Faba beans as a feed for cattle and sheep

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Categories

Faba bean is a free-standing, upright annual legume crop that is sown in winter or spring and, even though primarily grown for its edible seeds (beans), it can also be used as a whole-crop.

Faba beans (*Vicia faba* L.) cover a wide range in the size and shape of their seeds (i.e. beans). Those with the largest (and flatter) seeds (*Vicia faba* var. *major*) are called broad beans (fava beans in USA) and are cultivated as a vegetable for human consumption. They are generally harvested while still immature, and typically have a 1000 seed weight of over *ca.* 800 g. Those used as an animal feed in Ireland are smaller and rounder than broad beans and are interchangeably referred to as field, horse or tic beans. More strictly, intermediate-sized seeds (*Vicia faba* var. *equina*) are horse beans (*ca.* 500-800 g/1000 seeds) and the smaller-sized seeds (*Vicia faba* L., var. *minor*) are tic beans (*ca.* <500 g/1000 seeds).

Beans (seeds) **as a feed**

The beans are an excellent source of both protein and energy for ruminants, as shown in Table 1. INRA quoted protein and energy values for faba beans are presented in Table 2. For comparative purposes, both tables show the corresponding values for barley grain, soyabean meal and pea seed.

Table 1. Average and range in chemical composition of faba bean seeds (beans) and, for comparison, average values for barley grain, soyabean meal and pea seed

Constituent	Units	Faba bean		Barley grain	Soyabean meal	Pea seed
		Average	Min.-Max.			
Primary characterisation						
Dry matter (DM)	g/kg	866	834-898	871	879	865
Crude protein	g/kg DM	290	252-335	118	518	239
Neutral detergent fibre (NDF)	g/kg DM	159	124-221	217	137	142
Acid detergent fibre (ADF)	g/kg DM	107	85-128	64	83	70
Ether extract (i.e. fat)	g/kg DM	14	9-21	20	20	12
Starch	g/kg DM	447	398-485	597	-	513
Sugar	g/kg DM	36	25-57	28	94	49
Ash	g/kg DM	39	33-46	26	71	35
Organic matter digestibility	g/kg	911	872-963	832	919	921
Gross energy	MJ/kg DM	18.7	18.2-18.9	18.4	19.7	18.3
Digestible energy	MJ/kg DM	16.8	15.0-16.8	14.8	18.2	16.5
Metabolisable energy	MJ/kg DM	13.3	12.5-14.5	12.4	13.6	13.4
N degradability (effective, k=4%)	%	80	64-92	76	72	64
Minerals						
Calcium	g/kg DM	1.5	0.8-2.7	0.8	3.9	1.2
Phosphorus	g/kg DM	5.5	4.4-6.8	3.9	6.9	4.5
Potassium	g/kg DM	11.5	9.5-14.5	5.7	23.7	11.3
Sodium	g/kg DM	0.1	0-0.5	0.1	0.1	0
Magnesium	g/kg DM	1.8	1.1-2.3	1.3	3.1	1.7
Manganese	mg/kg DM	10	6-20	19	45	10
Zinc	mg/kg DM	34	20-47	30	54	37
Copper	mg/kg DM	13	4-18	12	18	8
Iron	mg/kg DM	75	55-90	184	346	107
Amino acids						
Cystine	g/kg protein	12	10-15	22	15	14
Lysine	g/kg protein	62	54-68	37	61	72
Methionine	g/kg protein	8	6-10	17	14	10
Secondary metabolites						
Tannin	g/kg DM	6.5	0.9-12.4	0.8	6.9	0.7
Condensed tannin	g/kg DM	4.8	0.1-11.3	-	-	0.1

Source: http://www.feedipedia.org/node/4926

Table 2. INRA quoted protein and energy values for faba beans

	Faba beans	Barley grain	Soyabean meal	Pea seed
Crude protein (g/kg DM)	302	116	539	240
PDIA (g/kg DM)	52	35	212	34
PDIN (g/kg DM)	192	80	395	150
PDIE (g/kg DM)	112	100	272	96
UFL (per kg DM)	1.20	1.10	1.21	1.20
UFV (per kg DM)	1.20	1.07	1.21	1.22
OMd%	91	83	93	92
ME (MJ/kg DM)	13.4	12.3	13.6	13.4

Source: Sauvant *et al.* (2004). DM: Dry matter; PDIA: Digestible proteins in the intestine of dietary origin; PDIN: Digestible protein in the intestine where nitrogen is the limiting factor for rumen microbial activity; PDIE: Digestible protein in the intestine where energy is the limiting factor for rumen microbial activity; UFL: Forage unit for milk production; UFV: Forage unit for meat production; OMd: Organic matter digestibility; ME: Metabolisable energy.

The **protein** is extensively and rapidly degradable in the rumen and protein not degraded in the rumen should be accessible later in the intestinal tract (Ramos-Morales *et al.,* 2010). The very soluble nature of the protein in faba beans that makes them easily degraded in the rumen will provide a pulse of nitrogenous substrate for rumen microbes, and diets need to be formulated to best harness this supply to provide essential amino acids for the ruminant itself. Some heat treatments of beans can increase the proportion of protein that by-passes digestion in the rumen, but there is much variability in this effect and ultimately in how heat treatments affect animal performance (Yu *et al.*, 2004). Thus, heat treatments need to be precisely tailored to the characteristics of the feedstuff to which they are applied. Faba beans have been successfully used as a replacement for soyabean meal in dairy cow and sheep rations – animals offered soyabean meal or faba beans within appropriately balanced diets had similar feed intakes, milk yields, milk composition, growth rates and carcass composition (Crepon *et al.*, 2010; Tufarelli *et al*., 2012). However, compared to cereals, the content of lysine is relatively high and the contents of the sulphur-containing amino acids cysteine and methionine are low (Crepon *et al.*, 2010).

The **energy** value of faba beans is at least as good as cereal grains such as barley. They have a high content of starch, some of which can bypass the rumen and be digested at a later stage of the digestive tract. Their content of fibre is relatively low, with much of it being in the hull (seed coat). Oil concentration is also low, but the oil that is present has a high content of linoleic and linolenic acids (Table 1).

Some level of **processing** is required to ensure adequate digestion of the protein and starch within the beans. This processing can be by rolling/cracking, coarse grinding or more intensive processing such as micronizing (infrared heating), extrusion, steaming, autoclaving, etc., or dehulling, flaking, soaking, germinating, etc. Some of these processes can reduce the activity of anti-nutritional factors in the beans or contribute to repartitioning some of the protein and/or starch digestion from the rumen to later in the gastro-intestinal tract (Crepon *et al.*, 2010).

Faba beans are usually quite **palatable** for ruminants. It is important, however, to prevent mould growth occurring on processed beans or rancidity occurring in finely ground beans as these will, at a minimum, reduce palatability. This prevention can be facilitated by having the beans sufficiently dry during storage and, if grinding them finely, to do so in batches that will be consumed within a relatively short period of time.

A range of **secondary metabolites** have been identified in faba beans, some of which have anti-nutritional effects in animals. Tannins, including condensed tannins, are the most studied of these compounds and in faba beans they are located mainly in the hull. The presence of some tannins with faba beans can protect protein from degradation in the rumen but allow it be subsequently digested post-ruminally (Martinez *et al.*, 2010). They can also have beneficial effects in reducing bloat and enteric methane, and in providing an anthelminthic effect. However, high concentrations of some tannins can reduce feed intake and thus animal performance (Butter *et al.*, 1999). As a general rule, white-flowered varieties tend to have a lower concentration of tannin than coloured flower varieties (Jansman, 1993), and varieties with a high tannin content that are grown in Europe usually have a relatively large black spot on their wing flower petals (Crepon *et al.*, 2010). Other secondary metabolites identified in faba beans include pyrimidine glycosides (e.g. vicine and convicine), protease/trypsin inhibitors, lectins, flatulent oligosaccharides, gallic acid and phytic acid (Dvorak *et al.*, 2006; Duc *et al.*, 2011). Anti-nutritional substances in faba beans are not currently considered problematic for fully-developed ruminants (Melicharová *et al.*, 2009).

Faba beans are generally low in calcium, manganese and iron, but have an adequate content of phosphorus.

Conserving high moisture faba beans by ensilage

Faba beans are normally stored dry and, prior to feeding to ruminants, they are processed by cracking, rolling, coarse grinding or steam flaking. Grains with a moisture content higher than optimal for extended storage can be aerobically stored following artificial drying or treatment with agents such as propionic acid or ammonia that inhibit aerobic microbial activity. An option for beans of even higher moisture content is to ensile them with or without physical processing pre-ensiling, and the opportunity exists to manipulate the ensilage process by treating the harvested grains with additives that restrict or enhance fermentation.

An experiment was undertaken to assess the effects of crimping and additive treatment of faba beans, harvested at a high moisture content and then ensiled, on their subsequent chemical composition, in-silo loss and aerobic stability characteristics (O'Kiely *et al.*, 2014).

The crop had a yield of 4.9 tonnes beans/ha, and whole or crimped faba beans (751 g dry matter (DM)/kg) were ensiled for 160 d either without additive or following the application of acid, urea, *Lactobacillus buchneri* or *Lactobacillus plantarum* plus *Pediococcus pentosaceus* based additives. The average composition of the beans at ensiling was crude protein 255 g/kg DM, *in vitro* DM digestibility (DMD) 804 g/kg, ash 35 g/kg DM, starch 335 g/kg DM, water-soluble carbohydrates 130 g/kg DM and buffering capacity 209 mEq/kg DM.

The beans conserved successfully, undergoing limited fermentation and in-silo losses, and were aerobically relatively stable during feedout (Table 3). Each additive had its unique influence with no single additive improving all traits.

Table 3. Conservation characteristics of ensiled high moisture crimped faba beans

Additive	None	Acid	Urea	Bacteria[1]	Bacteria[2]
Dry matter (g/kg)	729	721	694	687	722
DM digestibility (g/kg)	813	805	809	794	805
Starch (g/kg DM)	340	323	319	343	340
Crude protein (g/kg DM)	289	286	328	295	288
Sugars (g/kg DM)	75	94	81	60	69
pH	5.9	5.9	8.9	4.9	5.2
Fermentation products (g/kg DM)	17	12	12	39	23
Ammonia-N (g/kg N)	3	3	24	11	5
In-silo losses (g DM/kg DM)	38	44	101	98	56
Aerobic stability (days)	4	3	7	10	3

Source: O'Kiely *et al.* (2014) [1]Heterofermentative; [2]Homofermentative; DM: Dry matter

The evidence from this study is that faba beans harvested at a high moisture content can be efficiently conserved by ensilage, resulting in retention of nutritive value and minimal quantitative losses. It would be essential, however, to minimise the duration of access of the ensiled beans to air during feedout. This would require good compaction of crimped beans at ensiling and a rapid rate of progress through the feed face during feedout.

These Irish results are supported by the findings from Germany (Gefrom *et al.*, 2012). The latter authors also found that the lactic acid fermentation during ensilage was associated with a marked reduction in the content of particular oligosaccharides (raffinose, stachyose and verbascose), non-tannin and tannin phenols, and condensed tannins.

Ensiling whole-crop faba bean

Faba bean can be harvested as a whole-crop and ensiled – the whole-crop includes all parts of the plant above a 6-10 cm stubble. Whole-crop yields of 9-10 tonnes DM/ha have been reported (Faulkner, 1985; Caballero, 1989; Louw, 2009) but yields from 3-8 tonnes DM/ha were also reported (McKnight *et al.*, 1977; Caballero, 1989; Fraser *et al.*, 2001; Borreani *et al.*, 2009; Louw, 2009). Whole-crop DM yield increases rapidly as the faba bean crop advances through its growth stages, as shown in Table 4 for a crop in Wales that was harvested after 10 (first pod set), 12 (pods fully formed) and 14 (pod fill) weeks since sowing (29 April) (Fraser *et al.*, 2001). Similar patterns have been reported by Louw (2009) in South Africa.

Table 4. Yield, morphological composition and chemical composition of whole-crop faba bean at harvest

Harvest time post-sowing	DM yield (t/ha)	DM (g/kg)	Crude protein (g/kg DM)	NDF (g/kg DM)	Starch (g/kg DM)	WSC (g/kg DM)	Buffering capacity (mEq/kg DM)	% of DM yield		
								Leaf	Stem	Pod
10 weeks	3.70	121	213	375	45	88	392	48	52	0
12 weeks	5.17	135	187	372	73	104	345	33	52	15
14 weeks	7.76	153	180	376	64	97	341	22	45	33

Source: Fraser *et al.* (2001). DM: Dry matter; NDF: Neutral detergent fibre; WSC: Water-soluble carbohydrate

The contribution of different plant parts to whole-crop yield changes as the faba bean crop advances through its growth stages. This change is primarily a replacement of the % leaf in particular, and % stem to a lesser extent, by pods (Table 4). Comparable results by Caballero (1989) indicate that the increase in yield of pods is much more an increase in beans than pod-shells.

Whole-crop faba bean usually has relatively low DM and water-soluble carbohydrate (WSC) concentrations and a sometimes a relatively high buffering capacity (Tables 4 and 5). These indices indicate a crop that can be difficult to preserve satisfactorily. As shown in Table 5, satisfactory lactic acid dominant fermentations can sometimes occur (in both of these cases the crop was wilted prior to ensiling) but alternatively clostridial fermentations with high ammonia-N and/or butyric acid concentrations also occur. For these reasons, whole-crop faba bean crops require effective wilting and/or treatment with an additive (or co-ensilage with an easy-to-preserve crop) that will secure a lactic acid dominant fermentation (Pursiainen *et al*., 2008; Borreani *et al*., 2009) In addition, it is important that the crop be harvested and ensiled free of soil contamination.

Table 5. Composition of whole-crop faba bean pre- and post-ensilage

Source	Fraser *et al.* (2001)*		Mustafa *et al.* (2003)**		Pursiainen *et al.* (2008)		Borreani *et al.* (2009)	
Relative to ensiling	Pre-	Post-	Pre-	Post-	Pre-	Post-	Pre-	Post-
DM (g/kg)	196	188	258	261	155	147	237	199
Crude protein (g/kg DM)	196	204	200	222	179		197	208
WSC (g/kg DM)	104	12	48	7	93	39		
Starch (g/kg DM)	33	41	29	44	185			
NDF (g/kg DM)	419	429	457	428	361		329	
Ash (g/kg DM)			106	106	75		85	139
BC (mEq/kg DM)					588			
pH		3.8		3.8		4.2		5.5
Ammonia-N (g/kg N)		77				100		172
Lactic acid (g/kg DM)		100		50		97		25
Acetic acid (g/kg DM)		14				20		29
Butyric acid (g/kg DM)		0				16		72

DM: Dry matter; WSC: Water-soluble carbohydrate; NDF: Neutral detergent fibre; BC: Buffering capacity; *After use of crimper mower followed by 2-day wilt in windrows; **Chopped and field wilted.

The generally low DM concentration of whole-crop faba bean crops means that when they are ensiled very large volumes of effluent will be produced (>250 L/tonne crop). Although wilting is an obvious solution to overcome this loss, excellent drying conditions are needed to create an effective wilt (Borreani *et al*., 2009) and the substantial square stems on the crop can result in negligible drying sometimes occurring even after 2 days 'wilting' (Fraser *et al*., 2001).

Silages made from whole-crop faba bean are usually relatively stable (slow to hear or become mouldy) when exposed to air during feedout (Pursiainen *et al*., 2008). This agrees with the general finding that legumes tend to produce silages that are aerobically more stable than whole-crop cereals such as maize (O'Kiely *et al.*, 1992). However, management during feedout needs to continuously prevent conditions that cause aerobic deterioration of silage.

Whole-crop faba bean silages have a high crude protein concentration (Faulkner, 1985; Caballero, 1989; Louw, 2009; Table 4; Table 5) which is highly soluble and degradable (Mustafa *et al.*, 2003). This can lead to relatively high amounts of nitrogen excretion in urine compared to in faeces when such silage is fed alone (Fraser *et al.*, 2001). The energy content of whole-crop faba bean silages is variable, with cited DMD values of 652-684 g/kg (Caballero, 1989), effective DM degradability of 662 g/kg (Mustafa *et al*. 2003), digestible organic matter in the dry matter (DOMD) of 630 g/kg DM (Fraser *et al.*, 2001) and organic matter digestibility (OMD; at harvesting) of 743 g/kg (Pursiainen *et al*., 2008). Ruminal degradability of DM, neutral detergent fibre (NDF) and crude protein decline as faba bean crops become progressively more mature (Louw, 2009). Intakes have been found to be comparable to those for forage pea silage (Fraser *et al.*, 2001) and higher than for grass-legume silage (McKnight *et al.*, 1977). Cows fed whole-crop faba bean silage produced as much milk of similar protein and total solids contents as when grass-legume silage was fed (McKnight *et al.*, 1977).

INRA quoted energy, protein and fill values for fresh and ensiled whole-crop faba bean are presented in Table 6 (Jarrige, 1989).

The recommendation from Scotland is that crops of whole-crop faba bean should be harvested "when pods are fully formed and the beans are pliable with a rubbery texture" (Baddeley *et al.*, 2014).

Table 6. Energy, protein and fill values for fresh and ensiled whole-crop faba bean

	Net energy (/kg DM)		Protein value (g/kg DM)			Fill value(/kg DM)			C.protein (g/kg DM)
	UFL	UFV	PDIA	PDIN	PDIE	SFU	LFU	CFU	
Fresh whole-crop									
Flowering	0.87	0.81	39	109	92	0.78	0.90	0.83	174
Pod setting	0.87	0.81	38	105	90	0.83	0.92	0.87	167
Firm seeds	0.89	0.83	33	92	88	0.89	0.95	0.91	146
Beginning of seed maturity	0.88	0.82	28	79	84	0.95	0.98	0.96	126
Silage									
Firm seed; fine chop with additive	0.77	0.69	27	82	68	1.20			145

Source: Jarrige (1989). DM: Dry matter; UFL: Forage unit for milk production; UFV: Forage unit for meat production; PDIA: Digestible proteins in the intestine of dietary origin; PDIN: Digestible protein in the intestine where nitrogen is the limiting factor for rumen microbial activity; PDIE: Digestible protein in the intestine where energy is the limiting factor for rumen microbial activity; SFU: Fill unit for sheep; LFU: Feed unit for lactating dairy cattle; CFU: Feed unit for other cattle.

References

Baddeley, J. and Walker, R. (2014). Field beans. http://www.sruc.ac.uk/info/120582/organic_farming_technical_summaries/1288/field_beans_and_lupins

Borreani, G., Revello-Chion, A., Colombini, S., Odoardi, M., Paoletti, R. and Tabacco, E. (2009). Fermentation profiles of field pea (Pisium sativum), faba bean (Vicia faba) and white lupin (Lupinus albus) silages as affected by wilting and inoculation. Animal Feed Science and Technology, 151: 316-323.

Butter, N.L., Dawson, J.M. and Buttery, P.J. (1999). Chapter 5: Effects of dietary tannins on ruminants. In: Secondary Plant Products – antinutritional and beneficial actions in animal feeding (eds. J.C. Caygill and I. Mueller-Harvey). Nottingham University Press, p51-70.

Caballero, R. (1989). Yields and chemical composition of whole-crop field beans and their components during pod-filling. Grass and Forage Science, 44: 347-351.

Crépon, K., Marget, P., Peyronnet, C., Carrouée, B., Arese, P. and Duc, G. (2010). Nutritional value of faba bean (*Vicia faba* L.) seeds for food and feed. Field Crops Research, 115: 329-339.

Duc, G., Marget, P. and Arese, P. (2011). Breeding priorities for improved nutritional value of *Vicia faba* seeds. Grain Legumes, 56: 17-18.

Dvorak, R., Pechova, A., Pavlata, L., Klejdus, B., Kovarcik, K., Dostalova, J., Culkova, J., Filipek, J., Svajdlenka, E. and Capkova, V. (2006). Reduction in the content of antinutritional substaces in fava beans (Vicia faba) by different treatments. Slovenian Veterinary Research, 43 (Suppl.):174-179.

Faulkner, J.S. (1985). A comparison of faba beans and peas as whole-crop forages. Grass and Forage Science, 40: 161-169.

Feedipedia: http://www.feedipedia.org/

Fraser, M.D., Fychan, R. and Jones, R. (2001). The effect of harvest date and inoculation on the yield, fermentation characteristics and feeding value of forage pea and field bean silages. Grass and Forage Science, 56: 218-230.

Gefrom, A., Ott, E.M., Hoedtke, S. and Zeyner, A. (2013). Effect of ensiling moist field bean (*Vicia faba*), pea (*Pisium sativum*) and lupine (*Lupinus spp.*) grains on the contents of alkaloids, oligosaccharides and tannins. Journal of Animal Physiology and Animal Nutrition, 97: 1152-1160.

Jansman, A.J.M. (1993). Tannins in feedstuffs for simple-stomached animals. Nutrition Research Reviews, 6: 209-236.

Jarrige, R. (1989). Ruminant Nutrition – Recommended allowances and feed tables. Institut National de la Recherche Agronomique. 389 pages.

Louw, A.W. (2009). The nutritive value of faba bean silage for lactating dairy cows. Master of Science in Agriculture thesis. Stellenbosch University, South Africa. 85 pages.

Martinez, T.F., Moyano, F.J., Diaz, M., Barroso, F.G. and Alarcón, F.J. (2004). Ruminal degradation of tannin-treated legume meals. Journal of the Science of Food and Agriculture, 84: 1979-1987.

McKnight, D.R. and MacLeod, G.K. (1977). Value of whole plant faba bean silage as the sole forage for lactating cows. Canadian Journal of Animal Science, 57 (3): 601-603.

Melicharová, V., Pechová, A., Dvorak, R. and Pavlata, L. (2009). Performance and metabolism of dairy cows fed bean seeds (*Vicia faba*) with different levels of anti-nutritional substances. Acta Veterinaria Brno, 78: 57-66.

Mustafa, A.F. and Seguin, P. (2003). Characteristics and *in situ* degradability of whole-crop faba bean, pea and soybean silages. Canadian Journal of Animal Science, 83 (4): 793-799.

O'Kiely, P. and Muck, R.E. (1992). Aerobic deterioration of lucerne (Medicago sativa) and maize (Zea mays) silages - effects of yeasts. Journal of the Science of Food and Agriculture, 59 : 211-216.

O'Kiely, P., Stacey, P. and Hackett, R. (2014). Conserving high moisture spring field bean (Vicia faba L.) grains. Grassland Science in Europe, 19: 583-586.

Pursiainen, P. and Tuori, M. (2008). Effect of ensiling field bean, field pea and common vetch in different proportions with whole-crop wheat using formic acid or an inoculant on fermentation characteristics. Grass and Forage Science, 63: 60-78.

Ramos-Morales, E., Sanz-Sampelayo, M.R. and Molina-Alcaide, E. (2010). Nutritive evaluation of legume seeds for ruminant feeding. Journal of Animal Physiology and Animal Nutrition, 94: 55-64.

Sauvant, D., Perez, J-M. and Tran, G. (2004). Tables of composition and nutritional value of feed materials. Institut National de la Recherche Agronomique. Wageningen Academic Publishers. 304 pages.

Tufarelli, V., Khan, R.U. and Laudadio, V. (2012). Evaluating the suitability of field beans as a substitute for soybean meal in early-lactating dairy cow: Production and metabolic responses. Animal Science Journal, 83: 136-140.

Yu, P., Tamminga, S., Egan, A.R. and Christensen, D.A. (2004). Probing equivocal effects of heat processing of legume seeds on performance of ruminants – A review. Asian-Australasian Journal of Animal Sciences 17: 869–876.