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Short communication

Effect of level of inclusion and method of presentation of a single distillery by-product on the processes of ingestion of concentrate feeds by horses

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Abstract

The eating behaviour of horses offered wheat distiller grains at varying levels in the concentrate was examined in two experiments. The objective of the study was to evaluate the effect of rate of inclusion and presentation (dry vs. soaked) of wheat distiller's grains, and the responses in behaviour and processes of intake. In both experiments, the rates of inclusion were 1.00:0, 0.75:0.25, 0.50:0.50, 0.25:0.75 and 0:1.00 for wheat distiller's grains/concentrate, respectively. The various mixtures of concentrate were offered to 10 horses according to two 5×5 Latin squares for 10 min and the rate of eating and processes of ingestion were assessed. When offered at a rate of 0.75 in the dry matter and not soaked, there was a significant reduction ($P < 0.01$) in the rate of ingestion of DM and chews per kg DM ($P < 0.01$). However, the rate of ingestion of soaked mixed concentrate declined rapidly ($P < 0.01$) when the rate of inclusion was greater than 0.5 of the dry matter. The behavioural responses of the animals were commensurate to the observations of rate of eating in the case of non soaked concentrate. When 0.75 of the concentrate DM was replaced with wheat distiller's grains, a significant increase ($P < 0.05$) in the incidence of shorter than expected feeding bouts was observed. However if feeding was terminated, reversion of feeding occurred with a mean frequency of 0.767. The rate of cessation of feeding was also increased significantly when 0.75 or all of the concentrate DM was replaced with the distillery by-product. If the concentrate was soaked before offering, there was an increase ($P < 0.05$) in the number of feeding bouts when 0.25 of the concentrate was replaced with wheat distiller's grains. However the processes of ingestion were not affected until 0.5 of the concentrate DM was replaced. Cessation of feeding was affected significantly by the previous behaviour ($P < 0.001$) especially when the animal interacts with the environment and resumption of feeding was reduced significantly ($P < 0.01$) as the rate of inclusion of wheat distiller's grains increased. Wheat distiller's grains can be used as a substitute to other energy and protein feeding-stuffs in the ration of the horse. However the inclusion rate depends on the method of presentation of the feed to the animal. Soaking of the concentrate prior to feeding allowed a reduced level of distillery by-product to be incorporated into the ration. Least cost formulation of concentrates for horses should therefore consider the nutritive composition of the feeding stuff, the potential of the novel feeding-stuff to disrupt behaviour during feeding and the cost of the formulation.

Keywords: Distillery by-products; Horse; Voluntary intake; Behaviour

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1. Introduction

Distillery by-products are generally high in metabolisable (approximately 12.5 to 13.0 MJ/kg DM) and crude protein (300–340 g crude protein/kg DM). They are utilised extensively as a component of ruminant concentrate feeds. However, the rate of inclusion of distillery by-products is generally restricted by the presence of anti-feeding agents that can either confer a bitterness to the feed or reduce the availability of protein in the rumen and small intestine (Chamberlain and Wilkinson, 1996).

The use of distillery by-products in equine rations is limited (Leonard et al., 1975). Estimations of digestible energy of distillery by-products range from 11.5 to 14.2 MJ/kg DM (DLG, 1995) and concentrations of crude protein of greater than 250 g/kg DM may allow the products to be an alternative to soya-bean meal or dried skimmed milk powder (Frape, 1998). Wheat distiller's grains also contain a relatively high concentration of oil and copper which may be an important alternative energy and mineral supply to performance horses (DLG, 1995; Orme et al., 1997). Equids can however be very sensitive to the inclusion of novel feeds into the diet. The sensitivity to the novel feed or compound may be a taste-aversion response or a neophobic response (Launchbaugh, 1995). Randall et al. (1978) examined a range of novel compounds added to the diet of horses. Compounds with acidic or bitter tastes (for example acetic acid or quinine) were rejected as solutions but when added to solid food, higher concentrations of the compounds were tolerated. These observations have implications for the management of the horse in certain circumstances for example horses with chronic obstructive pulmonary disorder where the animal has to be fed diets that have been pre-soaked.

Ellis and Hill (2000) investigated the pattern of chewing and short-term intake rate of horses offered lucerne feeds (high-temperature or fermented), and observed an increase in comminution but a decrease in overall rate of ingestion of DM in horses offered the fermented feed compared to the dry feed. Also, when offered in a choice selection experiment (Hawkes et al., 1985), the dry lucerne feed was eaten in preference to the fermented feed. Horses can develop taste aversion learning to avoid certain feeds that could lead to a dysfunction in the process of ingestion or illness (Houpt, 1990) and these sensitivities may partially explain the commonly accepted concept of palatability ('like' or 'dislike') of feeds. The principal objectives of the experiment reported in this paper were to examine the effects on process of eating and pattern of feeding of horses offered concentrates containing distillery by-products at different levels of inclusion.

2. Material and methods

2.1. Experimental design

Two experiments were performed. The first experiment examined the effect of addition of dry wheat distiller's grains to the concentrate given to horses and the second study investigated the effect of feeding to horses the mixtures of concentrates after a period of soaking with water for 24 h. In both experiments, 10 horses (mean body weight 544 kg, S.E. 23.1 kg) were allocated to two 5×5 Latin squares with five horses per square and five concentrate treatments per square. Five ratios of inclusion of wheat distiller's grains were used in the experiment being 1.00:0, 0.75:0.25, 0.50:0.50, 0.25:0.75 and 0:1.00 for wheat distiller's grains/concentrate on a DM basis, respectively. Horses were offered 1.0 kg DM of concentrate mixtures according to the sequence of the Latin square design. No period of adjustment to the feeding stuff occurred and the concentrate mixtures were offered at 13:00 h. A period of 2 days between each treatment occurred with no inclusion of distillery by-product. The concentrate mixtures were offered to the animals for a period of 10 min via a feed tray (0.5 m diameter) placed on the floor of the stable at 13:00 h.

2.2. Animal management and feeds

The horses were housed individually and bedded on straw. The horses were offered a diet comprising 0.7 (7.0 kg DM/day) of medium quality perennial rye grass hay (Table 1 for composition) and 0.3 (3.0 kg DM/day) of concentrate. The chemical composition of the hay, concentrate and wheat distiller's grains are in Table 1. The concentrate was based on

Table 1
Chemical composition (g/kg DM unless otherwise stated) of hay and concentrates offered

	Hay	Concentrate	Wheat distiller's grains
DM (g DM/kg)	844	857	852
NDF	672	344	347
ADF	365	187	187
ADL	20.3	18.2	14.5
Crude fibre	427	109	76
Crude protein	87	129	279
Ash	92	68	54
Oil (AHEE)	21	52	126
Calcium	5.1	4.7	2.2
Phosphorus	2.2	3.4	3.8
Estimated ME (MJ/kg DM; ruminant)	8.8	11.7	12.5

wheat, barley, oats (cereal component 0.65 of DM), soya, sunflower seed and locust bean (protein feeds 0.25 of DM) and nutritionally improved straw and lucerne meal (0.10 of DM). The concentrate mixtures were offered either as a dry mixture (Experiment 1) or soaked with water (two parts concentrate DM to one part water w/w) for 24 h prior to feeding (Experiment 2) at 13:00 h. The concentrate feeds offered at 07:00 and 17:00 h contained no distillery by-product. The chemical composition of forage and concentrates were analysed according to the methods of Hill and Leaver (1999).

2.3. Measurements

After the period of 10 min of offer of concentrate mixtures, the refusals were weighed and dried at 100°C for 24 h to determine the rate of ingestion of concentrate DM. The behaviour of the horses was recorded continuously using a monochrome CCD camera (speed of 25 images per s) and a video recorder. The images were examined by developing an ethogram to analyse the detailed changes in position of the horse to the feed and the processes of chewing and eating (continuous sampling of behaviour). The data were classified into seven main types;

SO: sampling feed by olfaction (sniffing),
I: ingestion sampling (bites, nodding and blowing),
CT: chewing with tongue manipulation (head up position and chewing of feed with pre-molars),
C: chewing without manipulation of feed (head down position, rapid ingestion of feed),
IE: interaction with environment of the stable (head shaking, eating bedding, alert response),
L: Licking response — animal shows salivation response at end of feeding sequence,
RF: rejection of feed (animal moves away and shows no interest in eating).

Events I, CT and C were classified as behavioural types constituting the process of eating and therefore constituted the feeding bout. The behaviour associated with sampling of feeds (SO) was classified as the event that initiated feeding. However, reversion of feeding was determined if the animal resumed feeding (behavioural class I) after short periods of behaviour (25 s) not associated with feeding (IE or L).

2.4. Statistical procedures

In both experiments, analysis of variance (ANOVA) was applied to log 10 transformed data collated for the rate of ingestion (g DM/min), rate of chewing (number of chews/min), feed intake per bite (g DM eaten per number of bites recorded as behavioural events), feed intake per bout (g DM/bout) according to the model:

$$Yij = \mu + \beta i + \kappa j + \tau(\mathrm{t}) + \varepsilon ij$$

where Yij is the observation at the intersection of the ith row and the jth column and βi represents the row (period) effect, κj represents the column (animal) effect, $\tau(\mathrm{t})$ represents the treatment effect (represented in each row or column once) and εij the unaccounted error. In both experiments, the response to treatment was estimated on 28 error degrees of freedom (d.f.), with main effects of treatments (4 d.f.), periods (8 d.f.) and animals (8 d.f.) being considered by ANOVA. The effect of squares was removed accounting for one degree of freedom.

Transition matrices were calculated (frequencies of behavioural changes) from the behavioural observations according to Haccou and Meelis (1992).

Interaction with the environment (IE) and behaviour associated with termination of feeding (L and RF) were examined for occurrence during the period of offer. The relationships between mean ingestion bout length (duration of time spent in behavioural classifications I, CT and C) and category of preceding behavioural act were examined using Kruskal–Wallis ANOVA. Proportions of abortive feeding events (animal changes from behaviour I to any behavioural event not related to intake i.e. C or CT) in total number of behavioural events, shorter and longer than expected feeding bouts (bouts exceeding the duration of 1.96 s of mean calculated duration of feeding bout), interruptions of bouts by other behaviour and reversion to feeding after interruption of feeding caused by other behavioural events were calculated according to Kalueff (2000). All statistical analyses were performed using Unistat Version 4 (UNISTAT, 1995).

3. Results

3.1. Feed intake

3.1.1. Experiment 1: inclusion of dry distillery by-product

In Experiment 1, the inclusion of wheat distiller's grains into the concentrate component of the diet reduced significantly the rate of ingestion of feed DM ($P<0.01$; Table 2). A reduction in intake of DM per bout of feeding was also observed when all the concentrate DM was replaced by wheat distiller's grains ($P<0.01$). As the rate of eating declined with increasing level of addition of wheat distiller's grains, there was a reduction in the chews/g DM ($P<0.01$; Table 2). However, the rate of chewing of the different concentrates remained similar in all treatments with a mean (of all treatments) rate of chewing of 55 (S.E. 5.2) chews/min.

3.1.2. Experiment 2: effect of soaking concentrate mixtures

The effect of soaking the concentrate mixtures prior to feeding lead to a significant reduction in the rate of ingestion of feed DM when 0.50 of the concentrate DM was replaced by wheat distiller's grains ($P<0.001$; Table 3). The reduction of chews/g DM ($P<0.05$) was not however as great as expected if the results were considered with Experiment 1and the rate of chewing was reduced significantly ($P<0.05$) when all the concentrate was replaced with wheat distiller's grains (Table 3). The rate of chewing of the different concentrates remained similar in all treatments with a mean (of all treatments) rate of chewing of 53 (S.E. 6.9) chews/min except when all the concentrate was replaced by wheat distiller's grains. When the diet was totally replaced, chewing rate was reduced to 38 (S.E. 7.1) chews/min.

Table 2
Ingestion characteristics of horses offered varying levels of wheat distiller's grains in the concentrate: concentrate offered as dry feedingstuff

Inclusion of wheat distiller's grains (proportion of diet DM)	Ingestion rate (g DM/min)	g DM/eating bout	Ingestion rate (g DM/chew during eating bout)
0	203.1^{a}	110.0^{a}	3.7
0.25	171.6^{ab}	110.7^{a}	3.2
0.5	167.1^{b}	100.3^{a}	3.0
0.75	154.2^{b}	102.5^{a}	2.8
1.00	101.4^{c}	44.3^{b}	1.8
S.E.D.	14.84	11.43	

$^{a,b,c}P<0.05$ indicates level of significance of between treatment differences.

Table 3
Ingestion characteristics of horses offered varying levels of wheat distiller's grains in the concentrate: concentrate offered as wet (soaked) feedingstuff

Inclusion of wheat distiller's grains (proportion of diet DM)	Ingestion rate (g DM/min)	g DM/eating bout	Ingestion rate (g DM/chew during eating bout)
0	177.9^{a}	92.9^{a}	3.4
0.25	155.4^{a}	91.2^{a}	2.9
0.5	92.5^{b}	76.2^{ab}	1.7
0.75	55.2^{c}	62.5^{b}	1.1
1.00	39.2^{c}	18.6^{c}	1.0
S.E.D.	12.48	10.52	

$^{a,b,c}P<0.05$ indicates level of significance of between treatment differences.

3.2. Behavioural responses

3.2.1. Experiment 1: inclusion of dry distillery by-product

When dry wheat distiller's grains replaced all the concentrate DM, there was a reduction ($P<0.05$) in change from C to CT (0.326 to 0.254 for 0.75 and total replacement, respectively) and CT to C (0.298 to 0.228 for 0.75 and 1.0 replacement, respectively; Table 4). A concurrent increase in the proportion of behaviour associated with interaction with the environment was noted (C to IE; 0.185 to 0.224 for 0.75 and total substitution, respectively; Table 4).

The mean total number of feeding bouts increased with the inclusion of wheat distiller's grains into the concentrate when the rate of inclusion was increased from 0 to 0.50 of the concentrate DM. However the number of feeding bouts then remained relatively constant at even higher rates of inclusion of the distillery by-product (Table 5). Feeding events shorter than predicted occurred at a rate of 0.397 when no distillery by-product was added to the diet and increased to 0.479 ($P<0.05$) only when the concentrate was replaced completely by wheat distiller's grains. Also, the effect of preceding event (IE, L or RF) on the disruption of the processes of ingestion were significant, especially in the development of shorter than normal feeding bouts ($P<0.05$) when the diet was replaced totally by wheat distiller's grains. A similar pattern was noted with feeding bouts longer than predicted, however the incidence, decline in occurrence and effect of preceding event (IE and RF only) were lower than the observations made for shorter feeding bouts (Table 5).

The number of abortive feeding bouts (I) was very low in all treatments, on average accounting for less than 0.15 of all feeding bouts and the frequency of behavioural events not associated with eating interrupting feeding bouts was low and showed little variation between treatments (Table 5). Unusually, abortive feeding bouts did not seem to be affected by the preceding behavioural act (IE or RF). If feeding was interrupted by another behavioural event, resumption of feeding occurred with a mean frequency of 0.767. However, when 0.75 of the concentrate DM was substituted, there was an increase ($P<0.05$) in the rate of cessation of feeding (Table 5). Total replacement of the concentrate with wheat distiller's

Table 4
Transition matrices of horses (frequency of change in behaviour) offered varying levels of wheat distiller's grains in the concentrate: concentrate offered as dry feedingstuff

0 Wheat distiller's grains						
	SO[b]	CT	C	IE	L	RF
SO[a]		0.568	0.355	0.097		
CT			0.505	0.455		0.040
C		0.375		0.337		0.288
IE		0.195	0.261		0.187	0.357
L		0.140		0.550		0.310
RF				0.333	0.667	
0.25 Wheat distiller's grains						
	SO	CT	C	IE	L	RF
SO		0.588	0.344	0.068		
CT			0.444	0.425		0.131
C		0.385		0.332	0.069	0.214
IE		0.192	0.235		0.250	0.323
L		0.145		0.552		0.303
RF				0.345	0.655	
0.50 Wheat distiller's grains						
	SO	CT	C	IE	L	RF
SO		0.655	0.224	0.121		
CT			0.313	0.445	0.105	0.137
C		0.333		0.254	0.055	0.358
IE		0.201	0.225		0.255	0.319
L		0.185	0.200	0.455		0.160
RF				0.315	0.685	
0.75 Wheat distiller's grains						
SOCTCIELRF						
SO		0.768	0.145	0.087		
CT			0.298	0.552	0.088	0.062
C		0.326		0.185		0.489
IE		0.168	0.199		0.288	0.345
L		0.224	0.125	0.352		0.299
RF				0.295	0.705	
1.00 Wheat distiller's grains						
	SO	CT	C	IE	L	RF
SO0.7940.0760.130						
CT			0.228	0.521	0.227	0.024
C		0.254		0.224	0.227	0.295
IE		0.154	0.214		0.112	0.520
L	0.090	0.182	0.075	0.108		0.545
RF				0.272	0.728	

Behavioural frequencies underlined related to important transitions within process of eating.

[a] First behavioural event.

[b] Subsequent behavioural event (Haccou and Meelis, 1992).

Table 5
Incidence and type of abortive feeding of horses offered varying levels of wheat distiller's grains in the concentrate: concentrate offered as dry feedingstuff

	Inclusion of wheat distiller's grains into the concentrate				
	0	0.25	0.50	0.75	1.00
Total no. of feeding cycles per eating bout	5.9	6.2	6.3	6.8	7.5
Proportion of shorter than expected events	0.479	0.472	0.445	0.461	0.397
Proportion of longer than expected events	0.117	0.165	0.184	0.166	0.205
Proportion of abortive events	0.137	0.146	0.155	0.152	0.167
Proportion of interruptions with behaviour other than eating	0.127	0.129	0.138	0.112	0.155
Post interruption event reversion to feeding (frequency)	0.896	0.822	0.755	0.727	0.667

grain further increased the rate of cessation of feeding and was sensitive to the type of preceding act ($P<0.01$).

3.2.2. Experiment 2: effect of soaking concentrate mixtures

The transitions from C to CT and CT to C were significantly reduced ($P<0.001$ and $P<0.05$, respectively) by the addition of wheat distiller's grains to the concentrate. However the level at which dysfunction in feeding behaviour occurred differed between the transition sequences. In the case of C to CT the reduction in frequency occurred after 0.50 of the diet was replaced by distillery by-product, however the reverse behavioural sequence declined only when 0.75 of the diet was substituted (Table 6). An increase in the frequency of eating behaviour (CT and C) to interaction with the environment (IE) or rejection of feed (RF) was observed, however in contrast to the eating transitions, the increases were observed after 0.50 of the concentrate DM was replaced by wheat distiller's grains (Table 6).

The total number of feeding bouts increased when 0.25 of the concentrate was substituted with wheat distiller's grains, but then a decline in the number of bouts was noted when all the concentrate was substituted with distillery by-product (Table 7). The incidence of shorter than expected bout length was higher than in Experiment 1 and there was a reduction in incidence ($P<0.01$) when 0.75 of the concentrate was replaced with the distillery by-product. As in Experiment 1, the type of preceding event (IE, L or RF) affected significantly ($P<0.001$) the duration of the shorter than normal feeding bout, however the effect was noted when 0.50 of the concentrate was replaced by the distillery by-product. The incidence of longer than expected feeding bouts was similar to those observed in Experiment 1, however there was no marked decline in frequency (Table 7). However, the effect of the preceding act (IE, L or RF) on the development of longer than expected feeding bouts occurred when 0.75 of the concentrate was replaced by wheat distiller's grains.

In contrast to Experiment 1, there was a significant increase ($P<0.01$) in the frequency of abortive bouts of feeding (I). The increased incidence was first noted when 0.25 of the concentrate DM was replaced with wheat distiller's grains and continued until 0.75 of the concentrate was substituted. The increase in incidence of abortive feeding when greater than 0.75 of the concentrate DM was replaced with wheat distiller's grains was not significant (0.592 to 0.621 for 0.75 and complete substitution, respectively, $P>0.05$). The development of an abortive feeding bout was also sensitive to the preceding behavioural event. The rate of reversion to feeding after interruption of a feeding bout was reduced significantly ($P<0.001$) by the inclusion of wheat distiller's

Table 6
Transition matrices of horses (frequencies of changes in behaviour) offered varying levels of wheat distiller's grains in the concentrate: concentrate offered as wet (soaked) feedingstuff

	SO[b]	CT	C	IE	L	RF
0 Wheat distiller's grains						
	SO[b]	CT	C	IE	L	RF
SO[a]		0.535	0.310		0.065	0.090
CT			<u>0.544</u>	<u>0.427</u>		0.029
C		<u>0.324</u>		0.389		0.287
IE		<u>0.105</u>	0.227		0.137	0.531
L		0.110		0.640		0.250
RF				0.368	0.632	
0.25 Wheat distiller's grains						
	SO	CT	C	IE	L	RF
SO		0.577	0.264			0.159
CT			<u>0.512</u>	<u>0.374</u>	0.102	0.012
C		<u>0.365</u>		0.388	0.025	0.234
IE		<u>0.120</u>	0.269		0.144	0.467
L		0.137	0.105	0.450		0.308
RF				0.400	0.600	
0.50 Wheat distiller's grains						
	SO	CT	C	IE	L	RF
SO		0.700	0.200	0.100		
CT			<u>0.493</u>	<u>0.266</u>	0.105	0.137
C		<u>0.320</u>		0.277		0.403
IE		<u>0.226</u>	0.118		0.127	0.529
L		0.255	0.095	0.424		0.226
RF				0.441	0.559	
0.75 Wheat distiller's grains						
	SO	CT	C	IE	L	RF
SO		0.717	0.221	0.062		
CT			<u>0.217</u>	<u>0.553</u>	0.104	0.126
C		<u>0.322</u>		0.425		0.253
IE		<u>0.109</u>	0.127		0.212	0.552
L		0.100	0.105	0.521		0.274
RF				0.273	0.727	
1.00 Wheat distiller's grains						
	SO	CT	C	IE	L	RF
SO		0.695	0.055		0.110	0.140
CT			<u>0.167</u>	<u>0.617</u>	0.107	0.109
C		<u>0.127</u>		0.239	0.197	0.437
IE		<u>0.100</u>	0.153		0.207	0.540
L		0.126	0.125	0.276		0.473
RF				0.426	0.574	

Behavioural frequencies underlined related to important transitions within process of eating.
[a] First behavioural event.
[b] Subsequent behavioural event (Haccou and Meelis, 1992).

grains, with incidences being as low as approximately 0.24 when complete substitution of the base concentrate occurred (Table 7). The effect of the preceding event (IE and RF only) was again found to be significant ($P<0.05$) in the rate of resumption of feeding with modifications of behaviour being noted when 0.25 of the concentrate was replaced with wheat distiller's grains.

4. Discussion

Least cost formulation of concentrate diets for herbivores can lead to the incorporation of plant products not usually offered to the animal. Distillery by-products are the residual organic matter resulting from the fermentation of small grain cereals by the brewing and distillation industry (Leonard et al., 1975). They have been viewed by the ruminant and monogastric feed sector as an important source of carbohydrate, protein and lipid (Lonsdale, 1989). Incorporation of these products into equine diets may however be limited to certain sectors or types of feed even though the chemical compositions are similar (Table 1) to the more traditional high protein–oil supplements. The substitution of more expensive protein and oil sources (for instance soya bean meal) may be feasible with wheat distiller's grains (Ott et al., 1979; NRC, 1989; Cuddeford, 1999). Recent interest in the utilisation of oil by the performance horse could lead to an increase in the incorporation of distillery by-products into equine diets. The benefits of including oil supplements in performance horse diets are twofold; the increased energy density of the diet (Hintz, 1974) and the possible glucose sparing effect of elevated mobilisation of free fatty acids (Eaton et al., 1995; Orme et al., 1997; Harris, 1997).

The rate of eating or intake processes (bite weight, chews per bite or chews per kg DM) of horses offered forages or concentrates have not been measured extensively (Vernet et al., 1995). The rates of ingestion of concentrate feeds offered to horses in the experiments reported in this paper were comparable to ruminants (Tables 2 and 3 and Vernet et al., 1995; Grenet, 1989; Webster, 1979; McGraham, 1964). However the rate of ingestion of DM and processes of eating have been shown to be partially

Table 7
Incidence and type of abortive feeding of horses offered varying levels of wheat distiller's grains in the concentrate: Concentrate offered as wet (soaked) feedingstuff

	Inclusion of wheat distiller's grains into the concentrate				
	0	0.25	0.50	0.75	1.00
Total no. of feeding cycles per eating bout	6.1	8.5	9.3	10.4	15.3
Proportion of shorter than expected events	0.508	0.553	0.575	0.281	0.264
Proportion of longer than expected events	0.230	0.224	0.260	0.203	0.151
Proportion of abortive events	0.016	0.211	0.388	0.592	0.621
Proportion of interruptions with behaviour other than eating	0.131	0.188	0.247	0.484	0.491
Post interruption event reversion to feeding (frequency)	0.750	0.533	0.375	0.313	0.235

dependent on the presentation of the feed (Tables 2 and 3) and the level of inclusion of the feed. The rate of ingestion of concentrates in general was similar to those observed by Vermorel and Mormede (1991), however when the addition of distillery by-product exceeded a certain level (0.75 in dry feeding system and 0.5 in wet feeding system), a reduction in the rate of ingestion was noted. It is also important to note that there may be differences in the rate of ingestion during the feeding bout (von Meyer et al., 1975; Vermorel and Mormede, 1991), however the present study did not address this issue. Horses are not, by nature, meal or bout feeders but so-called 'trickle' feeders and therefore human intervention has attempted to alter the pattern of feeding. Management of the horse in the stable environment or for athletic performance has indirectly altered the feeding behaviour of the horse. Human intervention has attempted to change the animal to a meal bout feeding strategy, by feeding discrete concentrate meals twice or three times daily while offering hay at a restricted level of feeding to maintain fibre intake primarily (Frape, 1998). Bout feeding strategies have the advantage in providing exact levels of digestible energy and amino acids; however, do they optimise the utilisation of the nutrients?

The process of ingestion of feed over a long duration of time ('trickle-feeding') reflects the anatomy and physiology of the digestive tract (Frape, 1998). Equids are colonic fermenters and therefore more efficient than ruminants in capture of energy substrates, especially when diets of very low or very high nutritive value are offered (Van Soest, 1994; Russell and Gahr, 1999). The rate of ingestion of DM of dry feed is higher than that of wet feed (Tables 2 and 3) reflecting a difference in biomechanical properties of wet and dry feed as well as the modification of behaviour of feeding (Tables 4 and 6; Lachica et al., 1995). Vernet et al. (1995) suggested that the type, structure, chemical composition and digestibility of the feed affects the ingestion rate as time is required for the animal to grip the feed, chew and make the bolus. The magnitude in decline of rate of ingestion of concentrate DM depended on the presentation of the feed. Rates of addition of 0.75 (dry) and 0.50 (wet) reduced the rate of ingestion of feed DM. However, the processes involved in the reduction of rate of ingestion are more complex than the preceding statement suggests and may reflect modifications of the process of eating without a change in the rate the food is processed (Table 4 and 6; Houpt, 1990; Albright, 1993; Launchbaugh, 1995).

Few papers have examined in detail the behavioural processes of eating of concentrate feeds by horses (Randall et al., 1978; Schryver et al., 1987; Ellis et al., 2000; Ellis and Hill, 2000). No evidence of neophobia was observed in the behavioural patterns of ingestion of the horses used in the experiments. If neophobia is classified by periods of low or rapidly accelerating intake of feed, even at the highest rate of inclusion of the dry distillery by-product, the duration and pattern of feeding was not altered. The pattern of intake was disrupted more frequently by other non-ingestive behavioural patterns (Tables 4–7) but little variation in the bout length was observed. When the concentrate was soaked, there may be circumstantial evidence of neophobia. The inclusion rate of distillery by-product, the incidence of shorter than expected feeding cycles and the strong influence of preceding act on reversion to feeding could suggest neophobia only when distillery by-product was included as the sole concentrate. The current experiments did not examine the consequences of offering distillery by-products in the diets of horses on the general pattern and duration of nycthemeral ingestion of the total diet. Therefore, the implications of incorporation of distillery by-products to rations of horses have to be evaluated further with respect to commercial utilisation of the by-product.

5. Conclusions

If horses are to be managed intensively utilising concentrates to provide the majority of digestible energy and protein, the process of formulation must consider three factors, the acceptability of the concentrate to the animal, the nutritive value and the cost. Least cost formulation will lead to the use of novel plant products in the concentrate feed either to manipulate the digestible energy supply or to improve the supply of amino acids and protein. However, refinements in the nutritive value are limited by the acceptability of the feedingstuff to the animal. If alterations in the behavioural processes controlling ingestion are too great, the feed will have limited value to the equine industry.

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