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DAIRY RESEARCH HIGHLIGHTS

Barley Grain for Dairy Cattle

Corn, barley and sorghum are the principal feed grains used in dairy diets. Although they are primarily used as energy sources due to their high starch content,[27] they are also important sources of protein, especially in the case of barley. The relatively high fibre and protein content of barley and the rapid digestion of barley starch in the rumen need to be taken into account when barley replaces corn in dairy cattle diets. Barley-based diets can support similar milk yields and can be more cost effective than those based on corn.

Composition of barley

Table 1 summarizes starch and crude protein contents of feed grains.[10] Barley has a higher crude protein (CP) and a lower starch concentration than corn or sorghum. The mean starch content of 60 barley cultivars examined at the University of Alberta[15] was 55.2 with a range of 48.3 to 62.5% (see article **1B2**). Crude protein content in the same group of samples ranged from 10.8 to 16.2 with a mean of 13.3%. Besides being higher in CP and lower in starch compared with corn or sorghum, barley starch is more completely digested in the rumen. This can have important implications for the dietary inclusion level of barley, the optimal method of processing and for microbial protein synthesis and milk composition.

Digestion and utilization of barley

Because barley starch is rapidly digested in the rumen, starch flow to the intestine is much less for ruminants fed barley compared with those fed corn or sorghum. Our evaluation of barley cultivars[15] showed that, compared to corn, barley has a larger soluble dry matter (DM) fraction and a 3-fold faster rate of DM degradation.

FEEDSTUFF	MODAL VALUE AND RANGE Starch	Crude Protein
	----- % of Dry Matter	-----
Corn grain	72 (65-76)	10.0 (9.3-10.1)
Sorghum grain	72 (68-80)	10.5 (9.5-12.0)
Wheat grain	77 (66-82)	14
Barley grain	57 (55-74)	12.0 (10.0-19.5)
Oats grain	58 (45-69)	12.6 (12.5-12.8)

Table 1 : Starch and CP content of grains.[10]

The influence of starch source on the site of starch digestion is clearly illustrated by the studies summarized in table 2. Lactating cows were fed high-grain diets in which barley or corn were the the sole grain source. In both studies, ruminal and total tract starch digestibility was significantly higher while postruminal starch digestibility was significantly lower for the barley based rations.

Data in table 3 summarise the effect of different processing methods on the extent of starch digestion in the rumen, intestine and the total tract when animals were fed barley, corn, sorghum, wheat or oats. The lowest total tract digestibility was observed for sorghum and the highest overall for wheat and oats. Total tract digestibility of barley, wheat and oats starch is generally quite high and is not markedly influenced by method of processing. Similarly, comparison of rolled dry barley with rolled or ground high moisture barley demonstrated consistently high total tract starch digestibilities (table 4).[12]

Steam rolling of barley, wheat and oats appears to have a relatively minor effect on the extent of ruminal digestion compared to those observed when corn or sorghum are processed with heat

	McCarthy et al.[17] BARLEY	CORN	Overton et al.[23] BARLEY	CORN
Dry matter intake, kg/day[a]	21	24	20	23
Starch Intake, kg/day[a]	8.4	10.6	6.7	7.5
Apparently digested in rumen, kg/day[a]	6.5	5.2	5.0	3.2
.... percent of starch intake[a]	77.0	49.2	74.4	41.9
Passage to Duodenum,kg/day[a]	1.9	5.4	1.7	4.3
Apparently digested postruminally, kg/day[a]	1.6	4.7	1.4	3.6
.... percent of starch intake[a]	19.7	44.0	21.8	49.0
Apparently digested in the total digestive tract, ... percent of starch intake[a]	96.8	93.2	96.2	90.8

[a]Means differ significantly (P <.01) between corn and barley.

Table 2 : Ruminal and postruminal digestion of barley and corn starch in lactating dairy cows.

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and/or steam.[30] The extent of ruminal digestion of grains may also be influenced by their level of inclusion in the diet; at higher levels ruminal escape of starch appears to be enhanced. More comprehensive reviews of barley digestion and utilization can be found in references 14 and 21.

The impact of rapid ruminal digestion of barley starch on the nutritional value of barley is an area of considerable debate among nutritionists. The end products of starch digestion in the rumen are volatile fatty acids and lactate whereas starch digestion in the intestine yields glucose. Theoretically, the latter is a more efficient process. However, any gains in starch utilization efficiency appear to be offset by the greater microbial protein production arising from increased energy availability in the rumen. Based on the results of production studies, the site of starch digestion does not have a major impact on the nutritional value of barley. However, based on the rapid rate of ruminal barley starch digestion, nutritionists are concerned that substitution of barley for corn in the diet of lactating dairy cows may result in low rumen pH, reduced fibre digestion, DM intake (DMI) and milk fat percent.

In a trial where cows were fed 50% chopped alfalfa hay and 50% concentrate, rumen pH, milk yield and milk fat were not affected when corn was replaced by barley at 40.3% of dietary DM.[4] Although Rode and Satter[28] found a trend towards reduced rumen pH when barley replaced corn in the diet of lactating cows, this reduction was not significant.

	DRY ROLLED	HIGH MOISTURE ROLLED	HIGH MOISTURE GROUND
Barley,% of diet DM	51	51	61
Dry Matter Intake, kg/day			
experiment 1	18.8	18.0	NA
experiment 2	18.5	18.1	17.9
Digestibility, % (exp 2)			
Dry Matter	67.9	68.5	66.0
Starch	97.2	96.2	96.2
Milk Yield, kg/day			
experiment 1	31.1	32.1	NA
experiment 2	36.1	33.4	35.5
Fat Yield, kg/day			
experiment 1	0.76	0.83	NA
experiment 2	0.74	0.70	0.68
Protein Yield, kg/day			
experiment 1	1.00	1.02	NA
experiment 2	1.06	1.00	1.06

Table 4 : Digestion and utilization of dry vs. high moisture barley.[12]

More recent work[23] reported a linear decrease in rumen pH as the proportion of barley starch increased at the expense of corn starch in lactating cow diets. Rumen pH was reduced from 5.91 to 5.82 when 25% corn starch was replaced with barley and was further reduced to 5.79 when corn starch was completely replaced by barley starch. Dry matter intake and milk production declined linearly when barley provided

GRAIN	PROCESSING METHOD	STARCH INTAKE kg/day	DIGESTIBILITY RUMEN % intake	DIGESTIBILITY POSTRUMEN % intake	DIGESTIBILITY POSTRUMEN % entering	DIGESTIBILITY TOTAL %	REF
Barley	Dry Rolled	4.27	79.3	14.3	73.4	93.4	10
	Steam Rolled	4.53	84.6	13.6	88.0	98.2	10
	Steam Rolled	8.4	77.0	19.7	84.0	96.8	17
	Dry Rolled	6.3				97.2	12
	Steam Rolled	6.7	74.4	21.8	82.3	96.2	23
Corn	Dry Rolled	2.59 ±0.70	75.3 ±7.9	17.2 ±6.5	65.9 ±16.7	92.5 ±3.3	10
	Steam Flaked	2.20 ±0.52	84.8 ±4.1	14.1 ±3.7	92.6 ±4.1	98.9 ±0.8	10
	High Moisture	3.89	89.9	6.3	67.8	95.3	10
	Ground	10.65	49.5	44.0	86.5	93.5	17
	Ground	7.5	41.9	49.0	83.7	90.8	12
Sorghum	Dry Rolled	4.84 ±1.55	51.9 ±23.5	27.0 ±11.0	62.5 ±16.2	87.1 ± 5.4	10
	Steam Flaked	4.80	78.3	19.8	90.0	98.0	10
	High Moist Ground	3.64	73.2	19.6	46.1	92.8	10
	Ground	3.81	70.0	15.4	51.0	91.0	10
Wheat	Dry Rolled	2.94	88.3	9.9	85.4	98.2	10
	Steam Rolled	2.87	88.1	10.0	88.2	98.6	10
Oats	Dry Rolled	1.53	92.7	5.6	76.3	98.3	10
	Steam Rolled	1.49	94.0	4.5	78.8	98.8	10

Table 3 : Digestibility coefficients for barley, corn, sorghun, wheat, and oats starch.

75% and 100% of the starch. The diets were fed as total mixed rations and contained 30% alfalfa silage, 15% corn silage and 33% starch on a DM basis.

These potential detrimental effects of feeding high levels of barley grain can be overcome through:

- the use of high buffer capacity forages like alfalfa;
- the use of total mixed rations;
- balancing rations to provide adequate effective fibre, judicious use of high acid cereal silages, and;
- the use of ruminal buffers or alkalizing agents..

Production responses to barley

A trial at the University of Saskatchewan[3] examined the effects of barley processing on production reponses. Milk production, milk fat content and yield, concentrate intake and total DMI were not different when barley was steam rolled as compared to dry rolled. When the grain was ground and pelleted there was a tendency toward increased milk yield, however milk fat content was significantly depressed. As a consequence, 4% FCM production was not different between the pelleted and rolled grains.

----------- FORAGE -----------		CONCENTRATE		STARCH							
SOURCE	DMI kg/d	STARCH SOURCE	DMI kg/d	SOURCE % conc	% diet	DMI ----- kg/d -----	MILK	FAT ------ % ------	PROT	COWS	REF
Brome Grass Hay	9.4	Barley	12.3	66	37	21.8	28.8	2.65	3.06	18	11
	8.8	Corn	13.1	64	37	22.4	29.5	2.71	3.05	18	
Alfalfa-grass Silage	9.3	Barley	11.4	89	49	20.7	32.5	2.96	3.16	8	17
+ Corn Silage	10.7	Corn	13.1	82	45	23.8	35.6	2.72	3.18	8	
Corn Silage	9.6	Barley	9.6	70	35	19.2	31.8	3.22	3.08	38	2
+ Alfalfa Hay	10.3	Corn	10.3	63	32	20.7	32.1	3.38	3.10	38	
Corn Silage (80%)	10.8-15.2	Barley	6.5-10.8	66		21.7	29.1	3.25	3.36	22	4
+ Alfalfa Hay (20%)	11.0-15.4	Corn	6.6-11.0	60		22.0	29.7	3.44	3.36	24	
Alfalfa Hay (50%)	11.5	Barley	14.6	64	36	26.1	40.9	3.38	3.11	†	7
+ Alfalfa Silage (50%)	12.0	Corn	15.3	44	25	27.3	40.4	3.43	3.13	†	
Alfalfa Hay and	8.6	Barley	15.9	58	38	24.5	36.1	3.0	3.0	16	8
Cotton Seed Hulls	8.4	Milo	15.6	55	36	24.0	34.4	3.5	2.9	16	
Alfalfa Hay	8.9	Wheat	7.9	96	45	16.8	23.3	3.93	3.69	5	31
	8.8	Corn	7.6	96	44	16.5	23.9	3.83	3.53	5	
	8.9	Milo	7.7	96	45	16.6	23.7	3.77	3.66	5	
	8.9	Oats	8.2	95	46	17.1	23.2	3.14	3.45	5	
	8.9	Barley	7.9	96	45	16.8	23.5	3.97	3.58	5	
Grass Hay	6.0	Barley	9.0	82			16.1	4.49	3.15	16	29
	6.0	Corn	9.0	78			18.9	4.04	3.00	16	
	1.4	Barley	12.9	87			20.6	2.06	3.03	16	
	1.4	Corn	12.9	83			15.6	2.97	3.43	16	
Alfalfa Hay	9.2	Barley	9.2	80	40	18.3	27.4	2.81	3.23	8	4
	9.2	Corn	9.2	65	33	18.5	28.0	3.01	3.21	8	
Oat Silage	5.8	Barley	11.1	91	60	16.9	22.9	4.54	3.52	18	19
+ Alfalfa Hay	6.2	Wheat	11.9	91	60	18.1	24.0	4.19	3.84	18	
	6.1	Oats	11.6	91	60	17.7	25.1	4.72	3.12	18	
Grass Hay	3.6	Barley	8.9	64			15.9	4.20	3.39	8	18
	3.5	Oats	9.5	16			16.9	3.79	3.16	8	
Alfalfa Silage	9.9	Barley	10.8	97			22.9	3.41	3.22	6	32
	14.2	Corn	7.0	89			23.3	3.75	3.20	6	
Corn Silage	9.4	Barley	9.4	70	35	18.8	31.6	3.36	3.00	20	1
+ Alfalfa Hay	10.2	Corn	10.2	63	31	20.4	32.8	3.37	3.05	20	
Grass Silage	12.3	Barley	12.4	50	25	24.7	38.2	4.25	3.53	16	5
+ Corn Silage	12.2	Corn	1 2.2	50	25	24.4	37.1	4.34	3.55	16	
Alfalfa Silage + Corn	9.3	Barley	10.3	91	49	19.6	22.6	3.91	3.69	5	23
Silage + Soybean Hulls	11.3	Corn	11.5	172	40	22.8	26.9	3.58	3.36	5	

†23 cows were assigned to four treatments: corn plus four barley diets differing in density

Table 5 : Milk production responses to feeding barley, corn and other starch sources.

Data in table 6 summarize production trials in which barley replaced corn or other grain sources in the diet of lactating cows. Of the 15 trials evaluated, 12 involved comparisons with corn, one with milo, and two with wheat and oats. The 12 studies comparing barley and corn included two diets containing other grain sources. When barley was compared with milo, oats, or wheat, no significant differences in milk yield were observed. In the 10 studies which included only barley or corn as treatments, milk yield was similar in eight of the studies.

The two studies reporting higher milk yields for cows fed corn were McCarthy et al.[17] and Overton et al.[23] McCarthy et al.[17] reported milk yields of 35.6 kg/day for cows fed corn compared to 32.5 kg/day for those fed barley. In this study, concentrate was included at 55% of the diet with barley or corn contributing 49 or 45% of the total diet, respectively. Overton et al.[23] fed five experimental diets where the corn:barley ratio ranged from 100:0 to 0:100. The corn based diets were supplemented with soybean meal and soybean hulls to achieve similar fibre and CP levels to that present in the barley based diets. Cows fed the corn based diets had higher DM intakes and milk yields than those fed the barley based diets. As differences in protein and fibre sources were confounded with source of starch it is difficult to determine the extent to which observed differences in DM intake, milk yield and milk composition could be attributed to starch source.

Based on these data it can be concluded that barley can promote similar levels of milk production to that observed for corn.

In the studies summarized in table 6 the greatest impact of grain source was on milk fat percent. In some studies, cows fed corn as the grain sources had higher or tended to have higher milk fat percentages than those fed barley whereas in other studies no effect was apparent. Differential effects may have been related to the level of inclusion of barley or corn in the diet with the effects being more pronounced at high dietary inclusion levels of grain. Observed differences in milk fat content undoubtedly reflect differences in site and extent of digestion of these two grain sources.[21] Barley tends to promote higher propionic acid production in the rumen at the expense of acetate. This in turn may reduce the availability of precursors for milk fat synthesis in the mammary gland. Indeed, differences in site of digestion can also influence milk composition. The fatty acid composition of milk from cows fed barley had higher levels of C16:0 and lower levels of C18:0 and C18:1 than milk from cows fed corn.[11] Comparisons between barley and corn showed no evidence of an influence of grain source on milk protein percentage.

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