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Distillers dried by-products from barley as protein source for ruminants

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Abstract. The nutritive value of barley-derived distillers dried grains (BDDG) and distillers dried grains with solubles (BDDGS) was assessed in digestibility and *in sacco* rumen degradability experiments. The crude protein contents of BDDG and BDDGS were 26.4 % and 29.9 %, and the crude fibre contents 19.9 % and 17.4 % in DM, respectively. The ADF and NDF contents averaged 33 % and 67 % and the lignin 7.6 % of DM. The digestibilities of the nutrients were measured with four rams in both trials and the distillers by-products were given at two levels, 33 % ad 66 %, in hay-based rations. The digestibilities in BDDG and BDDGS were, respectively, 43.1 % and 47.7 % for organic matter, 64.5 % and 66.5 % for crude protein, and 86.7 % and 87.9 % for ether extract. Due to the low digestibilities, the energy values of the two products were low, 0.58 FU/kg DM and 8.0 MJ/kg for both, and DCP/FU 295 g for BDDG and 347 g for BDDGS. The rumen degradability of the crude protein of BDDG and BDDGS was found to be low and significantly lower than the degradability of wheat distillery by-products ($P < 0.05$). Fine grinding gave more rapid degradability. Due to the low total digestibility and reduced lysine content, BDDG and BDDGS may have limited protein availability when given as supplements.

Introduction

The desire to increase the domestic protein supply to meet the demand for cattle feeding has stimulated interest in utilizing various agro-industrial by-products. Distillers feeds consist of fermentation residues from the distilling industry. During yeast fermentation of grain nearly all starch is removed, so that the protein and other components become more cocentrated. Distillers dried grains (DDG) and brewers spent grains (BSG) are major by-products from commercial ethanol distilling and the brewing industry. At present little information is available concerning the characteristics and nutritional value of barley distillers by-products. However, barley is the main raw material in the integrated starch-ethanol production planned to start in 1987 in Finland, with an expected of 61700 tn DM feedstuff annual yield (LEHMUSSAARI 1984). Distillers grains from barley contain the fibrous barley hulls, which makes barley-derived products very

Index words: Barley distillers grain, barley distillers grains with solubles, protein supplement, ethanol fermentation by-products, ruminant nutrition.

different from those from wheat or other grains and also increases the residue yield (KAUFMANN and EMEIS 1965, NEWMAN and GRAS 1983).

The distillery by-products studied in the present experiments are quite different from the feedstuffs that will be obtained from the new process, but they should provide information on the nutritional value of ethanol fermentation residues from barley as protein supplements for ruminants.

Materials and methods

Barley-derived distillers dried grains (BDDG) and distillers dried grains with solubles (BDDGS) were obtained from OY Alko AB's Koskenkorva factory. From the whole barley stillage, the residues from the distillation process, the coarse grains were separated and dried to produce BDDG and the solubles were condensed by evaporating to produce BDDGS together with dried distillers grains. Drying was done in a drum dryer. Two digestibility and nitrogen balance trials were conducted, with four rams in each trial, to determine the nutritive value of barley distillers by-products. Each trial consisted of two 21-day periods. During the first period BDDG or BDDGS composed 33 % of diet dry matter (DM) and hay 67 %; during the second period BDDG or BDDGS composed 67 % of diet DM and hay 33 %. The ration was given at maintenance level, 50 g DM/kg $W^{0.75}$. Finn sheep rams weighing on average 83 kg received 1400 g of the BDDG diet daily, and Texel rams weighing on average 44 kg received 875 g of the BDDGS diet daily. In addition mineral mixture was given daily and water was available *ad libitum.*

Each of the two periods consisted of a 14-d adjustment period followed by a 7-d collection period, when faeces and urine were recorded daily and subsampled for analysis. Samples of the experimental feeds were taken for every period.

The dry matter contents were determined by oven heating at 103 °C and samples for feed analysis were dried in a vacuum oven at 50 °C. The feed analyses were made on the dried samples by standard methods. Acid detergent fibre (ADF), neutral detergent fibre (NDF) and lignin (ADL) were determined according to COERING and VAN SOEST (1970). Crude lignin and water-soluble carbohydrates were determined as described by SALO (1965). Hay was analysed for *in vitro* digestibility according to TILLEY and TERRY (1963). *In sacco* rumen degradability of barley and wheat distillery by-products was determined in a nylon bag (porosity 40 μm) as described by SETÄLÄ (1983).

The digestibilities for the distillers by-products were calculated by the regression technique from diet digestibilities, as the experimental rations composed different proportions of the individual feeds (SCHNEIDER and FLATT 1975). Effective protein degradability was calculated using a 0.04 dilution rate from the rumen according to the equation of KRISTENSEN et al. (1982).

Results and discussion

The chemical composition of the experimental feeds used in the digestibility trials are shown in Table 1. The barley distillers by-products had quite a high percentage of crude protein, 26—30 %, but very high contents of crude fibre, 17—20 % of DM. The lignin content was high, too, 7—8 %. The starch has been removed by the fermentation process and the proportions of the other constituents of barley are two to three times as great as in the original material. Barley hulls make up about 10—12 % of the grain and its chemical composition is comparable to straw (SALO and KOTILAINEN 1970), so that this fibrous material reduces the feed value of barley distillers grains. The chemical compositions of BDDG and BDDGS were similar. Wheat distillers grains had a higher crude protein content but a much lower

Table 1. Chemical composition of barley dried distillers grain (BDDG), barley dried distillers grain with solubles (BDDGS) and hay used in digestibility experiments.

	BDDG	BDDGS	Hay, experiment I	Hay, experiment II
Dry matter	94.8	94.5	85.0	84.1
Ash	4.1	4.4	6.1	5.6
Crude protein	26.4	29.9	7.8	5.9
True protein	21.6	27.6	5.8	4.3
Ether extract	7.7	6.4	1.9	1.4
Crude fibre	19.9	17.4	38.3	36.9
Nitrogen-free extract	41.9	41.9	45.9	50.2
Acid detergent fibre	33.0	33.8		
Neutral detergent fibre	61.9	69.4		
Acid detergent lignin	9.9	13.5		
Lignin	7.4	7.9		
Water-soluble carbohydrates	2.0	5.3		
In vitro digestibility				
Dry matter			64.9	66.6
Organic matter			63.5	64.6

crude fibre content (Table 4). Moss and Kezar (1982) reported 23 % crude protein and 21 % crude fibre for wet distillers grains from barley ethanol. The ADF and NDF of the present BDDG were a little higher than those found by Newman and Gras (1983). Water-soluble carbohydrates were low, which indicates that the fermentation was efficient.

Table 2 presents the digestibility values of the diets containing distillery by-products at two levels of the ration 33 and 67 %. The digestibilities for BDDG and BDDGS were calculated by the regression technique from the quantities of each feed consumed in each digestion trial and the digestion coefficients of the rations. This method eliminates the associative effects on digestibility of different feeds given together (Schneider and Flatt 1975).

The digestibilities of both BDDG and BDDGS were found to be low: for organic matter 43 % and 48 %, respectively, and for

Table 2. Digestibility coefficients of the diets including dried barley distillers grain (BDDG) or dried barley distillers grain with solubles (BDDGS) at two levels, 33 and 67 % diet of dry matter.

	33 % BDDG 67 % hay		67 % BDDG 33 % hay		33 % BDDGS 67 % hay		67 % BDDGS 33 % hay	
	x̄	s.d.	x̄	s.d.	x̄	s.d.	x̄	s.d.
Digestibilities								
Dry matter	57.9	1.7	50.0	2.5	58.1	1.0	52.1	1.9
Organic matter	58.8	1.6	50.9	2.4	59.7	1.2	53.9	1.9
Ash	43.7	3.3	34.3	5.1	27.9	13.1	16.4	7.1
Crude protein	67.9	0.8	65.3	3.1	58.2	1.1	63.8	1.9
Ether extract	79.9	1.6	83.8	2.4	83.5	1.6	86.2	1.9
Crude fibre	46.0	1.3	26.0	3.9	57.7	1.5	42.4	2.6
N.F.E.	63.1	3.0	55.6	1.9	59.9	1.0	51.6	1.9
Nitrogen balance, g/d	1.8	1.0	—6.1	3.4	2.9	0.4	4.8	1.1
Biological value	44.6	3.9	13.0	11.3	60.8	7.5	48.0	3.9

Table 3. Digestibility coefficients of barley distillers grain (BDDG) and barley distillers grain with solubles (BDDGS) calculated by regression and their feed values.

	BDDG	BDDGS
Digestibilities		
Dry matter	42.5	47.5
Organic matter	43.1	47.7
Crude protein	64.5	66.6
Ether extract	86.7	87.9
Crude fibre	—12.2	10.6
N.F.E.	47.8	41.5
Feed values		
FU/kg DM	0.576	0.578
kg/FU	1.74	1.73
DCP % of DM	17.0	20.0
DCPg/FU	295	347
van Es system		
GE, MJ/kg DM	20.47	20.33
ME, MJ/kg DM	8.16	8.15
q = ME/GE	0.40	0.40
NEW, MJ/kg DM	3.98	3.99
NEL, MJ/kg DM	4.45	4.45
km,f	0.49	0.49
k_l	0.56	0.56
ME, MJ/kg MAFF	8.01	8.02
ME, MJ/kg DM Axelsson	8.63	8.69

crude protein 65 % and 67 %. The values in this experiment were a little lower than the Canadian results for barley distillers by-products, whose DM digestibility was 54.5 % and whose crude protein value was 78.3 % (Moss and Kezar 1982). The values for wheat DDGS were 70—72 % for organic matter and 78—80 % for crude protein (Salo et al. 1982). The low digestibilities of BDDG and BDDGS may be attributed to their fibrous hull contents and to the rapid rate of passage of small particles through the forestomachs (Poutiainen 1968).

Due to the low digestibilities, the energy values were low. The calculated net energy values were the same fot both products, 0.58 FU/kg DM. In the net energy evaluation the value number 0.80 was used, which is given for distillery by-products in feed tables (Salo et al. 1982). The value is evidently overestimated for barley by-products, because the equation of Van Es (1978) yielded only 0.53 for the metabolization of gross energy compared with 0.95 for barley. Ettala and Näsi (1983) performed feeding experiments with growing cattle to evaluate some agro-industrial by-products as feed and found that BDDGS had a low nutritive value when used as supplement in a high straw diet. When cattle given BDDGS 1.5 kg plus 1.5 kg barley were compared with cattle receiving 3.0 kg barley supplemented with NPN, the daily gains averaged 786 g and 904 g, respectively. The dressing percentages were low for both treatments, 42.4 and 44.3 %. Thomas (1982), however, found that the performances with BDDG were similar to those with soybean as protein supplement for cattle.

The nitrogen balances were positive in the rams on rations containing BDDGS and increased with greater inclusion. The Texel rams gained 1.8 kg on average during the experiment. The rams on rations containing BDDG had a slightly positive balance at the

Table 4. Chemical composition of different barley and wheat distillers products used in *in sacco* rumen degradability measurements.

	Barley			Wheat		
	DDG	DDGS	DDGS fine	DDG	DDGS	DDGS fine
Dry matter	95.5	93.5	96.1	94.9	93.9	94.6
Ash	3.9	4.4	7.2	7.8	4.9	6.9
Crude protein	28.6	31.1	35.4	40.6	45.8	42.8
Ether extract	5.0	5.0	5.3	5.4	5.1	5.1
Crude fibre	17.4	16.1	11.2	9.9	10.8	10.1
N.F.E.	45.1	43.3	40.8	36.4	33.4	35.0

lower level but a negative balance at the higher level. The biological values were rather low for all the rations (Table 2). The protein values were fairly suitable, 295 g DCP/FU for BDDG and 347 g DCP/FU for BDDGS. Wheat DDGS has a FU value of 0.72/kg DM and 336 g DCP/FU (Salo et al. 1982).

The barley distillers grains had low *in sacco* rumen degradability (Table 5). The high temperatures during boiling and drying reduce the degradation of crude protein. Grain protein generally has rapid and high degradation in the rumen (Salo et al. 1982). Low degradability is suitable for ruminant protein supplement. BDDG and BDDGS had reduced contents of lysine, 3.2 and 1.7 g/16 g N and, the availability of lysine was very low (Näsi 1984). The protein in barley distillers by-products, although resistant to microbial degradation in the rumen, has limited value as a protein supplement because of its low digestibility and availability. WDDGS also had low degradability. This may result from the treatments during processing, especially condensing of solubles during drying. Fine grinding (average particle size 0.5 mm) was also compared with normal grinding (average particle size 1.0 mm). Fine grinding gave products with a lower fibre content but higher protein content, indicating that partial fractionation had occurred (Table 4). Fine grinding led to rapid and almost full degradation. This is partly due to the very small particle size. The solubility of the DM of these products in water was 64.6 % for fine WDDGS and 42.7 % for fine BDDGS. The corresponding values for WDDG and WDDGS were 34.8 % and 30.0 %, and for BDDG 21.7 % and BDDGS 22.7 %, respectively. In the feed tables of Salo et al. (1982) the degradability of the crude protein of DDGS is given as 60 % in two hours and the total degradability as 65 %. Waller et al. (1980) have shown that, due to its low rumen degradability, corn DDGS fed together with urea is comparable to soybean meal as a protein supplement for steers. Corn

Table 5. *In sacco* rumen degradability of barley and wheat distillers grain without of with solubles.

	Dry matter				Organic matter				Crude protein				Efficient protein degradability			
	2 h	6 h	18 h	24 h	2 h	6 h	18 h	24 h	2 h	6 h	18 h	24 h	2 h	6 h	18 h	24 h
Barley																
BDDG	21.4^{fl}	24.6^{fk}	28.4^{fl}	35.6^{dj}	21.0^{fl}	23.8^{fk}	27.8^{fk}	35.2^{dj}	29.7^{ej}	31.7^{dj}	37.9^{dejk}	44.1^{dj}	28.5^{ek}	30.2^{dj}	34.0^{dj}	36.5^{dj}
BDDGS	27.1^{ek}	29.6^{ej}	34.7^{ek}	36.0^{dj}	26.3^{ek}	27.5^{ek}	33.8^{ej}	35.1^{dj}	33.2^{dj}	33.0^{dj}	40.5^{dj}	40.0^{dj}	31.8^{dj}	31.7^{dj}	36.3^{dj}	36.3^{dj}
BDDGS fine	53.7^{ci}	56.9^{ch}	57.5^{ci}	67.8^{bh}	51.5^{ci}	55.0^{ci}	55.7^{ch}	66.9^{bh}	62.8^{bh}	66.0^{bh}	67.5^{bh}	76.7^{bh}	60.5^{bh}	65.5^{bh}	66.4^{bh}	70.2^{bh}
Wheat																
WDDG	59.1^{bh}	60.7^{bh}	61.8^{bh}	70.8^{bh}	57.5^{bh}	58.7^{bh}	59.8^{bh}	69.2^{bh}	50.0^{ci}	51.3^{ci}	54.4^{ci}	67.6^{ci}	48.0^{ci}	49.1^{ci}	51.0^{ci}	56.3^{ci}
WDDGS	35.8^{dj}	36.3^{di}	43.5^{dj}	51.4^{ci}	33.8^{dj}	34.2^{dj}	41.5^{di}	49.8^{ci}	28.0^{ej}	28.0^{ej}	34.4^{ek}	41.5^{dj}	26.9^{ek}	26.8^{ek}	30.7^{ek}	33.7^{ej}
WDDGS fine	75.0^{ag}	75.5^{ag}	78.0^{ag}	83.7^{ag}	73.5^{ag}	74.7^{ag}	76.2^{ag}	82.8^{ag}	88.5^{ag}	89.6^{ag}	89.8^{ag}	94.5^{ag}	85.0^{ag}	86.0^{ag}	86.3^{ag}	88.2^{ag}

Differences between means with different letters were statistically significant (a—f, $P < 0.05$; g—l, $P < 0.01$)

DDGS has also been shown to contain substances that stimulate the rumen, increasing protein utilization and cellulose digestion (Chen et al. 1977).

In the present experiments, performed to evaluate the nutritive value of barley distillers by-products, both BDDG and BDDGS were found to have a low energy value and limited protein availability. This is in good agreement with the results of an earlier feeding experiment with growing cattle (Ettala and Näsi 1983) and of a balance trial with pigs (Näsi 1984). Many suitable feedstuffs can be expected from the planned integrated ethanol-starch production, in which the barley raw material will first be dehulled and then divided into starch, protein and fibres. Only starch is used in ethanol fermentation. After distillation, condensed solubles are obtained. The different fractions can be combined in many different ways to yield suitable products for feeding purposes. Wet preservation of distillery by-products also deserves study as a means of eliminating protein denaturation during drying.

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SELOSTUS

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Tutkimuksessa selvitettiin ohrasta etanolin valmistuksen sivutuotteina syntyvien rankkirehujen: rankkijyvien (BDDG) sekä rankkijyvien ja rankkiuutteen seoksen (BDDGS) koostumusta, sulavuutta ja pötsihajoavuutta. Rankkirehujen valkuaispitoisuus oli 26—30 % ja raakakuitupitoisuus 17—20 %. Sulavuusmääritykset tehtiin pässeillä kahdessa kokeessa, joissa rankkirehuja syötettiin 33 tai 67 % heinään perustuvan dieetin kuiva-aineesta. Rankkijyvien ja rankkiseoksen sulavuuksiksi saatiin orgaaniselle aineelle 43 ja 48 %, raakavalkuaiselle 65 ja 67 % sekä raakarasvalle 87 ja 88 %. Rehuyksikköarvoksi saatiin 0.58/kg ka., muuntokelpoisen energian määräksi 8.0 MJ/kg molemmille rankkituotteille ja sulavaa raakavalkuaista oli 295 ja 347 g/ry.

Rankkirehujen pötsihajoavuus oli hidasta sekä vähäistä ja ohrarankkirehujen hajoavuus oli merkitsevästi vehnärankkituotteita vähäisempää. Alhaisesta sulavuudesta ja käyttökelpoisen lysiinin vähäisyydestä johtuen ohrarankkirehujen valkuaisarvo on melko heikko vähäisestä pötsihajoavuudesta huolimatta.

Integroidusta etanoli—tärkkelystuotannosta saadaan ohrasta käyttökelpoisia rehufraktioita, kun eri jakeita voidaan yhdistää halutulla tavalla ja kuumennuskäsittelyjä voidaan tarkemmin kontrolloida.