral detergent fibre (NDF) — 15 to 22%, acid detergent fibre (ADF) — 6 to 13%, starch — 30 to 40%, OMD — 90 to 92%, DE — 16 to 17 MJ kg⁻¹ dry matter (DM) and gas production (48 h) of 110 to 145 ml g⁻¹ DM. *Lupinus* however showed much higher values of CP (29.1% and 34.4%), NDF (26.9% and 28.6%), ADF (22.9% and 24.6%), EE (5.4% and 7.2%) and lower values of starch about 0.8%, OMD (83.6% and 86.0%) and gas production (95.9 and 104.6 ml g⁻¹ DM). Gas production (48 h) was negatively correlated to CP ($r = -0.74$; $P < 0.05$), NDF ($r = -0.93$; $P < 0.001$), ADF ($r = -0.78$; $P < 0.01$), positively with starch ($r = 0.70$; $P < 0.05$) and positively with OMD ($r = 0.68$; $P < 0.05$). Gas production in this type of feed was not shown to be a good criterion for assessing their OMD. © 1998 Elsevier Science B.V.

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1. Introduction

Mediterranean legume grains have a considerable role as protein suppliers in animal diets.

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However, since the late 1960s, their importance has been reduced due mainly to the use of oleaginous meals, mostly soybean which have been available at competitive prices.

As a consequence, an important reduction in legume grain cultivation was noted (Cubero, 1983). This was due to a lack of genetic and technological improvement. This seems to have happened also in other countries in South Europe (Duffus and Duffus, 1991).

In order to reduce the dependence of Europe in imported legume grains as protein sources for animals, the EU has initiated some production incentive policies (Todorov, 1988; Chominot, 1992).

Within the few researchers who have studied the nutritive value of mediterranean legume grains, special reference must be made to the work of Wiseman and Cole (1988) with pigs and Castanon and Perez-Lanzac (1990) with layer hens, and of Hadji-panayiotou et al. (1985) with sheep, pointed to the possibility of using these grains in animal diets, although in limited amounts.

In this study we used varieties of legume plants well adapted to the conditions of our country and considered of interest for animal nutrition for feeding grazing during the summer months (when in our conditions pasture gets scarce and poor).

The aim of the work presented was: (i) to evaluate the nutritive value of nine legume grains, growing in identical conditions, using rams in metabolic cages and (ii) to compare two different approaches, chemical composition and gas production (Menke et al., 1979), in estimating the nutritive value.

2. Material and methods

2.1. Feeds and analysis

Nine legume grains (selected lines) were studied: 1. (*Ps*) — Pea (*Pisum sativum* L.) cv. Gp 950; 2. (*Caw*) — White chick pea (*Cicer arietinum* L.) cv. Ch K283; 3. (*Cab*) — Black chick pea (*Cicer arietinum* L.) cv. Ch D 323; 4. (*Vs*) — Vetch (*Vicia sativa* L.) cv. do Caia; 5. (*Vf*) — Horse bean (*Vicia faba* L. vsr. minor) cv. Beja; 6. (*Lo*) — Cyprus vetch (*Lathyrus ochrus* (L.) DC.) cv. LAT 8290; 7. (*Lc*) — Red vetchling (*Lathyrus cicera* L.) cv. da Gramicha; 8. (*La*) — Blue lupin (*Lupinus angustifolius* L.) cv. Ilyarrie e 9. (*Li*) — Yellow lupin (*Lupinus luteus* L.) cv. Cardiga.

The grains were obtained in the National Plant Breeding Station in Elvas (south of Portugal), in dry farming conditions (600 mm rainfall) and clay soils. The selected lines were obtained in the same field and technological (screening, calibration, etc.) conditions. Representative amounts of each variety were taken. Chemical composition were assessed using two samples from each legume grain and the results shown are the corresponding means. They were analysed for ash, crude protein (CP), ether extract (EE) and crude fibre (CF) according to Association of Official Analytical Chemists (1980), water insoluble cell walls (WICW) according to Carré and Brillouet (1989) and neutral detergent fibre (NDF), acid detergent fibre (ADF) and acid detergent lignin (ADL)

according to Robertson and Van Soest (1981). The starch content was determined according to Thivend et al. (1965), the total sugars according to NP (1986) and gross energy (GE) in a calorimeter bomb (Parr 1261).

2.2. *In vivo* digestibility

The grains were mixed with barley straw and given to caged rams. The organic matter digestibility (OMD) and gross energy digestibility (GED) of each mixture (diet) were determined. OMD and GED of each legume grain were calculated by the indirect method as described by Lloyd et al. (1978). The digestibilities of the barley straw (OMD = 44.0%; GED = 45.1%) were previously determined using eight caged rams. The straw was chopped, supplemented with nitrogen and mineral and given to the rams.

Grains were broken using a mill of 5 mm round holes — so as to obtain practically no particles smaller than 1 mm.

Three groups of four Merino rams each time, each legume grain to each group, 50 kg average liveweight, in metabolic cages were used. Each animal received 200 g of chopped barley straw and 600 g of a particular legume grain by day in two identical meals, at 0830 and 1630 h.

Animals were restricted fed. The total absence of residues was checked. Animals were kept in identical environmental conditions in all trials.

The amounts of legume grains that were eaten by the animals in each trial did not apparently cause any troubles in their health.

The body condition (Jefferies, 1961; Frutos et al., 1995) of the rams stayed practically at 3.5 during the trials. The rams liveweights stayed practically at the same level during each trial period (25 days).

The OMD and GED of each diet were calculated per day and per animal, during 10-day data collecting periods. A 15-day period of adaptation was used.

Faeces were totally collected every 24 h during the trial period, dried in a forced ventilation oven at 65°C, and milled (1 mm mesh) for analyses.

GE, dry matter (DM) and ash were determined in grains, faeces and barley straw in each period; faeces determination were carried out per animal and collecting period.

2.3. Gas production

Three rumen cannulated rams (55 kg average liveweight) were used, each receiving 700 g of (*Avena sativa* — *Vicia sativa*) hay and 300 g of a concentrate (50% barley grain, 25% soybean meal, 21% soybean hulls and 4% minerals and vitamins) meal in two identical meals, at 0830 and 1630 h. The chemical composition of the feeds was: hay CP = 8.7%; ADF = 44.1%; concentrate CP = 32.6%; ADF = 20.0%.

The gas volume produced by the grains was evaluated using the Menke technique (Menke et al., 1979).

The grains were milled to pass a 1 mm mesh and a sample of about 200 mg of DM was used. The volume of gas was measured at 2, 4, 6, 8, 12, 24, 30 and 48 h after initiation of incubation. There were six measurements for each sampling period (3 tubes per hour of collection × 2 trial replicates).

2.4. Statistic

Data on OMD and GED and data on gas volume produced in 24, 30 and 48 h were subjected respectively to ANOVA II and ANOVA I tests, using the Duncan test for comparison of averages (Duncan, 1955).

Among the variables studied (chemical composition and OMD), a stepwise analysis was used to determine which among them best explained the variations in gas production.

Multiple linear regression analysis were used to verify the variable that best explains the variations in OMD.

3. Results

3.1. Chemical composition and gross energy

Table 1 gives the chemical composition and GE of the proteaginous grains.

Lupinus excepted the CP of most grains showed values between 21 and 24%. The high values of CP, characteristic of lupinus (about 30% or higher) may be partially due to the lower starch level (Elkowicz and Sosulski, 1982); the observed values were, as a rule, slightly lower than those given in the literature (MAPA, 1984; INRA, 1988, Castanon and Perez-Lanzac, 1990). The varieties used (Wiseman and Cole, 1988), the sites and growth conditions (Holl and Vose, 1980), may be responsible for the observed results.

The higher values of EE were found in (*Caw*), (*Cab*) and in lupinus, especially in (*La*), with 7.2%.

The values of cell walls, represented by NDF, varied between 10.9% in (*Caw*) to 28.6% in (*Li*), and the corresponding values of ADF were 5.8% and 24.6%. The WICW varied between 11.0% and 38.0%

As to starch, most proteaginous showed values between 38 and 46% except the lupinus which gave the lowest values of about 0.8%. INRA (1984) and Abreu et al.

Table 1
Chemical composition of legume grains (% DM)

Legume grains	Ash	CP	EE	CF	NDF	ADF	ADL	WICW	Starch	Total sugars ^a
Pea	3.3	21.0	1.7	7.2	14.6	8.1	1.1	17.1	45.3	3.7
White chick pea	3.0	21.5	5.2	3.9	10.9	5.8	1.3	11.0	46.0	2.4
Black chick pea	2.7	20.5	4.3	9.1	16.9	12.1	2.2	19.2	38.2	1.3
Vetch	3.4	23.0	1.9	5.0	21.7	7.5	0.9	13.5	43.5	1.7
Cyprus vetch	3.5	20.9	1.5	7.7	20.8	10.9	0.5	16.8	38.3	2.3
Red vetchling	2.9	21.7	1.4	7.3	22.1	10.7	0.6	16.9	44.2	1.5
Horse bean	3.8	23.7	1.4	10.0	20.2	13.1	2.4	17.2	40.0	1.9
Blue lupin	2.6	29.1	7.2	16.1	26.9	22.9	2.8	38.0	0.8	4.5
Yellow lupin	3.6	34.4	5.4	20.2	28.6	24.6	2.8	35.3	0.7	4.1

^aExpress as saccharose.

Table 2

Gross energy (GE), organic matter digestibility (OMD) and digestible energy (DE) of legume grains

Legume grains	GE (MJ kg ⁻¹ DM)	OMD (%)	DE (MJ kg ⁻¹ DM)
Pea	18.4	91.1 a	16.5 ab
White chick pea	19.3	92.1 a	17.6 a
Black chick pea	19.0	90.2 a	16.9 ab
Vetch	18.3	90.5 a	16.3 ab
Cyprus vetch	18.0	91.5 a	16.1 b
Red vetchling	18.4	90.0 a	16.2 ab
Horse bean	18.1	91.7 a	16.3 ab
Blue lupin	20.1	86.0 b	16.5 ab
Yellow lupin	20.0	83.6 b	16.9 ab

Values in the same columns followed by different letters are significantly different ($P < 0.05$).

(1992) showed starch values (acid hydrolysis) of around 42% for (*Ps*) and (*Lc*), respectively. In turn Daveby and Aman (1993) have found values for (*Vf*) between 40 and 45%.

The soluble sugars ranged between 1.3 and 4.5%, the lower value corresponding to (*Cab*) and the higher to (*La*). Values of the order of 1.5% to 2.2% were observed by Abreu et al. (1992) and INRA (1984) for the grains (*Lc*) and (*Ps*), respectively.

GE varied between 18.0 and 20.1 MJ kg⁻¹ DM, lupinus showing the highest values due, probably, to their higher contents of EE.

3.2. Digestibilities and digestible energy

Table 2 gives in vivo OMD and digestible energy (DE) of legume grains. OMD values ranged between 90 and 92%. Exceptions were the lupinus whose values (83.6% and 86.0%) were significantly lower.

Hadjipanayiotou et al. (1985) obtained slightly lower values than ours for (*Lo*), (*Vf*) and (*Caw*), probably due to the higher feeding levels adopted. Values in the order of 90% and 87% for (*Ps*) and (*Vs*) were referred by INRA (1988).

Table 3

Gas production for different legume grains (ml g⁻¹ DM)

Legume grains	Incubation time (h)							
	2	4	6	8	12	24	30	48
Pea	22.8	28.0	47.0	63.4	102.2	135.9	142.3	146.7 a
White chick pea	16.8	22.6	36.6	61.0	102.2	131.2	135.7	139.6 ab
Black chick pea	15.6	22.0	37.5	56.0	94.6	118.3	126.0	131.3 abc
Vetch	23.8	31.2	35.9	49.8	72.6	113.9	119.0	119.9 bcd
Cyprus vetch	24.0	33.5	36.5	51.0	66.0	104.5	109.8	115.9 cde
Red vetchling	24.0	34.4	36.9	49.8	73.1	106.8	109.7	112.0 cde
Horse bean	19.8	29.8	34.1	43.2	71.1	99.8	106.6	110.2 de
Blue lupin	18.0	22.2	32.4	54.1	75.2	100.7	102.8	104.6 de
Yellow lupin	13.8	25.5	33.0	46.4	59.7	87.2	92.0	95.9

Values in the same columns followed by different letters are significantly different ($P < 0.05$).

Fig. 1. Evolution of gas production for different legume grains.

DE was slightly different between grains (16.1–17.6 MJ kg⁻¹ DM) influenced probably by the levels of fat (EE) and fibre (NDF, WICW) in these feeds.

3.3. Gas production

Table 3 shows gas production for different grains under different periods of incubation. The data obtained 24, 30 and 48 h apart from (*Lo*) did not show significant differences between themselves.

However, during the first hours of incubation (2 and 4 h) the values observed were somewhat overlapping, making comparison difficult (Fig. 1).

At 48 h, gas production varied between 95.9 and 146.7 ml g⁻¹ DM, the lower value being for (*Li*) and the higher for (*Ps*).

4. Discussion

4.1. Chemical composition

Starch values showed negative correlations with CP values ($P < 0.001$) and in a lesser extent (not significant) with EE values. This may be the result of the substitution of starch for fat as energy stored in legume grains. In fact Daveby and Aman (1993) showed that in these feeds the major components are CP, starch and/or crude fat.

Values of ADF/NDF ≤ 0.55 were found in (*Caw*), (*Vs*), (*Lc*) and (*Lo*) whereas those in lupinus were ≥ 0.85 . This is a consequence of the high hemicelluloses content of the cell walls in lupinus.

ADL/NDF values of 0.12 or higher were obtained in chick peas and in (Vf), but values of 0.04 or below were obtained only with (Vs), (Lo) and (Lc). This is a consequence of the differences between grains according to lignin (ADL) levels. Values of 0.72 and 0.09 were observed by Bruno-Soares et al. (1996) in the lupinus (Ll) for the ratios ADF/NDF and ADL/NDF, respectively.

The importance of the WICW, in legume grains, derives from the presence of significant amounts of pectic substances in these grains (Carré and Brillouet, 1986), in particular in lupinus (Table 1). As it is known, these substances are not included in NDF fraction although being part of the plant cell walls (Van Soest, 1982).

4.2. Gas production

Gas production in the first hours of incubation does not allow the discrimination of the legume grains, as shown in Fig. 1. However, negative correlations could be observed with ADL, possibly through the adverse effects of lignin on microbial activity fermentation (Van Soest, 1982; Jung and Fahey, 1983), particularly in the initial phases of fermentation. In fact, during the first hours of incubation, ADL alone explains about 62% of the variation in gas production ($Y = 25.5 - 3.5 \text{ ADL}$; $P < 0.01$).

In the final stage of incubation at 48 h, NDF becomes the best single predictor of gas production ($Y = 175.7 - 2.8 \text{ NDF}$; $r^2 = 0.84$; $P < 0.001$). Pell and Schofield (1993) observed that the degradation of NDF was directly related with the increase of gas production after the first hours of incubation.

The correlations between gas production (48 h) and DE, although positive, were not significant, which reflects, in these feeds, the importance of GE in determining the DE.

Positive but weak correlations were, however found between gas production and the OMD ($r = 0.69$; $P < 0.05$), possibly due to the variation in the organic matter composition of these feeds.

The negative correlations between gas production (48 h) and CP ($P < 0.05$), NDF ($P < 0.001$) and ADF ($P < 0.01$) may be a result of the reduction of microbial activity, from increasingly adverse environmental conditions as incubation time progresses. The antinutrient substances (ANF) present in these feeds may also contribute to the reduction of the microbial activity (Wood and Plumb, 1995).

The positive correlation found between gas production at 48 h and starch ($P < 0.05$), may be a consequence of its easy degradation.

4.3. Organic matter digestibility

The differences in OMD of legume grains reflect differences in their chemical composition namely in relation to levels of CP ($P < 0.001$), ADF ($P < 0.001$) and starch ($P < 0.001$), with lupinus showing significantly lower values. The presence of ANF substances also may affect the OMD of these feeds (Duffus and Duffus, 1991; Saini et al., 1993).

The variation of the OMD may be explained in 86% by the CP ($\text{OMD} = 103.4 - 0.57 \text{ CP}$) and in 87% by the starch content ($\text{OMD} = 84.8 + 0.15 \text{ starch}$).

Otherwise, gas production (48 h) only explains about 40% of the total OMD variation, which is very few if compared with the values given by Menke and Steingass

(1988) for concentrate feeds (about 72%). As suggested by Menke and Steingass (1988), the estimation of OMD is improved when the CP ($r^2 = 0.83$) or the starch content ($r^2 = 0.85$) is added to the volume of gas production in 48 h ($\text{OMD} = 103.7 - 0.0018 \text{ gas} - 0.58 \text{ CP}$; $P \leq 0.001$ and $\text{OMD} = 83.9 + 0.0087 \text{ gas} + 0.14 \text{ starch}$; $P \leq 0.001$, respectively).

5. Conclusions

Gas production in itself was therefore not enough to assess OMD of legume grains.

The variables of chemical composition, namely CP, ADF and starch, were shown to be the best single predictors of OMD.

The accuracy of the estimates of OMD was not improved with the inclusion of the gas production in multiple regression equations based on chemical parameters.

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