



**Identifying nutritive, physical and volatile characteristics of  
oaten and lucerne hay that affect the short-term feeding  
preferences of lactating Holstein Friesian cows and  
Thoroughbred horses**

A thesis submitted in total fulfilment of the requirements for the degree of

Doctorate of Philosophy

By

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# Abstract

Feeding behaviour is controlled by the integration of both perceived cues from the plant and post-ingestive signals received by the animal. In general practice, dairy cattle are presented with a variety of feedstuffs throughout each day, in addition to changing feedstuffs over time. In the Australian context, the feeds generally include fodder (usually hay) and pasture whilst grazing, as well as various concentrates. For horses that are stabled for prolonged periods, their diet consists of fodder (again usually hay or chaff) and concentrates, in addition to the pasture consumed whilst allowed access to graze. In such situations, where animals are presented with a range of feedstuffs, some of them novel and for discrete periods of time, it is important that they readily accept the feeds when they are first presented to them. For both lactating dairy cows and performance horses, for example, it is important to avoid periods of low intake, as this can have immediate and sometimes longer-term consequences to animal performance.

The daily rate of food intake is the single most important factor affecting animal performance and productivity (Illius et al. 2000) and an animal's responses to a feedstuff can be considered the ultimate measure of its quality. The animal's first response to the presentation of a new feed, which in this particular study was oaten or lucerne hay, is its level of voluntary intake, which depends in part on palatability. Palatability is an integrative term (Provenza 1995); to provide a quantitative measure of the acceptability of a feedstuff, a '*preference value*' can be obtained by describing the preference of one hay relative to an alternate hay also on offer.

The Australian fodder industry is increasingly adopting more objective measures of hay quality to improve marketing opportunities, especially in the export industry, and to meet the demands and expectations of local and overseas purchasers of hay. Being able to efficiently and reliably predict the preference value of any particular hay would be beneficial to processors, exporters, users (purchasers) of hay, and possibly plant breeders, to make more informed decisions. This thesis describes a comprehensive analysis of the chemical and physical characteristics of a selected number of oaten and lucerne hays and their relationship to the acceptability or '*preference value*' of the hays for lactating Holstein Friesian cows and Thoroughbred horses.

The project aimed to (i) quantify preference values for a large number of oaten hays with dairy cows and horses and a similarly large number of lucerne hays with horses only, and (ii) develop predictive equations for animal preferences based on the chemical and physical properties of the hays and the

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animal's short-term rate of consuming the hays. A total of approximately 8,500 preference tests were conducted with 85 oaten hays offered to lactating Holstein Friesian cows and Thoroughbred horses, and 70 lucerne hays offered to Thoroughbred horses. The hays were selected to cover a range of nutritive values. The intake rate and preferences for all the hays were quantified in a series of tests replicated over time and with different animals. Each 'trial' hay was offered with four 'standard' hays (in separate tests). A suite of chemical (nutritive value) traits and physical traits were quantified for the hays. An assessment of the 'odour profile' was also included in the characterisation of the hays. The nutritive, physical and volatile traits were then related to hay preference values in multiple and simple linear regression models and equations generated to predict hay preference values. A prediction of hay preference made directly from the spectra obtained by near infrared reflectance spectroscopy (NIRS) was also developed.

Overall, the average preference value of an oaten hay (i.e., that obtained using the comparisons with all four standard hays) could be predicted from a range of nutritive value traits, typically the contents of acid detergent fibre (ADF), hemicellulose, crude protein (CP) and water soluble carbohydrates (WSC) - with a correlation co-efficient of about 79% with cows and 61% for horses. Acid detergent fibre and CP contents tended to have the biggest influence on preference value for both cows and horses, followed by WSC and hemicellulose content. Examination of lucerne hays offered to horses increased the correlation co-efficient to 74%, with ADF, hemicellulose and CP each having a similar magnitude of effect. This means that these traits, with an appropriate weighting for each, could account for up to about three-quarters of the variation in hay preference values for cows and horses. The *in vitro* digestibility of dry matter (IVD) of oaten and lucerne hay was nearly as accurate in predicting preference values as using the four nutritive value traits of ADF, hemicellulose, CP and WSC, which was anticipated as digestibility is a function of these chemical traits. Hay physical traits could also be used to predict preference values, although not as accurately as the nutritive value traits or IVD. Of the physical traits, shear energy had the largest effect (co-efficient approximately -1.15 compared to an average of -0.35 for the other traits in the equation). The use of NIRS to directly predict preference values was also encouraging, with the best calibration model yielding a correlation co-efficient of 61 to 81%, depending on the hay (oaten or lucerne) and the animal (cows or horses).

Of the total 120 volatile compounds isolated from the oaten hays, six had some relationship with cow preferences and there were also six oaten hay volatiles related to horse preferences. Of the oaten hay volatiles significantly related to preference, four were positively related to cow preference whilst two were negatively related to cow preference. Similarly there were four volatiles positively related to horse

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preference and two consistently negatively related. Of the six oaten hay volatiles found to influence the preferences of dairy cows and horses, four were common to both species. Of the total of 147 volatile compounds isolated from the lucerne hays, 15 had some relationship with horse preference, with nine positively related to horse preference and six negatively related.

The data reported here suggest that a predicted preference value for a hay can be generated using commonly measured quality traits, which would improve a buyer's confidence of animals responding favourably when first offered the hay. More specifically, for an average preference value, the most reliable prediction equation was based on nutritive value traits: ADF, hemicellulose, crude protein and water soluble carbohydrates solely. Alternatively a combination of nutritive and physical traits can be used to predict preference: *in vitro* digestibility, crude protein, water soluble carbohydrates and shear energy. The visible and near infrared spectra obtained by NIRS was also a promising method of prediction, and given the speed and affordability of NIRS, this technology could be further refined and used for routine measurement of predicted hay preference values. The volatile compounds shown to influence preference value of the hay should be identified and further research undertaken to investigate novel approaches to manipulate the preference of hays. Caution should be taken when attempting to use these prediction equations on a single specific hay in a single specific situation. The predictions and relationships investigated in this thesis are based on populations of hays and preferences of a group of animals and therefore some care should be taken when applying them to a particular situation with difference circumstances. Other factors that can influence feed preferences include an animal's feeding experiences, basal diet and diet history and various environmental factors unaccounted for here.

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# Declaration

This thesis is a record of original work and contains no experimental material which has been accepted for the award of any other degree or diploma in any university or other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text.

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Sarah Jean Pain  
November 2008



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# Abbreviations

A	Standard oats hay A
ADF	Acid detergent fibre
AFIA	Australian Fodder Industry Association
BC	Standard oats hay BC
CIR	Lactating Holstein Friesian cow oats hay intake rate (g/min)
CP	Crude protein
CPrefA	Lactating Holstein Friesian cow preference when fed in combination with oats hay standard A (log ratio trial hay eaten:standard hay eaten)
CPrefave	Average of CPrefA, CPrefBC, CPrefD and CPrefE
CPrefBC	Lactating Holstein Friesian cow preference when fed in combination with oats hay standard BC (log ratio trial hay eaten:standard hay eaten)
CPrefD	Lactating Holstein Friesian cow preference when fed in combination with oats hay standard D (log ratio trial hay eaten:standard hay eaten)
CPrefE	Lactating Holstein Friesian cow preference when fed in combination with oats hay standard E (log ratio trial hay eaten:standard hay eaten)
CSIRO	Commonwealth Scientific and Industrial Research Organisation
D	Standard oats hay D
E	Standard oats hay E
GCMS	Gas chromatography mass spectroscopy
GE	Gross energy
Hem	Hemicellulose
HIR	Thoroughbred horse oats hay intake rate (g/min)
HLIR	Thoroughbred horse lucerne hay intake rate (g/min)
HPrefA	Thoroughbred horse preference when fed in combination with oats hay standard A (log ratio trial hay eaten:standard hay eaten)
HPrefave	Average of HPrefA, HPrefBC, HPrefD and HPrefE
HPrefBC	Thoroughbred horse preference when fed in combination with oats hay standard BC (log ratio trial hay eaten:standard hay eaten)
HPrefD	Thoroughbred horse preference when fed in combination with oats hay standard D (log ratio trial hay eaten:standard hay eaten)
HPrefE	Thoroughbred horse preference when fed in combination with oats hay standard E (log ratio trial hay eaten:standard hay eaten)

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HPrefLA	Thoroughbred horse preference when fed in combination with lucerne hay standard LA (log ratio trial hay eaten:standard hay eaten)
HPrefLave	Average of HPrefLA, HPrefLB, HPrefLC and HPrefLP
HPrefLB	Thoroughbred horse preference when fed in combination with lucerne hay standard LA (log ratio trial hay eaten:standard hay eaten)
HPrefLC	Thoroughbred horse preference when fed in combination with lucerne hay standard LA (log ratio trial hay eaten:standard hay eaten)
HPrefLP	Thoroughbred horse preference when fed in combination with lucerne hay standard LA (log ratio trial hay eaten:standard hay eaten)
IVD	<i>In vitro</i> dry matter digestibility
LA	Standard lucerne hay LA
LB	Standard lucerne hay LB
LC	Standard lucerne hay LC
LMM	Log ratio of maximum and minimum stem diameter measurements
LP	Standard lucerne hay LP
ME	Metabolisable energy
NDF	Neutral detergent fibre
nir (prefix)	Hay trait determined using near infrared spectroscopy (eg, nirADF)
NIR	Near infrared
nirs (prefix)	Hay trait determined using near infrared spectroscopy and the value standardised (eg, nirsADF)
NIRS	Near infrared spectroscopy
nm	Nanometres
RIRDC	Rural Industries Research and Development Corporation
SA	South Australia
SD	Stem diameter
SE	Shear energy
SPME	Solid phase micro extraction
UWA	University of Western Australia
VIC	Victoria
WA	Western Australia
wc (prefix)	Hay trait determined using near wet chemistry (eg, wcADF)
WC	Wet chemistry

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wcs (prefix)	Hay trait determined using near wet chemistry and the value standardised (eg, wcsADF)
WSC	Water soluble carbohydrate