Knowing your oats

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Summary

Although oats is widely used as a feed grain for ruminants and horses its value is often discounted because of the variability in its nutritional value. This paper investigates the major factors leading to variable digestibility and animal performance when oat grain is fed to sheep and cattle. Commercial samples of oat grain can contain significant quantities of free groats or free hulls and it is necessary to first to determine digestibility of the grain based on the 'cleanness' of the grain and its general appearance. This is best done by measuring the content of insoluble non starch polysaccharide (NSP) or acid detergent fibre (ADF) and using this to predict digestible energy (DE). There are a number of calibrations for this prediction using wet chemistry or near infrared reflectance spectrometry (NIR). The second factor influencing DE is the lignin content of the hulls. The lignin content is genetically determined and it is possible to select high– or low–lignin cultivars with a degree of confidence such that, all other factors being similar, low–lignin oat grain will have a DE value approximately 1.5 MJ/kg dry matter higher than the equivalent high–lignin oats. The third factor that influences DE of oat grain is the level of intake. When oat grain forms the major component of a production diet with intake approximately 2% of live weight, the DE value will be approximately 0.9 MJ/kg dry matter less than that measured at a maintenance level of feeding (approximately 1% of live weight per day). When oats constitute the sole component of the diet, feed intake may be significantly higher for animals fed high–lignin oats than low–lignin oats. On the other hand animals fed low–lignin oats compensate for reduced feed intake by having a better feed conversion efficiency and less gut fill (higher dressing percentage) than animals fed high–lignin oat grain. It is recommended that producers purchasing oat grain for livestock feeding should be prepared to pay a premium for low–lignin oats compared to high–lignin oats. There do not appear to be any detrimental effects on plant growth or disease resistance associated with hulls with low lignin and it is suggested that oat breeders should select cultivars with that attribute.

Key words: oats, lignin, digestible energy, ruminants

Introduction

Oat grain has long been recognised as an excellent ingredient in the diet of humans and animals. Shaw (1907) declares that "viewed from the standpoint of adaptation for feeding live stock no cereal grain grown in [the USA] compares with the oat". Oats has been used extensively as a human food since cereals were first cultivated some 10000 years ago, and are considered to contain a very good balance of amino acids, oils and minerals as well as highly digestible starch (Schürch 1989). Even the high non–starch polysaccharide (NSP) content of oat grain is considered to be a benefit in human nutrition in assisting in the prevention of constipation and diverticular disease. In human nutrition only the groat is used and there appear to be no concerns about variability of nutritional value. On the other hand whole grain is fed to ruminants and horses and its variable nutritional value is the main reason it is discounted against most other grains considered to be of more consistent quality. Variability in the nutritional value of oat grain has been the subject of numerous studies (e.g. Pickering *et al*. 1982; Crosbie *et al*. 1985; Margan *et al*. 1987; Rowe and Crosbie 1987; Oddy *et al*. 1990) which show clearly that there are a number of factors to be considered if we are to accurately predict the performance of animals given this feed.

This paper concentrates on the nutritional value of whole oat grain for ruminants. The purpose is to draw together results from a number of studies both published and unpublished to provide an overview of the most important factors influencing its nutritive value.

Factors that determine the nutritive value of whole oat grain

Ratio of groats to non–groat material

The dominant factor determining nutritional value of any particular sample of oat grain is the ratio of groats to non–groat material. The non–groat fraction consists mainly of the fibrous hull but can also include variable amounts of other material such as weeds and seeds from other plants as well as chaffed head, leaf and stem material not separated from the grain in the harvesting process. Samples of oat grain can also contain significant quantities of free groats if the hulls and groats are separated during harvesting and when this occurs the nutritive value of the sample can be improved considerably. The amount of non–groat material and the presence of free groats in an oat sample can be seen easily, but unfortunately it is not always accounted for in ascribing variability to oat grain quality. Increasing amounts of non–groat material tend to decrease the density of an oat sample and is almost certain to decrease its nutritional value (Pickering *et al*. 1982). For this reason oat grain is sometimes traded on the basis of hectolitre or bushel weight. Oddy *et al*. (1990) reported that bulk density measured as kg/hL or as weight per hundred grains was poorly correlated with acid detergent fibre (ADF) and these authors suggested bulk density is of little or no value in predicting oat grain quality. This conclusion regarding hectolitre weight, and therefore groat to hull ratio, is based on a range of diets for sheep constructed from oat fractions to match the extreme range of chemical compositions of oats grain found 'in the field' (Oddy *et al*. 1990) and so overlooks the value of grain density as a predictor of groat to hull ratio in clean samples of oats.

The study of Oddy *et al*. (1990) with the constructed diets shows the importance of accounting for the variable hull to groat ratio. Although the relationship with digestible energy is very good (Figure 1) it is important to realise that the most digestible 'oat' diet in this study was in fact pure groats and that the least digestible 'oat' contained approximately 75% oats and 25% additional oat hulls. Therefore while this is a very important predictive relationship when buying or selling oats with either a lot of free groats or an unusually high proportion of non–groat material, it does not necessarily provide an accurate description of differences among 'normal' oats with only small contents of free groats or non–groat material. The problem of using ADF to predict the digestibility of 'normal' oats is shown in Figure 2. The data have been taken from three experiments with sheep in which the digestibility of different oat samples were measured; two samples were the true oat grain samples described by Oddy *et al.* (1990), eight values come from the data of (Margan *et al*. 1987) and two come from Rowe and Crosbie (1988). The challenge is to understand the causes of the variability shown.

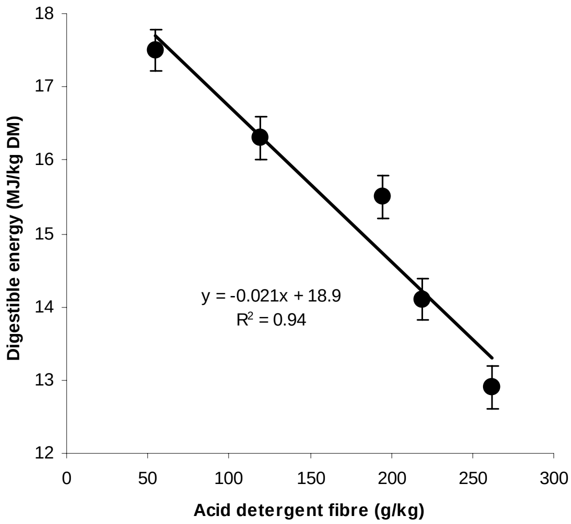

Figure 1 Relationship between ADF and digestible energy of oat diets measured in sheep feeding experiments as reported by Oddy *et al.* (1990).

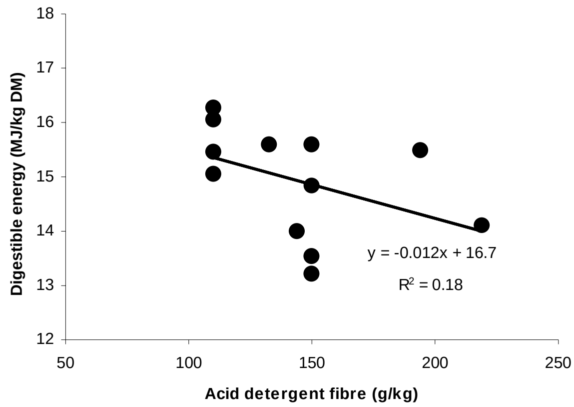

Figure 2 Relationship between ADF and digestible energy of oat grain without added groats or hulls. Two values are the grain samples with 180 g ADF/kg and 25 g ADF/kg of Oddy *et al.* (1990), eight are taken from the data of Margan *et al.* (1987) and two from Rowe and Crosbie (1988).

Hull lignin as a factor influencing digestibility

Crosbie *et al*. (1985) reported that there was considerable variation in hull lignin content between different cultivars of oat grain and that these differences are predominantly genetically controlled. Most cultivars were found to be either 'high' lignin with around 3% lignin in the whole grain and around 6–10 % in the hull fraction, or 'low' lignin with around 1% lignin in the whole grain and 1–3% in the hull. This discovery provided a possible explanation for the experience of many livestock managers that certain cultivars of oat grain were better for livestock production than others. Rowe and Crosbie (1988) then showed that the differences in hull lignin content in high– and low–lignin oat cultivars had a very significant effect not only on the digestibility of the hulls but of the whole grain. With

ADF, the ratio of hulls to groats, and the concentrations of protein and ash all held constant between two cultivars, Rowe and Crosbie (1988) found that a difference of approximately 20 g lignin per kg grain resulted in an improved digestibility of the order of 15%. An independent study by Margan *et al*. (1987) reported significant differences in digestibility between the grains from two cultivars, Coolabah and Cooba. They also differed in lignin content, though that was not the reason they were chosen for the study, and so their results add considerably to appreciation of the importance of hull lignin content. Table 1 summarises the effect of lignin content on digestibility of oat grain in sheep fed principally oats at a rate of approximately 1.6% of body weight per day.

While the ADF content of grains of the high–lignin cultivars is slightly higher, this difference would only explain approximately one third of the change in DE with ADF indicated by the predictive equation shown in Figure 1.

Level of feeding

With all feeds it is accepted that as the level of feeding increases there is a slight decrease in the efficiency of digestion, and DE/kg of feed consumed is reduced. For most feeds the decrease in digestibility with increasing level of feed intake is relatively minor. However, in the case of whole oats, level of intake appears to be an important factor as shown in Figure 3 which uses data from Margan *et al*. (1987).

Combining hull lignin and level of intake with ADF to predict DE

When we account for both level of feed intake and lignin content of oat hulls in the prediction of digestible energy of oats grain we are able to explain much of the variability shown in Figure 2. Figure 4 illustrates the same data as those used in Figure 2, but level of feed intake has replaced ADF as the independent variable

Table 1 Analysis of the major components (g/kg dry matter) of four samples of oat grain and the digestible energy (DE, MJ/kg dry matter) obtained with sheep fed these diets at rates equivalent to approximately 1.6% of body weight per day. Data for 'Cooba' and 'Coolabah' were derived from the study of Margan *et al.* (1987) and for 'Murray' and 'Mortlock' from Rowe and Crosbie (1988).

Cultivar	Lignin	ADF	DE
Low–lignin			
Murray	8	133	15.6
Cooba	10	110	15.4
High–lignin			
Mortlock	23	144	14.0
Coolabah	30	150	13.5
Average difference between high– and low–lignin cultivars	17.5	25.5	1.8

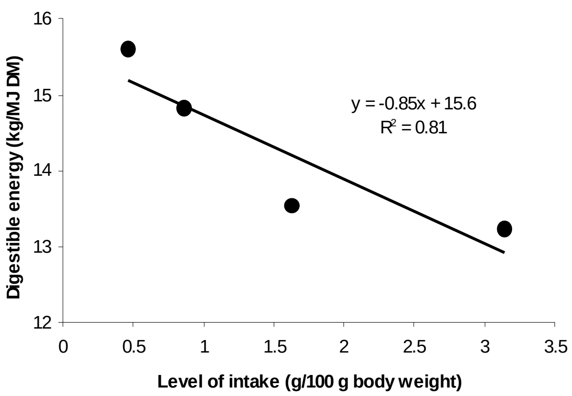

Figure 3 Decrease in digestible energy value of oats grain with increasing intakes by sheep. Data are for Coolabah oats as reported by Margan *et al.* (1987).

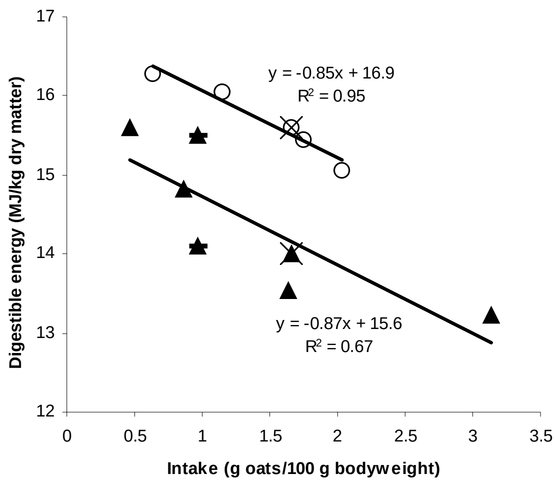

Figure 4 Prediction of digestible energy of oat grain taking into account level of feeding and grains as high–lignin (▲) or low–lignin (○). As for Figure 2, eight values (plain triangles and circles) are taken from the data of Margan *et al.* (1987), two (closed triangles with a single horizontal line) are from Oddy *et al* (1990), and two (triangles and circles with an X) are from Rowe and Crosbie (1988).

and grains have been separated on the basis of their lignin content. The two data points representing 18% ADF and 25% ADF oats are shown as the filled triangles each with a single line through them; that they fall either side of the line of best fit suggests that the prediction of DE based on feed intake and lignin could be further improved by considering ADF as a measure of groat to non–groat material. A robust method of predicting DE would be to use the predictive equation based on the results of Oddy *et al*. (1990), add 1.5 MJ/kg if the grain is low lignin, and then adjust DE for level of intake by 0.86 MJ/kg for each 1% of body weight consumed above or below the 1% base level used by Oddy *et al*. (1990).

Oat grain in feeding for production

The conclusions of the preceding section suggest it would be logical to expect that an oat cultivar with a low content of lignin in the hull would promote better liveweight gain and feed conversion efficiency than a grain with higher lignin. Not only would there be benefits from improved digestibility and nutrient availability, but it is generally accepted that feed intake by ruminants increases with increasing feed digestibility. We conducted two experiments to test the hypothesis that low hull lignin would have a beneficial effect on feed intake, liveweight gain and feed utilisation in sheep and cattle fed diets with oat grain as the major component of their diet. Two other factors considered in the design of the experiment were protein content of the grain and acid insoluble ash content of the hulls. An earlier study in Western Australia (J.L. Suiter, pers. comm.) had shown a positive relationship between protein content of oat grain and liveweight gain of sheep fed solely on the grain. Acid insoluble ash was included because the study of Crosbie *et al*. (1985) had found a negative correlation between acid insoluble ash and pepsin–cellulase digestibility of oat hulls.

Sheep production experiment

Samples of grain from the cultivars Mortlock (high lignin) and Murray (low lignin) were collected from commercial growers throughout the south western land division of Western Australia. There were approximately 30 samples, each weighing around one tonne, and measurements were made of free groats and hulls and total nitrogen in each of these. Hulls were separated manually for measurement of lignin and acid insoluble ash. Based on these measurements composite diets were formulated to create five levels of protein and five levels of acid insoluble ash for both the high lignin and low lignin cultivar, giving a total of 10 diets. The groat to hull ratios were almost identical for each diet. In order to evaluate the inherent importance of grain protein without N being a limiting nutrient for microbial fermentation we added non–protein N as urea and ammonium sulphate (9:1) to each diet to achieve a constant level of 14% crude protein. All diets also contained 1% limestone to ensure that Ca availability did not limit performance. Each diet was fed *ad libitum* for a period of 10 weeks to six individually housed Merino sheep. The weight of the sheep at the start of the experiment was 31 kg. Measurements were made of daily feed intake and animals were weighed each week. Mid–side patches (10 cm x 10 cm) were clipped after three weeks on the diets and again at the end of the study. The amount of wool grown between weeks 3 and 10 was used to estimate daily growth of clean wool.

The feed intakes and liveweight changes of sheep on the 10 diets are summarized in Figure 5. It is clear that there was no effect of either protein content of the grain or acid insoluble ash in the hull on feed intake or liveweight gain. There were however significant effects due to the lignin content of the hull on both feed intake and liveweight gain that were the reverse of what was expected at the outset of the experiment. The intake of high–lignin, Mortlock grain was higher than that of the low–lignin Murray cultivar. Similarly liveweight gain of sheep consuming the high–lignin grain was better than those on the low–lignin grain. The results for feed intake, weight gain and wool growth with respect to lignin content are summarized in Table 2. It is clear that the higher intake of high–lignin grain was the major factor affecting liveweight gain and wool growth. The higher digestibility of the low–lignin Murray grain did not compensate in terms of liveweight gain.

The reduced intake of low–lignin grain compared to the high–lignin cultivar was unexpected. It is, however, consistent with the results of Margan *et al*. (1988) who reported higher intakes by sheep offered the high–lignin Coolabah cultivar than those offered the low–lignin Cooba cultivar. Since the same phenomenon has been observed for two different pairs of high– and low–lignin cultivars in two independent studies it appears that this is more than a ‘random’ factor associated with the Murray low–lignin cultivar but may be a general factor. One possible reason for this phenomenon could be that low lignin oats contain higher levels of non–lignin phenolics than the high–lignin oats. This is speculative, but it is consistent with the observation that most low–lignin oats have a slightly darker hull colour than the high–lignin cultivars and it is known that a number of phenolic compounds are pigmented. Another possibility is that the additional digestible energy available to the animals fed low–lignin oats created a demand for extra nutrients such as amino acids at the tissue level and that an imbalance of nutrients caused the reduction in feed intake. This hypothesis was tested in a preliminary experiment in which additional protein in the form of fishmeal was provided to sheep on the low– and high–lignin diets (J.B. Rowe and G.B. Crosbie, unpublished). While there was a slight increase in intake in response to the additional protein the differences between Mortlock and Murray were not reversed.

Cattle production and carcass yield in cattle fed oat grain

A feeding experiment was conducted in cattle (May *et al*. 1989) using the same low– and high–lignin oat cultivars, Murray and Mortlock respectively, as used in the sheep feeding study described above This study (Table 3) demonstrated a significant effect of high–lignin oats on gut fill and dressing percentage, thus explaining the apparent paradox of a feed with lower digestibility producing better live weight gain and feed conversion efficiency than a similar feed of higher digestibility. As in the sheep experiment, feed intake was higher (P = 0.07) in cattle fed Mortlock than for those given the higher digestibility Murray grain. Liveweight gain and feed conversion based on liveweight were also significantly better. However, due to the accumulation of low digestibility roughage in the rumen and a much larger rumen in cattle fed high–lignin Mortlock grain, carcass gains for the two grains were similar. Feed conversion based on carcass weight change was marginally (P = 0.09) better for the low–lignin cultivar and this is consistent with its improved digestibility.

Oat lignin content, gut fill and carcass yield in sheep

Following the above study in cattle we designed an experiment in sheep to determine the effect of hull lignin content on gut fill and carcass weight change to determine if the reduced intake of a low–lignin oat cultivar was compensated for by increased digestibility. In this experiment (Rowe and Coss 1992) sheep of approximately 33 kg liveweight were offered either 1 kg/d of chaffed wheat hay or 800 g/d of a high– or low–lignin oat grain (Mortlock or Murray, respectively). Both the chaffed hay and oat grain contained 10 g/t of urea/ammonium sulphate (respectively 9:1 w/w). Twenty sheep had received each diet for three weeks when 10 sheep from each group were slaughtered and carcass and reticulo–rumen weights were measured. The remaining 10 animals were slaughtered and similar

Table 2 Intakes and liveweight gains of sheep fed either Mortlock (high–lignin) or Murray (low–lignin) oat grain balanced for protein, insoluble ash and free groats.

	Mortlock	Murray	SE	*P*<0.05
Intake (g/d)	759	599	20	*
Weight gain (g/d)	123	87	8	*
Wool growth (mg/cm2/d)	0.81	0.66	0.03	*

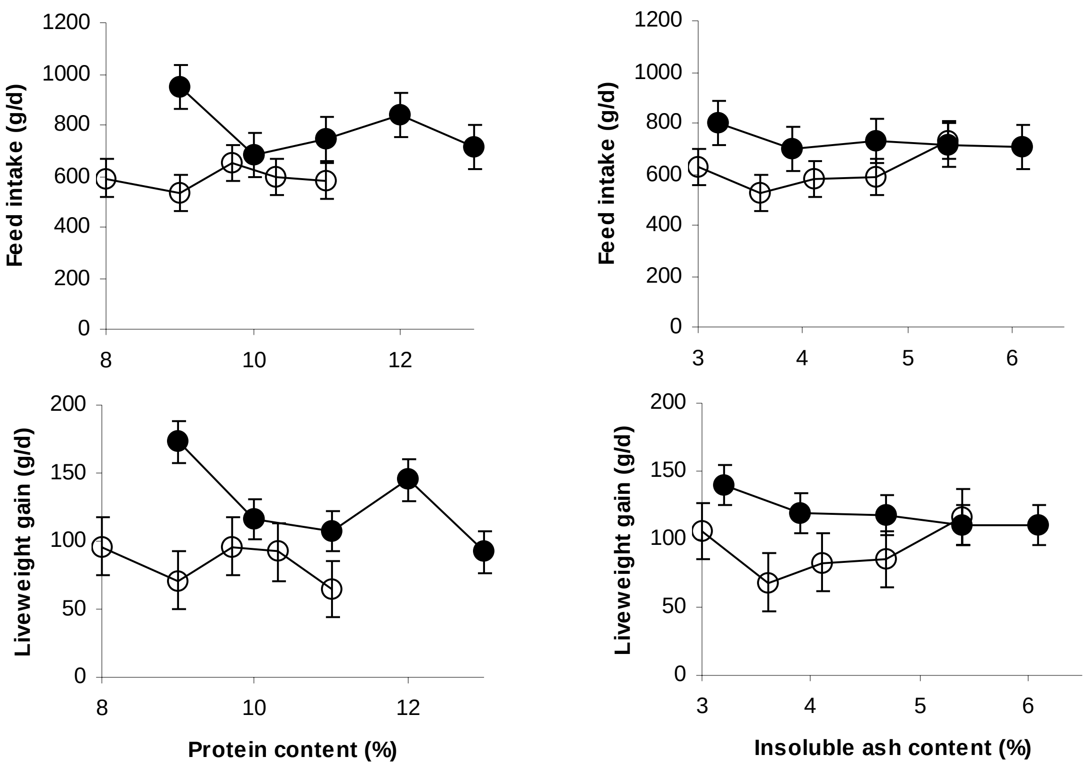

Figure 5 Feed intake and liveweight gain of Merino sheep fed low–lignin oat grain (cultivar Murray, ○) or high–lignin (cultivar Mortlock, ●) with varying levels of protein in the whole grain and varying concentrations of acid insoluble ash in the hulls.

measurements were made 7 weeks later. The results are summarized in Table 4.

The results of this experiment confirm the higher feed intake by the animals fed the lower digestibility high–lignin oat grain that was observed in previous experiments. Measurements of carcass weight and the reticulo–rumen also confirm the results of the cattle experiment showing that high–lignin oat grain produces a significant increase in gut fill that masks the reduced rate of carcass gain compared to low–lignin oats. In this study the higher digestibility of the low–lignin grain produced a higher rate of carcass gain than the high lignin grain even although approximately 20% less feed was consumed.

The study supports the conclusion that low–lignin oat grain provides a higher digestible energy per kg dry matter than the high–lignin, and that animals consume more of the high–lignin grain.

Oat grain as a supplementary feed

The effects of high– and low–lignin oat cultivars summarized above apply to situations where oat grain comprises the major part of the diet with only small amounts of minerals added to balance the diet. This is rarely the case in practical feeding applications where oats is more commonly used as a supplement for grazing animals with access to poor quality paddock roughage. Alternatively oats are fed at restricted levels to provide a maintenance diet for animals during an extended dry period when there is insufficient paddock roughage available. Under conditions of supplementary feeding it is considered unlikely that there would be any reduction in feed intake associated with the use of low–lignin oat cultivars and we conducted a further experiment to test this hypothesis.

Table 3 Diet composition (g/kg dry matter) and performance of cattle fed oat grain with high (Mortlock cultivar) or low (Murray cultivar) lignin contents in the hulls (from May *et al*. 1989a).

	Mortlock	**Murray**	**Significance of difference *(P)***
Crude protein	124	110	
Acid detergent fibre	124	104	
Lignin	24	11	
In vivo dry matter digestibility (%)			
Measured in sheep (maintenance)	70.2	82.4	
Measured in cattle (intake approx. 2.2% of body weight)	64.1	71.6	
Days on feed	107	104	
Feed intake (kg/d)	6.34	5.86	0.07
Relative dry matter intake (% of live weight)	2.29	2.20	NS
Average live weight gain (kg/d)	1.06	0.90	0.003
Dressing %	49.8	51.8	0.003
Rumen contents (% of live weight)	1.79	0.57	0.001
Average carcass gain (kg/d)	0.58	0.58	
Feed conversion live weight (kg feed/kg live weight gain)	6.05	6.60	0.03
Feed conversion carcass (kg feed/kg carcass weight gain)	11.15	10.19	0.09

Table 4 Feed intake, liveweight and carcass weight changes in sheep fed chaff or oat grain with high (Mortlock cultivar) or low (Murray cultivar) lignin contents in the hulls (from Rowe and Coss 1992).

	Chaff		**Mortlock**	**Murray**		
	Mean	**SE**	**Mean**	**Mean**	**SEM**	***P***
Initial liveweight (kg)	33.0	0.58	34.1	32.7	0.8	NS
Average feed intake (kg/d)	0.913	0.015	0.664	0.547	0.044	0.001
Live weight change (kg)	1.56	0.31	2.63	3.00	0.57	NS
Carcass weight (kg)	13.6	0.34	14.1	14.6	0.28	NS
Carcass weight change# (kg)	1.3	0.16	1.44	2.74	0.29	0.01
Reticulo–rumen (kg)	4.83	0.21	4.70	3.71	0.31	0.01

\# Carcass weight change measured between weeks 3 and 10. NB: feed intake was used as a covariate in the analysis
P Indicates significance of differences between the two oat grains

In this experiment, described in more detail by Rowe and Coss (1994), high and low–lignin oats were fed to Merino sheep at the three rates of 150, 300 and 450 g/day in addition to chaffed hay that was available *ad libitum.* There were l0 sheep per treatment, and a further 20 sheep were fed chaff only; average liveweight at the start of the experiment was 38 kg. Feed intake was measured daily and all sheep were weighed weekly. At the end of 7 weeks on the experimental diets all sheep were slaughtered and measurements were made of dressing percent and gut contents. The results are shown in Figure 6. Only the level of grain feeding had a significant ($P<0.001$) negative effect on the intake of chaff; there was no significant effect due to oat cultivar. While there was a significant ($P<0.05$) increase in dressing percent with increasing intake of low–lignin oats there was no increase with increasing intakes of the high–lignin oats.

Processing oat grain for animal feeding

The question of whether or not there is any advantage to be gained from processing oat grain before feeding it to cattle is a very important one in determining its suitability for on–farm use in situations where no grinding and mixing equipment are available. We are aware of three studies examining this question and the results are summarized in the Table 5. The consistent finding in all three studies was that there is little or no improvement in digestibility or animal performance in response to processing oat grain by rolling or hammer milling. Toland (1976) reported improvements of between 60 and 100% in the digestibility of wheat and barley starch as a result of rolling compared to feeding whole grain, but found no significant benefits in the case of oats. It is therefore safe to conclude that oat grain can be fed whole to cattle without any risk that it will be digested or utilized inefficiently for production. The data of May *et al*. (1989b) even suggest possible benefits in whole grain feeding to achieve slightly higher consumption. As is the case with all cereal grains, there is no benefit in rolling or grinding oats before feeding it to sheep.

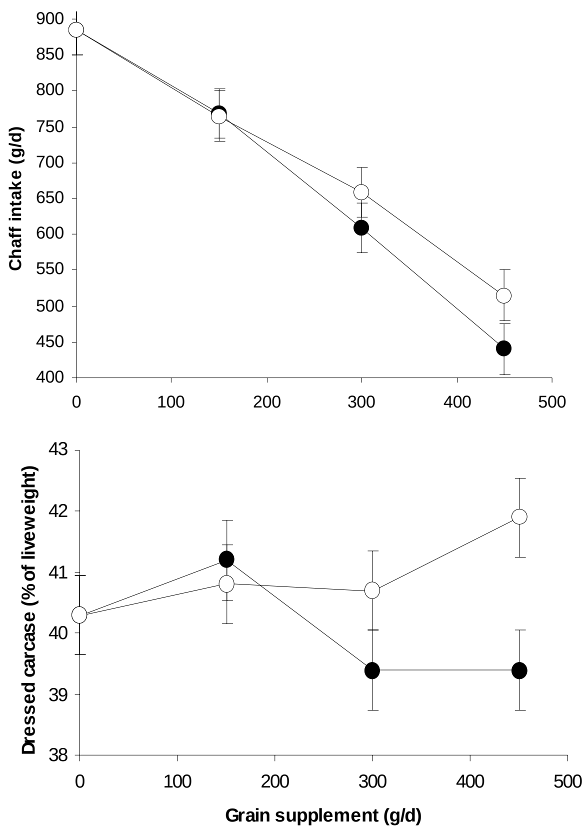

Figure 6 Chaff intake and dressing percent of young Merino sheep fed chaffed wheat hay *ad libitum* and varying amounts of oat grain of low lignin content (open circles) or high lignin content (closed circles).

Using oat hulls in animal feeds

The preparation of groats for the human and poultry markets produces quantities of hulls as a by–product that are often included as a source of roughage in mixed feeds for ruminants. Round (1988) investigated the nutritional characteristics of oat hulls on their own and in pelleted diets for sheep. In measurements of hull digestibility he reported that one source of hulls was very much more digestible (47.7% digestibility of dry matter) than hulls from three other commercial sources (average 37% digestible). While there is no record of cultivar or lignin content for these sources of oat hulls it is possible that the hulls of higher digestibility came from cultivars with low hull lignin. An alternative explanation could be that the higher digestibility hulls contained more grain fragments than the hulls of lower digestibility. The data of Rowe and Crosbie (1988) summarized in Figure 7 suggest that high–lignin hulls are almost indigestible; less than 10% of their dry matter disappeared from nylon bags incubated in the rumen for 96 h compared with low lignin hulls of which almost 30% disappeared in 96 h.

Although studies by Crosbie *et al.* (1987), Rowe and Crosbie (1988) and Crosbie and Rowe (1988) have suggested the digestibility of oat hulls is determined predominantly by lignin content, with a minor effect of silica (insoluble ash), the studies reported by Welch *et al*. (1983) and of A.G. Kaiser (pers. comm.) indicate that factors other than lignin may have an important influence on digestibility.

We have examined the data of Welch *et al*. (1983) to try to explain why these authors did not find lignin to be as important as in the studies of Crosbie and his colleagues. Welch *et al*. (1983) examined the effects of various components of the oat hull on digestibility measured using the pepsin–cellulase method, and although these authors reported a correlation coefficient of lignin and pepsin–cellulase digestibility of –0.73 for 11 cultivars, the correlation for all samples studied was less than –0.5 (R^2 = 0.23, see Figure 8a). However a closer examination of their data shows a good relationship (R^2 = 0.75) between hull protein and hull starch suggesting that the groats and hulls were not cleanly separated (see Figure 8b). This point is further illustrated in Figure 8c which shows a good relationship between starch content of the hulls and pepsin–cellulase digestibility (R^2 = 0.60). The relationship between starch content and digestibility has one data point off the line of best fit and it is interesting that this point represents the only sample of hulls in that study with a low lignin content (less than one–third the mean value of all samples). A possible conclusion is that, apart from the one sample of low lignin oat hulls, most of the variation in digestibility observed by Welch *et al*. (1983) could be explained by the incomplete separation of hulls and groats.

In commercially prepared samples of oat hulls, variable and incomplete separation from groats has an important effect on pepsin–cellulase digestibility. Table 6 summarises data for samples of oat hulls separated by hand and hulls from the same grain separated in commercial milling operations. The amount of starch in the hull fraction is an indicator of fragments of groat remaining in the hulls and of complete grains passing through in the hull fraction. The data of Round (1988) suggest that most modern milling operations produce a clean hull fraction with little starch and that under these conditions the characteristics determining hull digestibility (principally lignin) become even more important.

Measuring lignin content of oat hulls

Measurement of lignin content by wet chemistry is time consuming and expensive, and if the analysis is not made by an experienced technician it can yield uncertain results. Probably due to the painstaking task of measuring large numbers of lignin concentrations, combined with the difficult process of hand separation of hulls from groats, there are as yet no NIR prediction equations for hull lignin. Although not quantitative, a test developed by Crosbie and his co–workers provides a quick and accurate indication of whether samples of oat grain fall into the category of 'high–lignin' or of 'low–lignin'. The Crosbie oat hull assay is based on the pink colour that develops when a solution of phloroglucinol stains the lignin component of the hulls, and is most easily made by adding approximately 2 ml of a phloroglucinol solution to about 10 whole oat grains or to separated hulls from 3 to 5 grains. The solution is prepared by dissolving 1 g of phloroglucinol in 80 ml 2 M HCl plus 20 ml ethanol, and then filtering. The phloroglucinol solution should be kept in a dark bottle in a refrigerator (4ºC) and can be used for about 1 month if properly stored. Sufficient solution is added to cover the grains and/or hulls placed in a white ice–block tray; the volume of each well easily accommodates the sample and solution. The multiple compartments facilitate inclusion of known high– and low–lignin samples, and the white background enables ready detection of differences in colour.

Table 5 Summary of the effects of rolling, hammer milling or crushing oat grain on its digestibility by cattle and on the performance of cattle fed diets based on oat grain.

	Whole oats	Rolled, crushed or hammermilled	LSD
Toland (1976)			
Organic matter digestibility (%)	69.4	72.2	2.4
Starch digestibility (%)	93.4	99.1	6.1
Hodge *et al.* (1984)			
Dry matter digestibility (%)	69.5	72.3	10
ME (MJ/kg DM)	12.2	12.7	2
Milk production (L/d)	8.48	8.57	
May *et al.* (1989) Mortlock oats			
Relative intake (kg/100 kg body weight)	2.35	2.23	
Carcass weight gain (kg/d)	0.63	0.54	
Carcass gain kg/kg oat diet consumed	10.8	11.5	
May *et al.* (1989) Murray oats			
Relative intake (kg/100 kg body weight)	2.21	2.17	
Carcass weight gain (kg/d)	0.57		

A list of major cultivars of oat grains categorised by hull lignin content by the colorimetric method described above is summarized in Table 7. About half of samples of the West cultivar, categorised as 'medium' had high concentrations of lignin and half had low concentrations. When individual grains were grown to produce seed the low–lignin seeds produced grains with low hull lignin, and the high–lignin seeds produced high–lignin grain.

Visual appearance of low– and high–lignin oat grain

The visual assessment of all grains for evidence of mould or moisture damage is important because fungal contamination can have adverse effects on feed intake as well as a range of toxic effects. The presence of fungus is most easily identified as darker colorations because mycelium and spores are often black in colour. There has therefore been a preference amongst buyers for bright, light yellow colours in oat hulls. It is important to note that the hulls of low–lignin oat grain is often slightly darker than that of high–lignin grains, possibly due to accumulation of pigmented phenolics in the hull of low–lignin cultivars, and that this darker coloration is natural and does not signify fungal contamination. In order for buyers to have complete confidence when purchasing low–lignin grains of slightly darker colour it may be necessary to develop a quick assay for fungal contamination to complement the rapid colour method for differentiating between high– and low–lignin cultivars.

Conclusions

It is suggested that enough is now known about the factors affecting the nutritive value of oats for ruminant animals for oat grain to be traded and used with a considerable confidence based on objective measurement. Three steps are indicated in predicting nutritive value.

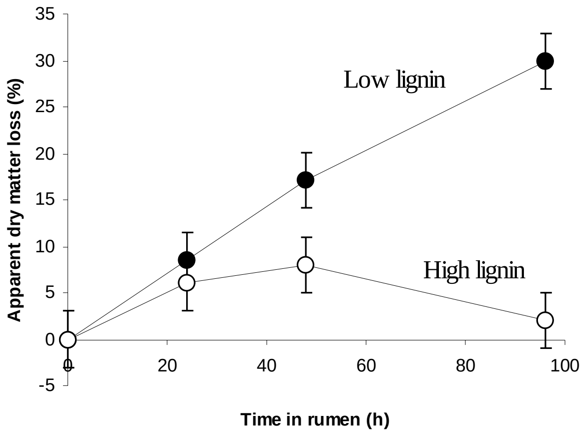

Figure 7 Disappearance of dry matter from nylon bags containing whole oat hulls from high–lignin Mortlock grain (open circles) or low–lignin Murray grain (closed circles) incubated in the rumen for varying lengths of time.

1 Irrespective of whether a grain has much free groats, free hulls or non–oat grain material, it is best given a 'first stage' assessment for nutritive value based on the predictive relationship shown in Figure 1 based on the data of Oddy *et al*. (1990):

Digestible energy (MJ/kg DM)
= 18.9 – 0.021 x ADF (g/kg DM)

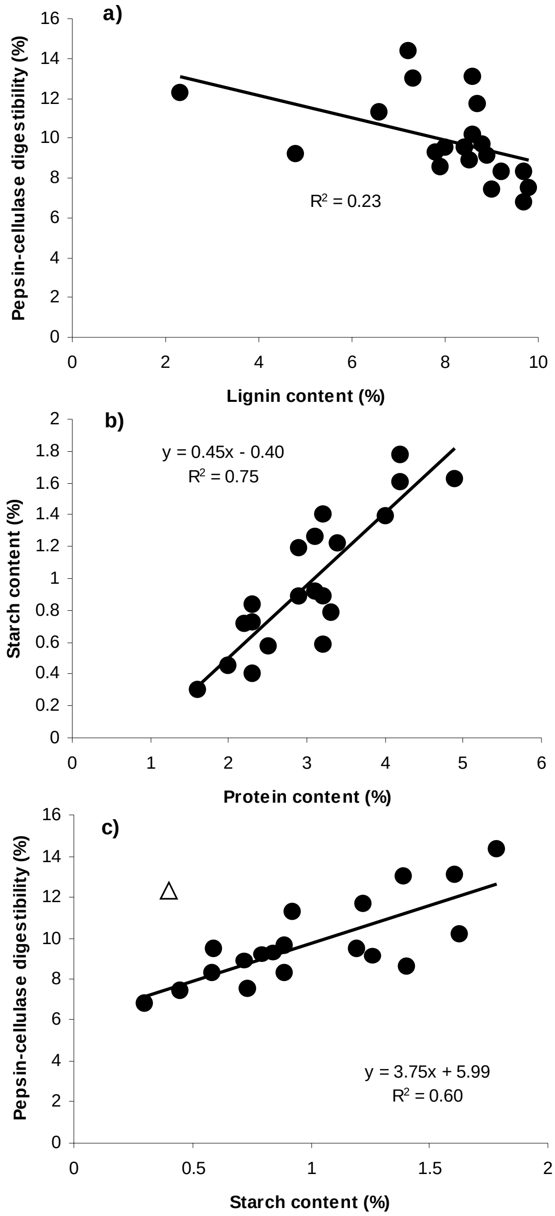

Figure 8 Regression relationships between the lignin, protein and starch contents of oat hull material and its pepsin–cellulase digestibility measured by Welch *et al.* (1983). In Figure 8c the open triangle represents the cultivar with the lowest lignin content and is not included in the calculation of the correlation coefficient.

It is likely that most commercial feed evaluation services in Australia would predict the digestible energy content of oats on this basis even if using an NIR calibration for DE.

2 The second step should be to determine whether the grain has high or low hull lignin content, and if it is low the DE value should be increased by 1.5 MJ/kg dry matter. This stems from the studies by Margan *et al.* (1987) and Rowe and Crosbie (1988) (Figure 4) and the fact that the prediction equation of Oddy *et al*. (1990) shown above was determined using high–lignin oat grain.

3 Before assigning a DE value to the grain the level of feeding should be determined because this will have a significant influence on digestibility. Although the data in Figure 4 are based on sheep feeding experiments it is supported by the data in Table 3 for cattle fed at 2.2% of body weight. Figure 4 suggests that DE should be corrected by 0.86 MJ for each 1% relative DMI (kg oat grain/ 100 kg body weight per day) that relative DMI differs from a base level of 1% of body weight. Therefore if oat grain is a major component of a diet used for production feeding, the DE estimated in steps 1 and 2 above should be reduced by around 1 MJ.

The results of several studies reviewed by Margan *et al.* (1987) indicate that the metabolizable energy (ME) of oats is greater than the 0.81 DE assumed for many other feeds, and that the relationship between those two variables might be taken to be ME = 0.86 DE.

The only negative effect associated with feeding low–lignin grains may be that feed intake will be slightly lower than for high–lignin grains, but the higher digestibility will compensate for this. For supplementary feeding the low–lignin grain appears to have only positive effects compared to high–lignin.

We consider that breeding and cultivation of low–lignin oat cultivars should be encouraged by grain users being prepared to pay more for the higher digestibility grain than for the high–lignin low digestibility cultivars. There are currently a number of low–lignin oat cultivars grown commercially and we are not aware of problems, such as lodging or rust resistance, being linked to lower levels of lignin in the hull.

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Table 7 Categorisation of oat cultivars tested with a combination of wet chemistry and the Crosbie colour test for lignin content. Information for this table was obtained from Crosbie *et al.* (1985), G.B. Crosbie (pers. comm.) and A.G. Kaiser (pers. comm.).

High lignin	Low lignin	Medium
Dalyup	Irwin	West
Echidna	Murray	
Kalgan	Swan	
Moore	Yilgarn	
Mortlock	Cooba	
Coolabah	Yarran	
Graza–50	Graza–70	
Pallinup	Marloo	
Dumont	Culgoa	
Bettong	Amby	
Cleanleaf	Bimbil	
Panorama–5	Carbeen	
	Nile	

Table 6 Examples of the composition of oat hulls from commercial mills showing variation in the content of starch that reflects variable separation of hulls from groats. Acid detergent fibre (ADF) values for data presented by Welch *et al.* (1988) were calculated as the sum of cellulase, lignin and ash.

	Starch	Crude protein	ADF	Pepsin–cellulase digestibility
Welch *et al.* (1983)				
Mill A	2.5	2.5	46.2	10.0
Mill B	12.3	4.5	41.1	16.1
Hand separated (Mill A)	0.7	2.2	47.3	8.9
Hand separated (Mill B)	0.3	1.6	49.5	6.8
Round (1988)				
Commercial Mill 1	0.8	4.4	29.5	
Commercial Mill 2	1.1	2.5	36.4	
Commercial Mill 3	1.6	3.7	35.1	

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