

## Evaluation of barley distillers dried grains with soluble, and condensed distillers solubles in the diet of growing pigs

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**Abstract.** Two digestibility and nitrogen balance trials were conducted to evaluate the feed value of barley-derived distillers dried grains with solubles (BDDGS) and semisolid distillers solubles from barley and wheat (BDS and WDS) in rations for growing pigs. The average crude protein, lysine, crude fibre and neutral detergent fibre contents of BDDGS, BDS and WDS were, respectively: 30.6, 20.6, 30.7 %; 1.7, 1.7, 2.6 g/16 g N; 16.1, 2.0, 3.1 %; 69.4, 2.3, 7.1 %. Available lysine was greatly reduced in all samples. The distillery by-products composed 33 % of diet DM in the barley based rations. The control diet was a mixture of barley and skim milk powder. The organic matter and crude protein digestibilities of BDDGS, BDS and WDS were 40.5, 80.4, 85.0 % and 52.4, 46.9, 77.5 %, respectively. Their FU values and DCP values were 0.50, 0.94, 0.94/kg DM and 319, 102, 253 g/FU. on the WDS diet, nitrogen retention, as g/d, was similar to that on the control diet, but on the diets with barley distillery products it was reduced due to the lower amount of protein absorbed, especially the lower lysine intake. Barley distillers by-products proved to have low feed values for pigs in this study, but the value for WDS was quite reasonable. The new integrated starch-ethanol process can be expected to yield more suitable fractions for use in pig rations.

### Introduction

Distillers by-products can be fractioned by screening or by centrifuging into solubles and grains, and these fractions can be dried together or separately to produce DDGS or DDG. The soluble fraction can be evaporated to a semisolid (PIEPER 1981). Distillers dried grains with solubles (DDGS) and whole stillage from wheat have been investigated in rations for growing pigs and it has been found that up to 5 % and 10 % of the pig

feed can be replaced with DDGS and wet-stillage, respectively (ALAVIUHKOLA 1978, SUOMI 1980). NEWMAN and GRAS (1983) have reported that 5 % barley dried distillers grains (BDDG) can be used to replace barley and soybean meal in diets for growing pigs. Higher levels tended to decrease the feed conversion efficiency, although the rate of gain was not impaired by up to 10 % BDDG.

A new ethanol plant using barley as raw material will start operation in Finland in

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1987. The process will be integrated ethanol-starch production, with an annual yield of 61700 tn DM grain fractions for feed purposes (LEHMUSAAARI 1984). The increased supply of distillers products expected in the next few years has encouraged reevaluation of these products, especially barley residues, for which little information is available regarding utilization in pig diets.

The present study was designed to evaluate three distillery products as feed for growing pigs by detailed analyses of chemical composition, and measurements of nutrient digestibilities and utilization of protein.

### Materials and methods

Two digestibility and nitrogen balance, trials were carried out, with four castrated Landrace pigs in each trial, during the growth period from 73 to 109 kg. Barley distillers grains with solubles (BDDGS), and condensed wheat distillers solubles (WDS) composed 33 % of the dry matter of the diet which was based on barley meal enriched with minerals and vitamins. The control ration was a barley, skim milk powder mixture (85 % + 15 %). In the second trial semi-solid barley distillers solubles (BDS) composed 33 % and 67 % of the dry matter of the diet, which was based on barley. This trial had to be abandoned during the second period, due to the severe diarrhoea of the pigs receiving the larger amount of BDS. Each test period consisted of a 9-day adjustment and a 6-day collection period. The daily feed ration was 2.7 kg, on average 85 g/kg  $W^{0.75}$ . The pigs were kept in metabolic cages, which allowed separate collection of faeces and urine. These were collected quantitatively twice daily and representative samples were frozen and stored until analysed. The pigs were weighed before and after the collection period.

Chemical analyses of the feeds and faeces were performed according to official procedures. Acid detergent fibre (ADF), neutral

detergent fibre (NDF) and acid detergent lignin (ADL) were determined according to COERING and VAN SOEST (1970). Amino acids were determined with a Technicon TSM autoanalyzer after hydrolysis of 6 hours in 6 N HCl. The availability of lysine was measured according to CARPENTER (1960). The mineral composition was analysed with an atom-absorption spectrophotometer and phosphorus was determined by the method of TAYSSKY and SHORR (1953).

The digestibilities of the nutrients in the distillery products were calculated by the difference method, using measured values for barley and table values for skim milk powder. The feed values were calculated according to SALO et al. (1982) and ANDERSEN and JUST (1979).

### Results and discussion

BDDGS and WDS had a crude protein content around 30 % of DM, but in BDS the value was 20 % (Table 1). During yeast fermentation of grain, nearly all starch is removed, which concentrates the protein and other components. The crude fibre content of BDDGS was 16 %, which is in good accordance with the results of NEWMAN and GRAS (1983). Barley contains 10–12 % hulls (SALO and KOTILAINEN 1970) and in DDG this percentage is increased, which is undesirable from the nutritional point of view since hulls consist of strawlike material. Barley also contains a fibre fraction primarily derived from endospermal cell walls,  $\beta$ -glucan, which is also poorly digested (CAMBELL et al. 1984). In BDDGS the contents of total cell wall constituents (NDF), 69.4 %, and lignocellulosic material (ADF), 33.8 %, were high and exceeded the values (65.2 % and 28.2 %) given by NEWMAN and GRAS (1983). Condensed distillers solubles (BDS and WDS) had low values for ADF and NDF, which was due to the water solubility of these materials.

In BDDGS and BDS, especially the latter, most of the essential amino acids were lower

Table 1. Chemical composition of distillers grain and solubles and barley meal, used in digestibility experiments with pigs.

	BDDGS	BDS	WDS	Barley
Dry matter	94.3	71.2	34.4	87.9
Ash	4.4	17.9	9.7	3.0
Crude protein	30.6	20.6	30.7	11.2
True protein	27.4	12.0	23.3	9.4
Ether extract	6.8	1.5	7.5	2.5
Crude fibre	16.1	2.0	3.1	5.6
Nitrogen-free extract	42.0	57.9	49.0	77.7
Acid detergent fibre	33.8	5.0	4.5	7.0
Neutral detergent fibre	69.4	2.3	7.1	53.3
Acid detergent lignin	13.5	3.4	1.9	1.1
Lignin	7.9	0.9	0.4	2.0
Water soluble carbohydrates	5.3	13.8	15.1	
<i>Amino acids g/16 g N</i>				
Alanine	4.3	3.7	3.4	3.5
Arginine	3.3	2.1	3.5	4.6
Aspartic acid	5.5	5.5	4.4	6.6
Glutamic acid	20.8	13.6	17.5	19.0
Glycine	3.9	4.7	4.2	3.8
Histidine	2.4	2.7	2.8	2.3
Isoleucine	4.0	2.5	2.8	2.6
Leucine	7.8	4.2	5.7	6.1
Lysine	1.7	1.7	2.6	3.4
Methionine	0.8	0.4	0.8	1.1
Phenylalanine	4.9	2.8	3.5	4.1
Serine	4.0	3.9	4.3	3.9
Threonine	3.6	3.7	3.1	3.9
Tyrosine	2.7	2.2	2.7	2.1
Valine	6.5	4.6	4.7	4.6
Available lysine	0.35	0.5	1.5	3.1
<i>Minerals</i>				
Phosphorus, g/kg DM	5.09	16.16	17.05	3.98
Calcium, »	0.65	1.35	0.61	0.53
Magnesium, »	1.55	6.30	4.94	1.14
Sodium, »	2.40	47.24	11.96	0.59
Potassium, »	7.55	19.50	22.21	6.05
Iron, mg/kg DM	196	162	122	64
Copper, »	18	7	7	9
Zinc, »	67	116	33	61
Manganese, »	38	98	69	21

than in the original grain barley (Table 2). In both the products the lysine content was only 1.7 g/16 g N, whereas in barley it was twice as high. The available lysine was reduced to the minimal value of 0.35–0.5 g. Methionine and threonine were also decreased. WDS had a slightly better amino acid profile than the barley distillers products. Distillers

products undergo heat and other processing treatments and these cause deamination and affect reactions with sugars, thus decreasing the biological value of the protein. ALAVIUKOLA (1978) and SALO (1978) found reduced lysine concentrations in wheat DDGS and decreased availability, too. SATTERLEE et al. (1976) and NEWMAN and GRAS (1983), how-

Table 2. Digestibilities and nitrogen balance of diets containing distillers soluble or distillers grain with solubles compared with values for barley meal supplemented with skim milk powder.

	BDS 33 % barley 67 % of diet		WDS 33 % barley 67 % of diet		BDDG 33 % barley 67 % of diet		Barley 81.5 % skim milk powder 16.4 % of diet	
	$\bar{x}$	s.d.	$\bar{x}$	s.d.	$\bar{x}$	s.d.	$\bar{x}$	s.d.
<i>Digestibility</i>								
Dry matter	81.0	2.0	83.5	0.4	69.4	0.8	85.4	0.7
Ash	68.9	2.1	54.9	2.4	33.7	0.6	51.9	1.6
Organic matter	82.1	1.9	85.6	0.4	71.2	0.8	87.2	0.7
Crude protein	60.8	5.2	79.5	1.9	65.2	1.1	87.3	0.8
True protein	56.4	5.6	82.8	1.4	68.6	1.3	89.4	1.0
Ether extract	35.8	6.3	84.4	1.8	83.8	1.0	86.9	1.3
Crude fibre	90.0	1.0	33.3	2.9	17.4	1.2	29.8	4.7
NFE	88.7	4.2	90.8	0.2	79.4	1.0	90.0	0.6
<i>Nitrogen balance</i>								
N intake, g/d	50.4	2.7	73.0	0.2	72.0	0.1	62.8	0.1
N in faeces, g/d	19.8	3.4	15.0	1.4	25.0	0.7	8.0	0.5
N absorbed, g/d	30.5	1.5	58.1	1.4	46.9	0.8	54.8	0.5
N in urine, g/d	18.9	1.0	36.3	2.3	32.2	0.8	35.6	0.8
N retained, g/d	11.6	2.3	21.7	2.0	14.7	0.8	19.2	1.2
% of intake	23.2	5.6	29.8	2.7	20.5	1.0	30.5	1.9
% of absorption	37.8	5.8	37.4	3.6	31.4	1.4	34.9	1.9
Biological value	51.2	4.5	45.9	3.4	42.6	1.2	44.7	1.8

ever, found fairly similar amino acid profiles in wheat, corn and barley DDG compared with the original grains.

The sodium, potassium and phosphorus contents were higher in condensed distillery solubles than in barley (Table 1). Sodium is added in fermentation to adjust the pH (LEHMUSSAARI 1983). The high sodium content in BDS was probably the reason for diarrhoea in the pigs receiving the larger amount of solubles in the second trial.

On the diet containing WDS, nitrogen retention was almost the same as on the control diet but on the diets containing barley distillers products, nitrogen retention was decreased. The differences are mostly due to the differences in DCP intakes, which were 191, 363, 293 and 343 g/d on the BDS, WDS, BDDG and control diets, respectively. The lysine intakes were 12.2, 14.2, 12.0 and 19.0 g/d, respectively. The availability of lysine was also much reduced in both barley

distillery products. However, the results of NEWMAN and GRAS (1983) indicated that apparent nitrogen retention was not affected when BDDG replaced soybean, composing up to 20 % of the diet. THONG et al. (1978) measured nitrogen retention with gilts and found no differences between DDGS and soybean used as protein supplements.

The digestibility coefficients indicated that WDS was similar to barley, though the crude protein was 5 %-units less digestible. BDS had slightly lower values for organic matter and NFE digestibility, but crude protein digestibility was only half that of barley. Barley BDGS was digested poorly by the pigs (Table 3). The values were lower than those measured with ruminants (NÄSÄ 1984). The organic matter digestibilities of distillers by-products are reported as 54–63 % for wheat (SALO 1978), 80 % for maize and 74 % for potato (ROTH and KIRCHGESSNER 1975); the crude protein digestibilities were 63–67 %,

Table 3. Digestibility coefficients of distillers grain and solubles and calculated feed values.

	Barley distillers solubles	Wheat distillers solubles	Barley dis- tillers grain with solubles	Barley
<i>Digestibilities</i>				
Dry matter	80.4	83.1	38.9	83.7
Organic matter	80.4	85.0	40.5	85.8
Crude protein	46.9	77.5	52.4	82.2
True protein	31.8	80.8	56.8	85.2
Ether extract	18.4	82.8	81.5	86.9
Crude fibre	204.1	44.2	8.2	30.3
NFE	90.0	92.3	37.2	90.4
<i>Feed values</i>				
FU/kg DM	0.94	0.94	0.50	1.16
kg/FU	1.49	3.09	2.11	0.98
DCP in DM, %	9.7	23.8	16.1	9.2
g DCP/FU	102	253	319	78
<i>Just system</i>				
ME MJ/kg DM	14.66	15.44	8.45	15.14
NE MJ/kg DM	9.12	9.70	4.46	9.48
NE FU/kg DM	1.18	1.26	0.58	1.23
<i>Axelsson</i>				
ME MJ/kg DM	14.40	14.70	7.90	14.83

53 % and 55 %, respectively. NEWMAN and GRAS (1983) did not find any differences in nitrogen digestibility between diets when up to 20 % of the soybean was replaced by BDDG.

When feed values were calculated from the chemical composition and digestibility values, both condensed solubles were found to have a FU value of 0.94/kg DM, but the value for BDDGS was low, 0.50/kg DM. The DCP value for BDS was low, about the same

as in grain, but WDS and BDDGS had higher values, 253—319 g/FU.

When barley distillery by-products are used in pig diets, the hull content has to be decreased to obtain an adequate energy value, and thermal processing treatments should be restricted as far as possible, to avoid impairing protein availability. The new integrated starch-ethanol process yields fractions which are more suitable for use in pig feeding.

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## SELOSTUS

### Ohrarankkirehun ja rankkiutteen arvo lihasikojen rehuna

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Sulavuus- ja typpitasekokeissa tutkittiin rankkituotteiden rehuarvoa ja valkuaisen hyväksikäyttöä kasvavilla lihasioilla. Ohrarankkirehussa oli raakavalkuaista 30.6 %, lysiniä 1.7 g/16 g N ja raakakuitua 16.1 % ka:ssa ja vastaavasti ohra- ja vehnärankkiuutteissa 20.6, 30.7 %; 1.7, 2.6 g sekä 2.0 ja 3.1 %. Käyttökelpoisen lysiinin määrä oli kaikissa rankkituotteissa hyvin alhainen. Eri rankkituotteilla korvattiin 33 % dieetin kuiva-aineesta sulavuusmäärittelyssä. Ohrarankkirehun sekä ohra- ja vehnärankkiuutteen orgaanisen aineen ja raakavalkuaisen sulavuusiksi saatiin 40.5, 80.4 ja 85.0 % sekä 52.4, 46.9 ja 77.5 %, vastaavasti. Laskennallisiksi rehuyksikköarvoiksi ja sulavan raakavalkuaisen mää-

riksi saatiin 0.50, 0.94 ja 0.94 ry/kg ka sekä 319, 102 ja 253 g srv/ry. Typen pidättyminen oli vehnärankkiuuttedieetillä samanlaista kuin vertailudieetillä, mutta ohra-rankkituotteita sisältäneillä dieeteillä huomattavasti vähäisempää, koska siat saivat näillä dieeteillä sulavaa valkuaista ja erityisesti lysiniä edellisiä vähemmän.

Ohrarankkituotteiden käyttökelpoisuus sikojen ruokinnassa on heikko johtuen valkuaisen alhaisesta sulavuudesta ja puutteellisesta aminohappokoostumuksesta. Lisäksi korkean kuitupitoisuuden takia ohrarankkirehun sulavuus jäi vähäiseksi. Käyttökelpoisia rehufraktioita on mahdollista saada integroidusta etanolitärkkelystuotannosta myös sikojen ruokintaan.