Rye in Pig and Cattle Feed

RYE BELT

GROWING PERSPECTIVES

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Content

Foreword

Rye is highly attractive!

With feeding it is important to achieve high daily gains and milk yields. At the same time it is very important that animals are fed in a healthy and cost-efficient manner. Feeding results from across Europe underscore just how well rye is able to fulfil these requirements. Good examples of this can be found in Denmark and Germany. In these places rye is an established high-grade food component in many self-mixing operations and it is enjoying increasing popularity because pigs and cows thrive on rye!

Hybrid rye, moreover, is able to generate very high grain yields in light to medium soil and comes with very good nutritional efficiency and stress tolerance. This enables you to have a very high degree of cultivation reliability in such locations and to produce feeding components efficiently and economically.

With this brochure we want to give you some valuable basic information about rye as a feeding component and to provide you with some empirical reports and dietary examples for the use of rye in the feeding of pigs and cattle. This practical guide also contains summarised scientific results from feeding trials conducted in Europe.

Since 2008 the project RYE BELT initiated by KWS LOCHOW has been promoting the cultivation of rye throughout Europe. The Project focuses on cultivation, utilisation, breeding and the marketing of rye. Find out more at www.ryebelt.com

At this point we would like to thank the authors and trial organisers for their willing support in the preparation of this brochure.

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1 The contents of rye

1.1 Nutritional contents and feed value

Comparisons of cereal types show that rye contains more starch than barley but less than wheat and triticale. On average between the years 2007 to 2010 the starch content of rye was 53.3%, whereas barley and wheat contained 50.8% and 59.1% starch respectively. Of all the cereal types, rye has the lowest protein content. The preliminary results for the 2011 harvest showed rye to have 10.4% crude protein, while wheat contained 12.2%, triticale 11.3% and barley 11.6% crude protein. Averaging over 5% sugar, rye is the most sugar-rich cereal type. This means that its sugar content is twice as much as that of barley or wheat. The results of the analyses of recent years show that the individual cereal types exhibit varying nutritional contents from year to year (Table 1). Apart from the weather conditions, other critical factors in play here include the fertilisation, the location and the variety. It therefore makes great sense to examine the cereal for the contents that determine its value and this information can be quickly and economically obtained using the NIRS detection method (NIRS = near-infrared spectroscopy).

Table 1:
Feed value of cereals from the harvests of 2007 to 2009[1] (NIRS analysis, LUFA Nord-West, Germany (Landwirtschaftliche Untersuchungs- und Forschungsanstalt – Agricultural Testing and Research Agency)

		Rye			Barley			Triticale			Wheat		
Year		2009	2008	2007	2009	2008	2007	2009	2008	2007	2009	2008	2007
Number of samples		146	118	120	311	306	316	114	109	126	223	244	267
Dry matter	%	86.1	86.1	84.9	86.4	86.0	85.7	86.1	86.7	85.7	86.5	86.0	86.2
Crude protein	%	8.2	9.2	9.2	10.6	11.1	11.3	10.1	10.3	11.7	10.9	11.1	11.8
Crude fat	%	1.9	1.9	2.0	2.8	2.7	2.6	2.0	2.0	2.2	2.1	2.1	2.2
Crude fibre	%	2.2	2.4	2.3	5.0	5.3	4.5	2.7	2.5	2.6	2.4	2.4	2.4
Starch	%	53.7	53.8	52.1	51.7	50.5	49.9	59.7	59.0	57.6	59.5	59.8	59.1
Sugar[2]	%	5.4	5.1	5.0	2.1	2.0	2.1	3.2	3.0	2.8	2.6	2.3	2.2
ME (pigs)[3]	MJ/kg	13.4	13.6	13.4	12.9	12.8	12.9	14.0	14.0	14.1	14.1	14.2	14.3
NEL	MJ/kg	7.5	7.5	7.5	7.1	7.1	7.1	7.4	7.4	7.5	7.5	7.5	7.5
ME (cattle)	MJ/kg	11.8	11.8	11.8	11.3	11.3	11.3	11.7	11.7	11.8	11.8	11.8	11.8
nXP	g/kg	145	146	146	143	144	145	146	146	149	149	149	151
RNB	g/kg	-10.1	-8.8	-8.7	-5.9	-5.4	-5.0	-7.2	-7.0	-5.1	-6.4	-6.2	-5.2
Lysine[4]	%	0.31	0.34	0.34	0.37	0.38	0.39	0.35	0.35	0.38	0.31	0.32	0.33
Meth. + Cystine[4]	%	0.32	0.36	0.36	0.41	0.42	0.43	0.41	0.41	0.46	0.43	0.43	0.46
Threonine[4]	%	0.27	0.30	0.30	0.36	0.37	0.37	0.31	0.32	0.36	0.32	0.32	0.34
Tryptophan[4]	%	0.09	0.10	0.10	0.13	0.14	0.14	0.11	0.11	0.12	0.14	0.14	0.15

[1] based on 88% dry matter [2] lower sample number (wet chemical analysis)
[3] mixed feed formula [4] calculated from crude protein content using estimating equations

Apart from starch and sugar the carbohydrate fraction also contains “non-starch polysaccharides”, such as cellulose, pentosans, beta-glucan among other substances (see Section 1.2.1). These can hardly be digested by pigs which lack the endogenous enzymes necessary. Table 2 shows just how much individual substances fluctuate within one cereal type and a harvest year.

Table 2:
Feed value of cereals from the harvest of 2010, average values and fluctuation ranges (NIRS analyses[1]), LUFA Nord-West, Germany)

		Rye n = 222	Barley n = 345	Triticale n = 181	Wheat n = 390
Dry matter	%	86.3 (76.7-90.9)	87.0 (75-91.7)	86.1 (77.3-90.1)	85.8 (80.7-94.3)
Crude protein	%	10.1 (7.6-13.9)	10.9 (8.0-15.8)	11.3 (8.0-16.5)	12.1 (7.8-16.7)
Crude fat	%	1.8 (1.7-2.1)	2.8 (2.5-3.2)	2.1 (1.9-2.5)	2.1 (1.5-2.7)
Crude fibre	%	2.2 (1.3-3.5)	5.4 (3.1-7.1)	2.6 (1.5-3.3)	2.6 (1.8-3.8)
Starch	%	53.7 (48.2-56.0)	51.0 (45.7-54.4)	57.1 (51.4-60.8)	57.9 (48.4-63.1)
Sugar[2]	%	5.5 (3.1-6.4)	2.5 (1.7-5.2)	3.5 (2.6-4.5)	2.4 (1.9-4.1)
ME (pigs)[3]	MJ/kg	13.7 (13.4-14.1)	12.8 (12.4-13.9)	14.0 (13.6-14.3)	14.1 (13.4-14.6)
NEL	MJ/kg	7.5 (7.5-7.6)	7.1 (7.0-7.2)	7.5 (7.4-7.6)	7.5 (7.5-7.6)
ME (cattle)	MJ/kg	11.8 (11.7-11.9)	11.3 (11.2-11.4)	11.7 (11.6-11.9)	11.8 (11.7-12.0)
nXP	g/kg	148 (144-154)	144 (136-156)	148 (143-156)	151 (143-161)
RNB	g/kg	-7.5 (-10.9 to -2.4)	-5.5 (-9.0 to 0.3)	-5.5 (-10.1 to 1.4)	-4.9 (-10.4 to 1)
Lysine[4]	%	0.37 (0.30-0.48)	0.38 (0.30-0.50)	0.37 (0.30-0.48)	0.33 (0.27-0.40)
Methionine + Cystine[4]	%	0.39 (0.3-0.53)	0.42 (0.33-0.57)	0.45 (0.34-0.61)	0.46 (0.34-0.6)
Threonine[4]	%	0.33 (0.26-0.45)	0.36 (0.28-0.5)	0.35 (0.26-0.49)	0.34 (0.25-0.44)
Tryptophan[4]	%	0.11 (0.09-0.14)	0.14 (0.11-0.19)	0.12 (0.09-0.16)	0.15 (0.12-0.18)

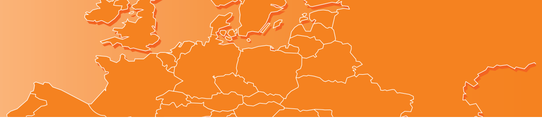
[1] Nutritional contents based on 88 % dry matter [2] lower sample number (wet chemical analysis)
[3] Mixed feed formula [4] calculated from crude protein content using estimating equations

Unlike the four specified cereal types only a few grain maize studies are available. Table 3 contains the results from the years 2008 to 2010.

Table 3:
Feed value of grain maize of the harvests of 2008 to 2010 (89 samples, NIRS analyses, LUFA Nord-West, Germany) [1)]

Dry matter	%	71.7
Crude protein	%	8.5
Crude fat	%	4.4
Crude fibre	%	2.2
Starch	%	63.1
ME (pigs)[2)]	MJ/Kg	14.5
NEL	MJ/Kg	7.1
ME (cattle)	MJ/Kg	11.4
nXP	g/Kg	140
RNB	g/Kg	-8.7
Lysine[3)]	%	0.23
Methionine + Cystine[3)]	%	0.35
Threonine[3)]	%	0.30

[1)] based on 88% dry matter
[2)] mixed feed formula
[3)] calculated from crude protein content using estimating equation



The feed value of cereals is first and foremost determined by the energy content. With regard to **pig feed** it must be noted that rye contains approximately 0.6 to 0.7MJ ME/kg less than wheat. The comparison of the analyses from the last four cereal harvests (Tables 1 and 2) show that rye at 13.5MJ ME/kg is positioned between barley (12.9MJ/kg) and triticale (14.0MJ/kg). Because pigs do not have any need for crude protein but amino acids instead, information about the amino acid content is of crucial importance for the determining the ration. Whereas barley at 0.38% takes pole position in relation to the first limiting amino acid, lysine, at 0.34% rye is slightly ahead of wheat at 0.32%. In relation to the other three first limiting amino acids, methionine + cystine, threonine and tryptophan, rye takes up the rear. However, it is not the gross contents that are ultimately decisive, but rather the content of digestible amino acids. The updated feeding recommendations are based on the praecaecal digestible amino acids (in the small intestine) and thereby enable the needs of animals to be better satisfied. The "Gesellschaft für Ernährungsphysiologie" (GfE – Society of Nutrition Physiology) has published digestibility rates for the amino acids of various feedstuffs. Because they do not have a sufficiently large data basis for rye, Table 4 contains values for rye provided by the company Evonik, the comprehensive data of which is stored in AminoDat 4.0.

Table 4:
Praecaecal digestibility of amino acids in % (GfE, 2006)

	Lysine	Methionine	Threonine	Tryptophan
Rye[1)]	76	81	75	76
Barley	73	82	76	76
Triticale	84	88	81	77
Wheat	88	88	90	88

[1)] according to Evonik, 2010

Only in barley protein the digestibility of lysine is below that of rye, otherwise barley, triticale and wheat all have clearly better amino acid digestibility. At 81% the digestibility of the sulphurous amino acid methionine in rye is roughly in the same range as barley. If the average values of the first limiting amino acid lysine are taken as the basis, we arrive at the following proportions of praecaecal digestible lysine: rye 0.26%, barley 0.28%, triticale 0.30% and wheat 0.28%. By supplementing free amino acids the lower level found in rye can be balanced as required.

Figure 1:
Lysine contents in cereal protein

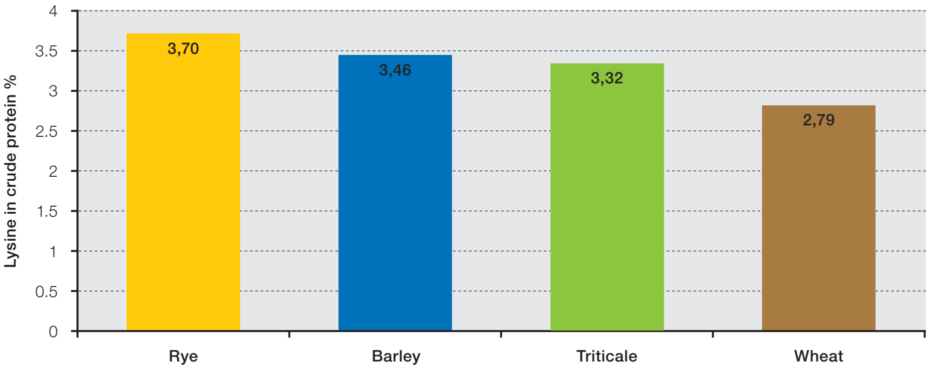


Figure 1 shows the lysine content of various cereal proteins based on the crude protein. With 3.70% lysine in the crude protein, rye exhibits the highest lysine content at an average crude protein content of 9.18%. In second and third place come barley and triticale with 3.46% and 3.32% with average protein contents of 10.98% and 10.85% respectively, whereas, with 2.79% lysine in crude protein at an average crude protein content of 11.48%, wheat exhibits the lowest lysine content.

Because rye contains relatively low levels of polyunsaturated fatty acids (polyenoic acids), it is attributed with having a positive effect on the characteristics of the fat.

In pig fattening feed trials (*Hagemann, L. et al.*, 1991; *Meyer, A. et al.*, 2003) no such change through higher rye proportions in feed could be found in slaughtered specimens.

With the use of cereals in **cattle feed** the readily soluble carbohydrates (starch and sugar) are particularly important for defining the dietary ration. The utilizable crude protein (nXP) content and the ruminal nitrogen balance (RNB) continue to play a part. With 7.5MJ NEL/kg rye contains as much energy as wheat and contains 0.4MJ NEL/kg energy more than barley. Even though rye contains less protein than the other cereal types, in common with the other cereal types it can contribute to an intensive formation of microbe proteins in the rumen. While it may only contain 92g crude protein, it does have 146g nXP per kg. This results in a negative RNB of -8.6g per kg.

That means that rye triggers a deficiency of nitrogen in the rumen. Given the fact that the overall diet is aimed towards achieving a stable nitrogen balance in the rumen, when feeding with rye it is necessary at the same time to add components with a positive RNB value. The upshot of this is that due to its negative RNB values, rye is best used to balance out protein-rich diets (positive RNB) and can reduce excessive nitrogen in the rumen. Barley, triticale and wheat provide similar nXP content, but with RNB values that are less negative due to the high crude protein content. In common with the other cereal types (apart from corn), rye has a low concentration of starch of about 15%, meaning that only 15% of the starch not broken down in the rumen, the so-called by-pass or ruminally undegradable starch encroaches into the small intestine where it is absorbed as glucose after being broken down by endogenous enzymes.

1.2 Specific contents of rye

1.2.1 Non-starch polysaccharides (NSP)

With all cereal types the various carbohydrate fractions constitute the highest proportion of the energy sources in the grains. The main constituent here is the starch easily digestible for all livestock followed by NSP, which pigs and poultry are only able to digest to a limited extent. Depending on the particular cereal the pure sugar component in the grains only amounts to 3 – 7% of the dry matter (DM). The primary fraction of the NSP is comprised of arabinose and xylose and held as pentosans.

Table 5:
Pentosan content in the grains of some cereal types in g/kg DM according to 1999 as well as the starch and sugar constituents according to 1997

	Rye	Wheat	Triticale	Barley	Corn
Pentosan	59-102	35-70	91-140	58-77	33-68
Starch	632	662	640	599	694
Sugar	68	33	40	18	19

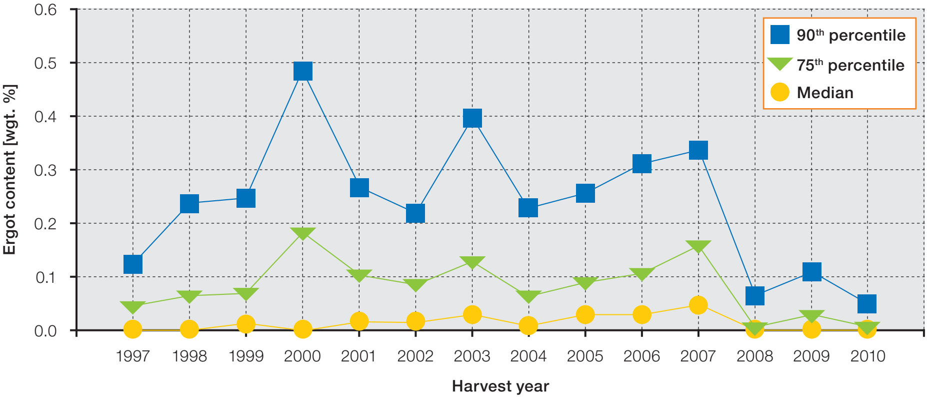
A high fluctuation range was recorded for the pentosan content. In this respect there is a broad range of influences on the content, something which has been confirmed by several trials conducted in recent years. At Bad Lauchstädt, Germany, among other locations *Braun* (2009) examined the influence of the varieties (Hacada, Nikita or Caroass) and the cultivation method (integrated or ecological) on the NSP content in rye grain. The average pentosan contents did not differentiate significantly over the two to three years of the study (varieties: 98g/kg DM, 111g/kg DM and 110g/kg DM; integrated 106mg/kg DM and ecological 107g/kg DM). The trials conducted by *KWS LOCHOW* (2011) for the years 2009 and 2010 on average showed for four different types at six different locations significantly

(p < 0.01) higher pentosan contents for the 2009 harvest year than for 2010. The differences in the pentosan content between the hybrid and population types on the other hand are insignificant, i.e. incidental.
According to *Simon and Vahjen* (2006) the livestock do not have any endogenous enzymes to break down the NSP. “Accordingly the degrading of NSP in the intestinal tract can only take place by way of microorganisms, meaning that only volatile fatty acids and lactic acid result as resorbable products.” Because the proportions of soluble ß-glucan and pentosan as NSP constituents can reach the highest concentrations in rye, restrictions are stipulated particularly in relation to its use as a feed for chicks and piglets. According to DLG e. V. (2006) chick feed should have no rye while feed for piglets up to 15kg LW may only have a 10% and over 15kg LW a 20% rye content respectively.
By adding in enzymes (ß-glucans and xylans), which can partially degrade NSP, a positive effect on digestion was proven particularly among piglets. With chicks on the other hand, *Simon and Vahjen* 2006 did not find any corresponding effects produced by enzymes.
As many trials on the use of rye among pigs > 35kg LW have shown, the increased NSP ratio of rye does not have any detrimental effect on the performance and health of the animals.

1.2.2 Ergot

The occurrence of ergot and its constituent ergot alkaloids vary quite greatly depending on the variety and the particular weather conditions during the flowering time of the rye. To prevent poisoning the animal feed legislation contains appropriate limits – cereal grain 0.1%. In figure 2 the contamination of rye with ergot is shown across recent years based on the "Besondere Ernte- and Qualitätsermittlung – BEE" *(special harvest and quality assessment report)*. No hazardous contents are recorded in the average of the measurements.

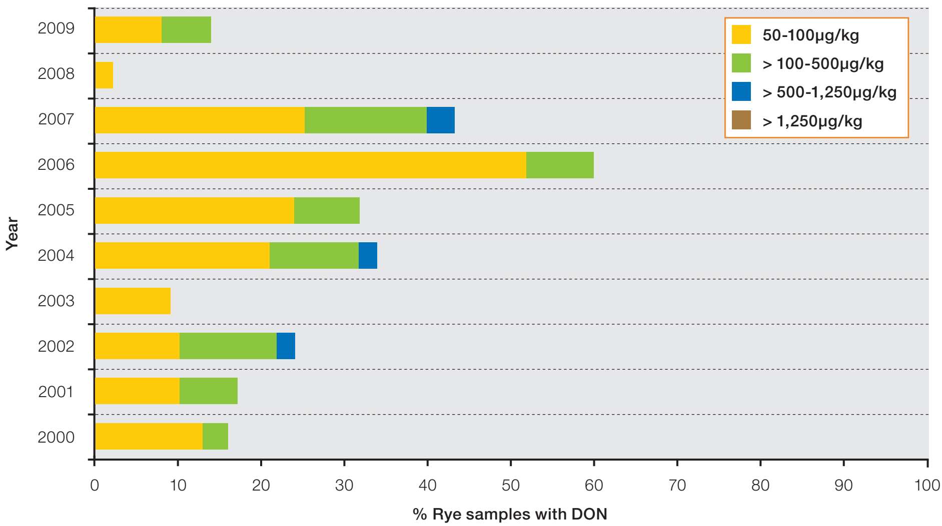
Figure 2:
Median, 75th and 90th percentile of the ergot content in the rye harvest in Germany from 1997 to 2010.
***Seling, S. et al.* (2010)**



1.2.3 Mycotoxins

Apart from the ergot alkaloids of the ergot, other toxins can be found in rye and may be caused by field and storage fungi. The most common contamination by toxins is caused by field fungi, particularly the *Fusarium* spp. genus. If the grain is properly stored it is possible to largely preclude the occurrence of toxins caused by storage fungi, particularly *Aspergillus* spp. With regard to the Fusarium toxins, the extensive trials to date been conducted among cereal types largely in relation to the occurrence of deoxynivalenol (DON) and its derivatives and of zearalenon (ZEA) and its derivatives. However, ochratoxin A (OTA), which is caused in stored grain by *Aspergillus* spp., can also be found in foodstuffs and livestock feeds.
If consumed, feedstuff contaminated with toxins firstly always triggers the risk that the health of the livestock will be affected, and secondly there is the possibility that the toxins or their still toxic degradation products can impair the food yielded from the animal.
To date it has still not been proven that DON can transfer to meat and milk. The trials conducted to date have also found there to be little risk that the residual products of ZEA will find their way into animal-based food products.
The extensive trials focusing on the mycotoxin contamination of cereal types produced in Germany all show that rye has a significantly lower DON and ZEA content compared to wheat. These results underpin the findings made across the years in the rye producing region of Brandenburg, Germany.

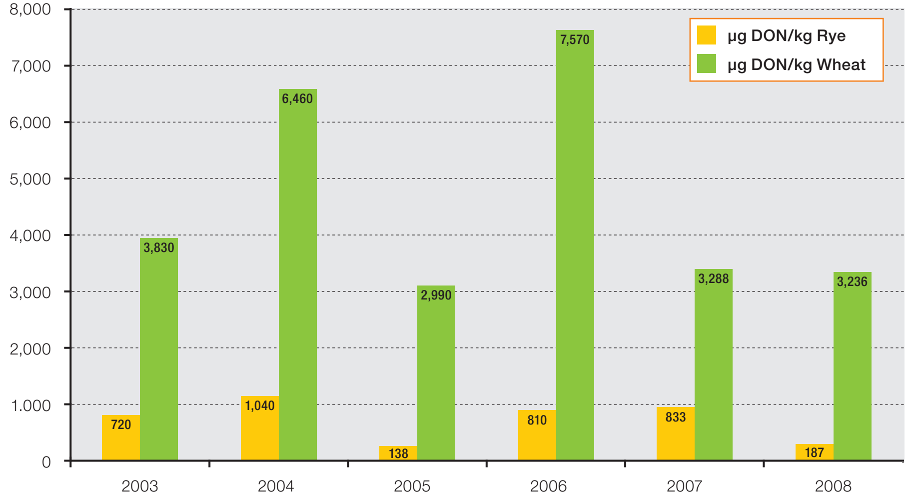
Figure 3:
Frequency of DON detected in rye samples



Final Reports 2000-2009, IGV Potsdam, Germany

During the ten years over which trials were performed, the DON concentrations in rye never attained >1,250µg/kg. For wheat, on the other hand, this level of concentration appears significantly more frequently in the years 2001, 2002, 2005, 2007 and 2009. Overall the proportion of wheat samples contaminated with DON was higher than that found in rye. With regard to ZEA the proportion of rye samples with >100µg/kg was only conspicuous in 2002 at approximately 1%: with wheat this range was found in approx. 3% of samples in 2002, approx. 2% in 2005 and approx. 9% in 2007. Overall the wheat samples also exhibited significantly greater ZEA-contamination than did the rye samples. Observations conducted in Bavaria in 2003 – 2008 (Figure 4), represented here by the maximum observed levels of DON contamination, confirm the findings made in Brandenburg.

Figure 4:
Maximum DON Contents in Rye and Wheat Samples from Bavaria



In the year 2011 *Grajewski, J.* and *M. Twarużek* (2011) examined 152 Polish cereal samples for mycotoxins. The results confirm the aforementioned findings (see Table 6). Once again, of all the cereal types examined, rye exhibited the lowest level of mycotoxin contamination.

Table 6:
Mycotoxin content in rye harvested in 2011 in Poland

Rye	Mycotoxin concentration (µg/kg)					
	DON	NIV	T2	HT2	ZEA	OTA
Average	33.9	3.49	1.31	2.75	7.32	8.90
% positive	100	75	100	100	100	50
Highest value	113	7.94	2.38	4.95	28.0	17.8

NIV–Nivalenol, T2–Toxin t-2, HT2–Toxin HAT-2

With regard to feedstuffs in Germany, back in 2000 the competent Ministry (BMVEL – *Federal* Ministry of Food, *Agriculture and Consumer Protection)* published orientation figures for the limitation of DON and ZEA in the daily diets of various livestock groups.

Table 7:
Orientation figures for DON and ZEA in daily diets of selected livestock groups (µg/kg feedstuff)

Livestock type	Animal category	DON	ZEA
Pigs	prepubescent female breeding pigs fattening pigs and breeding sows	1,000 1,000	50 250
Chickens	Laying hens and fattening chickens	5,000	-
Cattle	Calves (pre-ruminal) Female breeding cows, dairy cows Beef cattle	2,000 5,000 5,000	250 500 -

Threshold values, which if exceeded will entail a prohibition on feed and mixing, have to date only been issued in relation to aflatoxins. EU guideline values, which if exceeded may be “diluted” by mixing in uncontaminated feedstuffs, where issued in 2006 in respect of DON, ZEA, OTA and FUM (fumonisin(s) B1 and B2.

Table 8:
Selected guidelines values for particular mycotoxins according to the Annex to the EC Recommendation 2006/576/EC (µg/kg feed) – only selected livestock groups

Feed	DON	ZEA	OTA	FUM
Cereal and cereal products except corn by-products	8,000	2,000	250	60,000
Supplementary or sole feed for pigs	900	-	50	5,000
Supplementary and sole feed for piglets and young sows	-	100	-	-
Supplementary and sole feed for sows and fattening pigs	-	250	-	-

1.3 Preserving quality through proper storage

The cleaning and proper conservation and storage of fresh cereal forms the basis for preserving a high-grade feedstuff.

Cleaning
To minimise the risk of hygienic contamination by mould, insect eggs, bacteria and other pests the harvested crop must be pre-cleaned. At the very least an air separator should be employed to remove dust, insects, straw debris etc. A combination of an air separation unit and a sieve screen produces the best results as this will also remove grain impurities, weed plant seeds and grass and plant debris.

Conservation
Alongside conservation procedures such as drying, cooling and gas-tight storage, the chemical conservation of cereals using acids is an option suitable for operations planning to transform their cereal into feed by themselves. Propionic acid by itself, or in combination with benzoic, sorbic or formic acid, is the primary agent used in conservation. Propionic acid has an antimicrobial effect against fungi, yeast and bacteria. These are eliminated or their reproduction is prevented during storage through the acidic protection of the individual grains.
Grain weevils are killed off with a 2% supplement of propionic acid to stored cereal. An addition of 0.5 – 1% of this acid will also prevent insect damage. The energy of the propionic acid can then be exploited in the digestion. The energy value can be placed on a par with that of barley.
Because propionic acid is a skin irritant, the wearing of protection clothing is strictly necessary.
Because acids are highly corrosive, it is recommended that storage facilities be given an acid-proof coating or fitted with acid-proof plastic sheeting.

The correct application dose of propionic acid depends on the moisture of the particular cereal/cereal pellet/flour quantities and on the duration of storage (see Table 9).

Table 9:
Dosage recommendations for propionic acid (99.5%) in litres per 100 kg moist cereal

whole grains Conservation time, month					Cereal pellet/-flour Conservation time, month			
Moisture	1	to 3	to 6	to 12	Moisture	1	to 3	to 12
to 16%	0.35	0.45	0.50	0.55	to 16%	0.40	0.50	0.70
16-18%	0.40	0.50	0.55	0.65	16-18%	0.50	0.60	0.85
18-20%	0.45	0.55	0.65	0.75	18-20%	0.60	0.70	1.00
20-22%	0.50	0.65	0.75	0.85	20-22%	0.70	0.80	1.15
22-24%	0.55	0.70	0.85	0.95	22-24%	0.80	0.90	1.25
24-26%	0.60	0.80	0.95	1.05	24-26%	1.00	1.10	1.35
26-28%	0.70	0.90	1.05	1.15	26-28%	1.15	1.25	1.50
28-30%	0.80	1.00	1.15	1.30	28-30%	1.30	1.40	1.65
30-32%	0.90	1.10	1.25	1.45	30-32%	1.45	1.55	1.80
32-34%	1.00	1.20	1.35	1.60	32-34%	1.60	1.70	1.95
34-36%	1.10	1.30	1.50	1.75	34-36%	1.75	1.95	2.10
36-38%	1.25	1.45	1.65	1.90	36-38%	1.90	2.10	2.25
38-40%	1.40	1.60	1.80	2.05	38-40%	2.10	2.25	2.30
Requisite acid supplement with blow conveying +10% with storage at over 35°C +10% with fungi-contaminated cereals +10 to +20%					After flour is brought into store the surface must be treated with 1 litre propionicacid per square metre			

BASF SE, Nutrition Ingredients, Europe – Guide to conservation of feed

This conservation process requires the use of a dosage appliance that wettens the cereal grains with propionic acid via jets in a cereal screw conveyor that is at least 3 m long and has an inclination angle of at least 30°.

The number of nozzles depends on the diameter of the screw conveyor.

Screw conveyor diameter	Number of nozzles
< 180 mm	2-3
180-200 mm	3-4
> 200 mm	at least 4

BASF SE, Nutrition Ingredients,
Europe – Guide to conservation of feed

Conical piling should be avoided when placing the grain into storage. Cereal batches with different levels of moisture content may not be stored together.

Apart from conservation using acid, there are other processes for conserving moist cereal such as:

Conservation using caustic soda:
Apart from its conserving effect, caustic soda also triggers a disassociation (soda grain) of the cereal husk and the swelling of the starch. The addition of 3 – 4% caustic soda leads to an adequate disassociation and an adequate conservation of the cereal (DLG, 2011). This requires that the caustic soda be thoroughly mixed in. The storage of cereal treated in this way should be under-roof but without a cover sheet, so that excess caustic soda can evaporate from the cereal. If stored up to a maximum depth of 0.3m the cereal can be stored for up to 12 months.
When handling alkalis it is imperative to observe the occupational health and safety regulations.
In this process caustic soda is handled as a technological processing agent and not as a feedstuff supplement.

Conservation using urea:
The moist cereal conservation process is based on the transformation of the urea into ammonia in the moist medium. Within this process the temperature rises for a short time and the pH value increases from 8 to 9. This inhibits the development of damaging microorganisms such as mould and yeast.
To ensure that the reaction is strong enough, 0.5% water should be added to cereal with a moisture content of < 18%. The cereal will change colour to yellowish/brown due to the increase in temperature.
Mixing in the urea can be performed in the feed mixer trailer or in the screw conveyor using the appropriate dosage device.
The dosage is 2 – 2.5kg/dt cereal and is not dependent on the moisture of the cereal (Sanftleben, P.)
The cereal should be stored in a flat store, because the increase in temperatures and the water-absorption effect of the urea will cause the cereal to agglomerate. The cereal should be covered with sheeting for about four weeks to enable the ammonia to become evenly distributed in the pile and to prevent it escaping into the surrounding environs.
After approx. four weeks in storage the cereal must be passed through a crusher prior to feeding.

Cereal treated with urea may **only** be fed to **ruminants**, meaning this cereal cannot be placed on the open market.

When calculating the diet the increased RNB content of the cereal should be taken into account.

2 Rye in the feeding of livestock

Rye has become increasingly important in relation to animal feeds. The reservations of many farmers about using rye as a feedstuff have been alleviated by a great number of exact trials conducted by various scientific institutions as well as practical experience over the last 20 years, but in some places there is still clear scepticism concerning high rye proportions. Despite its peculiarities (NSP and possible ergot) rye has now found itself an established position primarily in the feeding of cattle and pigs. With its largely beneficial cost factor compared to the other standard cereal types or the significantly higher productivity especially of hybrid rye on light and medium soils, it can contribute to the sustainable improvement of the effectiveness of animal processing production. Compared to other cereal types, its feed value has a higher energy concentration, somewhat lower protein proportion, but with a high lysine content and a higher sugar supply. As with all foodstuffs, rye also experiences yearly and located-related fluctuations in the nutritional concentration, as can be seen from the information in Table 10.

Table 10:
Substances and energy contained in rye (88% DM) – 2010 harvest

	Crude protein g	nXP g	Crude fat g	Crude fibre g	Starch g	ME Pigs MJ	ME Cattle MJ	NEL MJ	RNB g	Lysine g	Meth. g	Thr. g
Rye[1)]	101 (76-139)	148 (144-154)	18 (17-21)	22 (13-35)	537 (482-560)	13.7 (13.4-14.1)	11.8 (11.7-11.9)	7.5 (7.5-7.6)	-7.5 (-10.9--2.4)	3.5	1.5	2.9
Rye - organic farming[2)]	76.2	-[3)]	20.1	27.2	559.5	13.4	11.7	7.6	-[3)]	3.0	1.3	2.6

[1)] Analysis LUFA Nord-West, Germany (fluctuation range); amino acids: Information KWS LOCHOW from 2010;
[2)] Analyses LVLF Brandenburg, Germany (State Office for Consumer Protection, Agriculture and Land Consolidation) (2001 – 2003);
[3)] – no details.

The cultivation process particularly influences the nitrogen fraction as is shown by the trials conducted by *Strobel, E. et al.* (2001) in Saxony-Anhalt, Germany, including for wheat and oats. The ileal digestibility of the amino acids of rye is roughly on a par with barley, but approx. 10% absolutely lower than is the case with wheat and triticale.

Table 11:
Mass and trace element contents of rye in the harvest years of 2009 and 2010 - KWS LOCHOW (2011; in kg DM; n= 39 and 36)

Harvest year	Calcium g	Phosphorous g	Copper mg	Zinc mg	Manganese mg
2009	0.48 (0.4-0.6)	3.56 (2.3-4.0)	2.7 (0.6-4.2)	29.9 (15.4-37.9)	30.5 (18.8-53.8)
2010	0.60 (0.5-0.6)	3.87 (3.4-4.4)	1.3 (0.3-4.5)	39.2 (31.1-49.6)	-29.0 (20.6-44.3)

(Fluctuation range)

The apparent variability of the macro and trace elements between the two harvest years and the locations emphasises the need to perform regular tests to ensure that the available feedstuffs including mineral feed can maintain the appropriate coverage of the requirement for livestock.

2.1 Rye in the feeding of pigs

The usage recommendations of the Videncenter for Svineproduction, Denmark are up to 20% for piglets, up to 30% for sows and up to 40% rye in the mixed feed for pig fattening. In exact trials in Germany (*Hagemann, L.* 1991, *Meyer, A.* 2003) it has been demonstrated that the total cereal component in pig fattening can be made up of rye without any downsides.

The following ration examples for pigs were prepared by SVINERÅDGIVNING VEST, Herning in Denmark.

2.1.1 Sows

As with all other feed components, with rye too there must be strict adherence to high hygiene standards in the breeding and farming area. This concerns the harvest of healthy cereal on the one hand and the quality preserving storage of the fodder cereals on the other.

Table 12:
Mixture for the feeding of lactating and gestating sows (% in the mix)

Feeding stuff		Gestation	Lactation
Barley 2010		50	35
Wheat 2010			34.30
Rye		35.40	10
Soybean meal, peeled		11.20	15.70
Lard		0.70	1.60
Mineral feed		2.70	3.40
		per kg compound feed (85.75% DM)	per kg compound feed (86.09% DM)
FEso ny		1.053	1.081
Crude protein	g	128.8	148.5
Crude fat	g	27.5	35.8
Lysine	g	5.26	7.12
Methionine + Cystine	g	3.86	4.56

SVINERÅDGIVNING VEST, Herning, Denmark

Because the nutritional contents in the concentrate fodder components can fluctuate very severely both from year to year as well as depending on location, regular checks should also be performed in relation to the individual feedstuffs.

2.1.2 Piglets

The extensive trials performed by LVLF Ruhlsdorf, Germany and in the LLFG Iden, Germany (*State Institute for Agriculture, Forestry and Horticulture*) (*Weber, M., et al.* 2004) confirm with a high degree of certainty that pig fodder too can contain 10 – 15% rye in the mix, without triggering fodder-related health impairments or drops in output.

Table 13:
Mixture recommendations for feeding piglets (% in the mix)

Feeding stuff		Piglets 23 – 33 kg
Barley		20.00
Wheat		47.90
Rye		5.00
Soybean meal, peeled		22.00
Lard		1.30
Mineral feed		3.80
		per kg compound feed (85.92% DM)
FEsvin ny		1.09
Crude protein	g	174.70
Crude fat	g	32.50
Lysine	g	9.49
Methionine + Cystine	g	5.52

SVINERÅDGIVNING VEST, Herning, Denmark

According to the recommendations of the Videncenter for Svineproduction, Denmark, the rye content in piglet fodder should not be more than 20% at an age of 3 weeks following weaning.

2.1.3 Fattening pigs

The success to be had using rye for fattening pigs of various breeds has been demonstrated not just by numerous trials but also in practice.

Table 14:
Mixtures for feeding fattening pigs (% in the mix)

Feeding stuff		Starter	Grower	Finisher
Barley		30	20	29.5
Wheat		27.4	17.5	-
Rye		20	40	50
Soybean meal, peeled		19.4	19.6	17.8
Mineral feed		3.2	2.9	2.7
		per kg compound feed (85.92% DM)	per kg compound feed (85.89% DM)	per kg compound feed (86.09% DM)
FEsv ny		1.05	1.051	1.043
Crude protein	g	163.5	161.8	153.9
Crude fat	g	2.02	1.97	1.99
Lysine	g	8.09	7.77	7.19
Methionine + Cystine	g	4.98	4.83	4.5

SVINERÅDGIVNING VEST, Herning, Denmark

Due to its low production costs and market price, rye always has a cost advantage compared to other cereal types. And it may also be assumed that there is a higher degree of hygienic safety with rye. The ergot frequency has been drastically reduced with modern hybrid varieties from KWS LOCHOW GMBH and can therefore be ignored for pig fattening. The exact trials in Germany, such as those conducted by the Landwirtschaftskammer Hannover, Germany (*Chamber of Agriculture*), *Meyer, A.* (2003), prove that the absorption of fodder is not impacted with high proportions of rye in the mix and that the output parameters do not significantly change.

Possible froth formation when using relatively fresh rye in liquid feed can be countered using technical innovations at the pumps on by adding between 0.5 – 1.0% oil into the fodder mash.

As shown by the exact study conducted by *Hagemann, L.* (1996), LVLF Ruhlsdorf, Germany, on the use of enzymes with high rye proportions in pig fattening, its use remains neutral.

Table 15:
Output with use of enzymes in rye-imbued fattening pig rations

		Monitoring (50% rye without enzymes)	Test (50% rye without with enzyme)
Daily gain	g	781	786
Fodder consumption/kg gain	kg	2.57	2.63
Lean meat content	%	56.8	55.4

Studies performed by *Alert, H.J.* (2005) and *Meyer, A.* (2006) on the use of enzymes in pig fattening fodder with high rye proportions also scarcely differ from those of fattening fodder without rye.

2.2 Rye in the feeding of cattle

In rye cultivation regions rye is securely established in the concentrate fodder supply for cattle, particularly dairy cows. The low starch and protein content of rye compared to wheat and triticale make it suitable both for corn silage-based, starch-rich cattle rations as well as for protein-rich rations with a high volume of grass and leguminous crops. An appropriate balance must be observed in both cases. The high sugar content boosts the rapid reproduction of rumen microorganisms. With balanced rations the cost benefit of rye will be determined by the current price of protein feedstuffs, which have to be used to compensate the protein intake.

2.2.1 Dairy cows

The modern method of feeding dairy cows using TMR (Total Mix Ration) also offers the possibility of directly mixing in rye, preferably in crush form, in the daily ration of dairy cows. Alongside the yield-dependent quantity and protein supply, with the introduction of rye as a concentrated feedstuff the maximum Rumen Load Index should be 0.6.

The Rumen Load Index (RLI) is the ratio of rapidly degraded carbohydrates (sugar and starch) to slowly degradable carbohydrates (NDF) in the feed ration. The RLI takes into account the effect of easily degradable carbohydrates on ruminal NDF digestion. The maximum recommended RLI is set to 0.6. which gives a moderate reduction of NDF degradation rate. A RLI of 0.6 corresponds to a diet with 240-280g starch per kg DM depending on starch source. The sugar and starch content of a diet will often be 290 – 320g/kg DM.
These maximum levels of starch and sugar are in accordance with previous Danish recommendations. The NRC (2001) recommends diets with a non-fibre carbohydrates content ranging from 360 – 440g/kg DM, depending on the NDF content of the ration; 360g/kg DM for diets with a low NDF content (250g/kg DM), and 440g/kg DM for diets with a high NDF content (330g/kg DM).

Table 16:
Possible basic structures of daily fodder rations for dairy cows (Danish Holstein 700kg LM with annual milk yield of 10,000kg with rye as specified concentrated fodder component (kg FW)

Feedstuffs		Dry matter g/kg	Energy MJ/kg DM	Crude Protein g/kg dry matter	Early lactation 0 til 28 days	High lactation 42 Kg ECM	Late lactation 30 Kg ECM	Dry cows	Stea-ming up
Rye	kg DM	850	7.53	96	2.1	3.4	2.4	-	1.5
Rapeseed cake, 10.5% fat	kg DM	885	7.31	333	3.2	4.1	2.2	0.6	0.8
Soybean meal, dehulled	kg DM	874	8.48	535	1.6	2.1	1.1	0.3	0.4
Sugar beet pulp, dried	kg DM	890	6.26	96	2.0	2.0	-	-	-
Clover grass silage mid. OMD, 40% clover	kg DM	418	6.05	161	5.1	5.6	6.2	2.1	1.3
Cornsilage, mid. OMD	kg DM	348	6.46	77	7.6	8.4	9.3	3.1	2.0
Straw	kg DM	850	2.45	44	-	-	-	4.6	5.2
Limestone	g DM	1,000	-	-	50	50	50	-	-
Minerals	g DM	1,000	-	-	100	100	100	100	100
Nutrient content per feed group									
Feed intake	kg DM/day	-	-	-	21.6	25.5	21.1	10.7	11.2
Concentrate	kg DM/day	-	-	-	9	11.6	5.6	0.9	2.7
Energy intake	MJ/day	-	-	-	146	171.2	140.7	53.1	56.3
Energy	MJ/Kg DM	-	-	-	6.76	6.71	6.68	4.98	5.03
Crude protein	g/kg DM	-	-	-	173	177	154	105	108
AAT	g/MJ	-	-	-	15	16.6	15.5	-	-
PBV	g/kg DM	-	-	-	20	17	10	0	0
Fatty acids	g/kg DM	-	-	-	27	28	24	15	16
NDF	g/kg DM	-	-	-	323	315	331	545	532
Rumen load index		-	-	-	0.47	0.52	0.55	0.14	0.23
Starch	g/kg DM	-	-	-	190	205	227	102	151
Chewing time index	min./kg DM	-	-	-	32	30	37	80	76
Fill value	FV	-	-	-	7.81	9	8.36	5	5
ECM yield	kg/day	-	-	-	38	42	30	-	-
Days in milk	days	-	-	-	14	60	280	-	-

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Practical experience reports that with annual outputs > 10,000kg milk/cow in high lactation up to 6 kg rye per cow per day can be very successfully fed to animals without any health impacts. The tests performed by *Mahlkow, K.* (2005) and *Preißinger, W.* (2003) in Germany confirm that 30 – 60% of the concentrated feed for dairy cows can consist of rye without any drawbacks whatsoever.

2.2.2 Beef cattle

The effectiveness of beef cattle is crucially determined by the amount of the feedstuff costs. Rye can also function as a price-effective concentrated feed in beef cattle rations. Because the majority of beef cattle rations have corn silage as their basis, the price of the protein carrier here again forms the criterion for the cost limit of the rye. The combination of protein supply with urea as the source of nitrogen for the rumen bacteria always produces a cost benefit given the physiological possibilities.
The tests performed by *Preißinger, W.* (2005) state the safe measure for using rye in beef cattle feed, i.e. 1.0 – 1.5kg/animal and day depending on the live weight.
Exploiting the fodder absorption capacity of fattening bulls was also not detrimentally effected by higher animal weights due to the use of rye. Back in 1990 Schneider et al. conducted tests that showed that fattening bulls with > 5 kg rye/day achieved the same fodder intake and growth performed compared to corn, barley and wheat as the cereal concentrate.

Table 17:
Possible basic structures of daily fodder rations for Danish Holstein (150 and 400kg LW) with average daily gains of 1290g/animal with rye as the determinant concentrate feedstuff component in combination with soybean meal (kg FW)

Feedstuffs		Dry matter g/kg	Energy MJ/kg DM	Crude Protein g/kg dry matter	150-200 kg 4.0-5.3 mo.	200-250 kg 5.3-6.3 mo.	250-300 kg 6.3-7.5 mo.	300-350 kg 7.5-8.7 mo.	350-400 kg 8.7-10.0 mo.
Rye	kg DM	850	7.5	96	1.4	2.3	1.9	1.9	2.1
Soybean meal, dehulled	kg DM	874	8.5	535	1.0	1.0	1.0	1.0	1.0
Maize cob silage	kg DM	513	7.6	83	2.0	2.2	2.8	3.2	3.4
Straw	kg DM	850	2.5	44	0.7	0.8	1.1	1.4	1.6
Limestone	g DM	1,000	-	0	50	50	50	50	50
Minerals	g DM	1,000	-	0	50	50	50	50	50
Nutrient content per feed group									
Feed intake	kg DM/day	-	-	-	5.1	6.2	6.8	7.5	8.1
Concentrate	kg DM/day	-	-	-	2.4	3.3	2.9	2.9	3.1
Energy intake	MJ/day	-	-	-	34.1	41.6	45	48.9	52.7
Energy	MJ/Kg DM	-	-	-	6.68	6.69	6.6	6.57	6.54
AAT	g/MJ	-	-	-	25.1	22.6	22.4	22	2.18
PBV	g/kg DM	-	-	-	3	0	0	0	0
Crude protein	g/kg DM	-	-	-	171	156	148	141	136
Fatty acids	g/kg DM	-	-	-	18	18	18	18	17
NDF	g/kg DM	-	-	-	270	269	291	303	313
Starch	g/kg DM	-	-	-	408	436	417	412	407
Chewing time index	min./kg DM	-	-	-	30	29	34	36	38
Fill value	FV	-	-	-	1.59	1.95	2.17	2.4	2.64
Daily gain	g/days	-	-	-	1,350	1,500	1,400	1,350	1,300

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2.3 Results of feeding trials from different countries of the RYE BELT

2.3.1 Fattening pigs

In a study of fattening pigs conducted by the former Landwirtschaftskammer Hannover, Germany (*Meyer et al.*, 2006) 70% rye was added. Because rye contains non-starch polysaccharides, particularly pentosans, an examination was performed to see what output could be achieved by using an NSP-hydrolysing enzyme in diets with rye as the sole cereal component. In the Leistungsprüfungsanstalt Rohrsen, Germany (*performance testing institute*) 26 piglets (PI x Danish hybrid) were kept in individual crates. The animals were given a starter feed containing 71% rye up to 50 kg LW and then a final fattening feed containing 69% rye. The test group feed differed from the control feed only by the addition of the enzyme Rovabio Exel AP (mixture of beta-glucan and beta-xylan, 50g/t). The female pigs were given feed ad libitum, while the castrated boars were given feed ad libitum up to 80kg LW after which the feed was then rationed. For piglet rearing only feed without rye was used, so that these animals received rye-based feed for the first time at the start of the fattening period.

Table 18:
Contents of feed mixes

		Control group (without enzyme)		Trial group (with enzyme)	
		Starter feed	Final feed	Starter feed	Final feed
Crude protein	%	19.1	17.0	19.1	17.7
Lysine	%	1.37	1.01	1.18	1.05
ME	MJ/kg	13.6	13.1	13.8	13.1
Phosphorous	%	0.59	0.44	0.54	0.44

The average fattening performance was a daily gain of 940g and feed consumption of 2.43kg per kg of growth, which is an extraordinarily high level. At 934g the animals in the trial group in pre-fattening stage gained 41g/day more than those in the control group. Because they were also able to absorb more feed per day, the feed consumption per kg of growth remained the same between the two groups. In the final fattening stage over 50kg, the daily gains were 939g (control group) and 976g (trial group) where the feed consumption per kg of growth was 2.71kg and 2.67kg respectively. In the overall fattening stage, the daily gains were 925g (control group) and 962g (trial group) while the feed consumption per kg of growth was 2.71kg and 2.41kg respectively. The differences in the fattening performance could not be backed up.

Table 19:
Fattening performance, carcass evaluation and meat characteristics

		Control group	Trial group
Number of animals		26	25
Initial weight	kg	25.5	25.7
Final weight	kg	115.2	115.3
Daily gains up to 50kg	g	893	934
Feed absorption/day up to 50kg	kg	1.57	1.65
Feed consumption/kg growth 50kg	kg	1.77	1.78
Daily gains over 50kg	g	939	976
Feed absorption/day over 50kg	kg	2.53	2.58
Feed consumption/kg growth over 50kg	kg	2.71	2.67
Daily gains. total	g	925	962
Feed absorption/day. total	kg	2.26	2.31
Feed consumption/kg growth. total	kg	2.45	2.41
Carcass weight	kg	90.3	90.2
Pork belly ratio	%	52.7	53.5
Index points		89.0	90.5

→ The carcass evaluation was performed using AutoFOM. There were no significant differences here or in the meat characteristics. The trial showed that extraordinarily good performance could also be achieved with very high proportions of rye. This is also confirmed with a fattening trial conducted by the Landwirtschaftskammer Hannover (*Meyer, A.,* 2003) using 64% rye.

In two separately performed pig fattening trials (*Schwarz, T.*, 2011), a comparison was made of feed mixes containing barley and rye under real conditions. The results of the trial were then analysed from an economic perspective.
In one trial pigs were given the feed in dry form ad libitum in three phases. The trial and the control group each consisted of 3 x 25 pigs. In another trial the feed was administered to the pigs in liquid form in two phases. The trial and the control group each consisted of 41 pigs. The rye proportion in the 3-phase feeding was 10% in the starter phase, 25% in the middle fattening phase and 50% in the final fattening phase. In the liquid feed the rye proportion in the starter and middle phase was 25% and 50% in the final fattening phase. The amounts of the nutrient content of the feed of the trial group and the control group were maintained at the same level.
In the trial with the dry feed it was found that the feed consumption per kg growth was somewhat poorer, but that there was a higher daily gain within the trial group (Table 20). In the trial with liquid feed no higher feed consumption was observed in comparison to the control group (Table 21).

Table 20:
Fattening performance and carcass evaluation of the animal groups of the dry feed trial

Parameter		Control group (barley)	Trial group (rye)
Daily gain	g	747	783
Feed absorption per day	kg	2.15	2.35
Feed consumption per kg growth	kg	2.66	2.77
Carcass yield	%	74.14	76.06
Fat thickness	mm	15.7	16.8
Loin	mm	58.3	60.5
Lean meat content	%	56.05	55.95

Table 21:
Fattening performance and carcass evaluation of the animal groups of the liquid feed trial

Parameter		Control group (barley)	Trial group (rye)
Daily gain	g	752	784
Feed absorption per day	kg	1.94	1.91
Feed consumption per kg growth	kg	3.00	2.83
Carcass yield	%	82.73	81.48
Fat thickness	mm	15.6	16.3
Loin	mm	60.1	58.4
Lean meat content	%	56.46	55.52

→ The carcass yield characteristics of the animals in the trial and control group were very similar to one another in both trials. The values of the carcass yield characteristics only differed slightly within the trial group with dry feed. This resulted in a higher carcass classification within this group, which had a positive impact on the price per kg carcass. Despite the low lean meat content, the trial group with liquid feed was able to achieve the same market price per kg carcass due to the higher carcass classification (Table 22 and 23).

Table 22:
Simplified contribution margin calculation of the trial group and control group with dry feed

Economic indicators	Control group (barley)	Trial group (rye)
Price per 1kg carcass (PLN/kg)	5.07	5.19
Price per carcass (PLN)	406.13	428.77
Sales value (PLN), total	29952.77	32154.96
Piglet costs (PLN), total	16455.71	16844.29
Feeding costs (PLN), total	11566.67	12587.68
Direct costs, (PLN) total	28022.38	29431.97
Contribution margin (PLN)	**1930.39**	**2722.99**

Table 23:
Simplified contribution margin calculation of the trial group and control group with liquid feed

Economic indicators	Control group (barley)	Trial group (rye)
Price per 1kg carcass (PLN/kg)	5.97	5.97
Price per carcass (PLN)	554.45	563.84
Sales value (PLN), total	22732.32	23266.29
Piglet costs (PLN), total	7629.40	7710.80
Feeding costs (PLN), total	10469.31	10555.49
Direct costs, (PLN) total	18255.71	18266.29
Contribution margin (PLN)	**4633.61**	**5000.00**

→ The evaluation showed that the use of rye in pig fattening feed makes sound economic sense.

2.3.2 Sows

Only a few feeding trials with sows have been performed in Germany. An extreme mix with 62% rye was used in a trial conducted by the Schaumann Forschungszentrum Hülsenberg (research centre) (1983). A wheat mix was used for comparative purposes.

Table 24:
Results of a sow feeding trial using rye and wheat (average from five litters)

Feed mix		62% Rye	62% Wheat
Rye	%	62	-
Wheat	%	-	62
Barley	%	-	15
Oats	%	15	-
Soy meal	%	20	20
Bi-phosphoric rearing	%	3	3
Performance:			
Liveborn piglets		11.0	11.2
Birth weight	kg	1.26	1.32
Weaned piglets		9.1	8.9
Weaned weight	kg	6.4	6.5
Litter interval	days	166	160

→ In the lactation period the sows in the groups only gained about 5kg/day. However, the piglets achieved a weaning weight of 6.5kg following a suckling period of 3.5 weeks. Overall, there were only minor differences in the results of the two groups.

2.3.3 Piglets

Trials with piglets have been conducted by German state institutions in Brandenburg, Saxony and Saxony-Anhalt in recent years. In 2004 at the LLFG Iden, Germany, and the LVFL (*regional office for consumer protection, agriculture and farmland redevelopment*) Ruhlsdorf, Germany, a parallel trial was performed with a piglet rearing feed I with 0, 10 and 15% rye and a piglet rearing feed II (from the 22nd day of rearing) with 0, 20 and 30% rye (*Weber, M. et al.*, 2004). The average age of the piglets at the start of the trial was 28 days and they weighed between 8.8 and 9.5kg. At the end of the 42-day rearing period no secured differences were detected in performance between the two trials.
And in a trial conducted by the Landesanstalt (State Institute) in Köllitsch in Saxony, Germany (*Alert, H-J.*, 2005), a feed with 15% rye, which was fed to piglets between 12 and 25kg in weight, had no effect on health and performance.

2.3.4 Dairy cows

Two feed trials conducted by the Bayerische Landesanstalt für Landwirtschaft (*Bavarian State Research Centre for Agriculture*) (*Preißinger, W. et al.*, 2003, *Preißinger, W.*, 2004) demonstrated that dairy cows could be fed concentrated feed with 30 and 60% rye without any negative impact on performance. The Landwirtschaftskammer Schleswig-Holstein, Germany performed trials to see if wheat could be wholly substituted by rye (*Mahlkow, K.*, 2005). In each case 36 newly and heavily lactating cows were fed concentrated feed with 44% wheat and rye respectively. For each kg of dry mass the grass-based Total Mix Ration contained 7.1MJ NEL and 161g utilisable crude protein (wheat group) or 159g (rye group). The performances are set out in the following table.

Table 25:
Results of the trial conducted by LWK Schleswig-Holstein

		Rye	Wheat
ECM	kg/day	36.3	36.1
Fat content	%	4.23	3.97
Protein content	%	3.39	3.36
Urea content	mg/l	209	240
Cell count	per ml milk	174.000	137.000

→ There were no significant differences in milk yield between the two groups. There was also no negative impact on the weight and physical condition of the cows caused by the use of approximately 4kg rye/cow and day.

At a test facility in Pawlowice, Poland (2010 and 2011) under real conditions the Polish National Research Institute of Animal Production examined the effects on the milk yield and milk content caused by the use of hybrid rye in milk cow feed (KWS LOCHOW POLSKA 2010/2011).
To this end trials were conducted using 25% and 40% rye in the concentrated feed. Polish Holstein Friesian cows (first lactation) were split into two groups. The only difference within the trial groups was the proportion of rye used.

→ Table 26 sets out the average result of controlling milking at the start and the end of the trial. It shows that the addition of 25% and 40% of rye had no effect on the milk yield or on the fat and protein content of the milk.

Table 26:
Results of the trial with 25% and 40% rye

		Trial 1		Trial 2	
		Control group	25% Rye	Control group	40% Rye
Number of animals	I II	33 32	33 33	28 28	28 28
Milk yield kg	I II	32.0 31.1	31.7 31.2	32.2 35.7	31.6 34.8
Fat %	I II	3.46 3.19	3.55 3.25	3.36 2.71	3.03 2.59
Protein %	I II	3.30 3.46	3.28 3.44	3.06 3.15	3.08 3.11

I – Start of the trial (80^{th} lactation day in Trial 1 and 50^{th} lactation day in Trial 2)
II – End of trial (100 days following start of trial)

The analysis of the fatty acid profile found that the C18:0 content (stearic acid) was reduced through the addition of rye and that the C18:1 n-9 content (oleic acid) in Trial Group 2 (40% rye) increased significantly. Oleic acid is a member of the group of mono-unsaturated fatty acids. The fatty acid make-up was positively influenced here.

2.3.5 Bulls

In a feeding trial with Simmental bulls, the LVLF Brandenburg, Germany, tested rye as the sole concentrated food component (*Drews, U. et al.*, 2004). Twelve bulls in each of the three feeding groups were fed corn silage ad libitum and 3kg concentrated feed/day up to about 620kg live weight. The concentrated feed of the rye group consisted of 45% rye up to a weight of 350kg rising to 50.4% thereafter, while the animals in the two other groups received no rye but barley, triticale and wheat instead. In one of these two groups straw was also added to provide fibre. The average level of gain was 1290g/day. There were no significant differences in the fattening performance and carcass evaluation between the control group and rye group, whereas the animals additionally fed straw exhibited a significantly higher meat ratio due to the lower feeding intensity. The summary of this 2004 trial stated that young bulls can be successfully feed up to 1.4kg rye/day.

During the course of a trial at a test facility in Pawlowice, the Polish National Research Institute of Animal Production analysed the effects of the use of rye on fattening performance and the quality of meat in young bull fattening, KWS LOCHOW POLSKA (2010/2011). 30 Polish Holstein Friesian young bulls were split into three groups. At the start of the trial the average live weight of the young bulls was 200kg and about 600kg at the end of the trial.

The feed diet was comprised of corn and alfalfa silage and concentrated feed with 0%, 20% and 40% proportions of rye. The average daily gains amounted to 1354g, 1345g and 1282g (Table 27).

Table 27:
Results of the trial with various proportions of rye in the concentrated feed

		Feed group – ratio in concentrated feed		
		0% Rye ratio	20% Rye ratio	40% Rye ratio
Number of animals	Units.	9	10	9
Final weight	kg	596.7	615.2[a]	588.4[a]
Daily gain	g	1,354	1,345	1,282
C18:0	%	13.32[a]	11.83[ab]	13.13[b]
C18:3 n-3	%	0.32[a]	0.46[a]	0.42
Vitamin E	µg/g	2.65[ab]	3.02[a]	3.08[b]

Different letters signify significant differences ($p < 0.05$).

→ The results show that the fatty acid C18:3 n-3 (alpha-linolenic acid) content in the meat increased through the proportion of rye in the feed. This fatty acid is a member of the group of Omega-3 fatty acids. The vitamin E content also increased.

The trial showed that 20% is the optional ratio of rye in the concentrated feed.

3 DLG usage recommendations for rye in the feeding of pigs and cattle

In 2006 the Deutsche Landwirtschafts-Gesellschaft (DLG) published new recommendations on the use of rye in the feeding of pigs and cattle (Table 28 and 29).

Table 28:
Usage recommendation for rye in the feeding of pigs

	up to .... % rye in the ration
Fattening pigs [1]	
28-40kg LW (preparatory ration)	30
40-60kg LW (initial fattening stage)	40
60-90kg LW (medium ration)	50
from 90kg LW (finishing ration)	50
Sows	25
Piglets	
up to 15kg LW	10
from 15kg LW	20

[1] In the event of foam formation with liquid feed the rye proportions should be reduced. But the addition of vegetable oil may also alleviate the problem. With the addtional use of triticale due to the high NSP content, the possible rye proportion should be reduced to a third of the triticale proportion (e.g. at 30% triticale the maximum recommended rye proportion is 40% in the final feed.

Table 29:
Usage recommendation for rye in cattle feed

	up to .... % rye
Calves	0 in starter feed 5-8 in the calf rearing feed[1]
Rearing cattle	40 in concentrated feed
Fattening cattle	20 in concentrated feed max. 1.0kg rye/day
Dairy cows	40 in concentrated feed max. 4.0kg rye/day

[1] Higher values cannot be currently backed up due to the absence of trial results

4 Actual operational examples with empirical findings on feeding with rye

Over the years increasing numbers of farmers have been using rye for feeding of pigs and cattle. Due to its low production costs per ha and its high energy content, rye is particularly attractive for on-farm feed mixers.
For this reason we questioned farmers in Germany, Denmark and Poland on the issue of “Using rye in livestock feed”. Below you will find some summarised points they made.

Cord Meyer, Stapel, Lower Saxony, Germany

Number of pig fattening places:
1,500

Rye ratio in pig feed:
26% in the starter feed
46% in the final feed

Time rye has been in use:
Mr. Meyer has been using rye in pig feed for more than 30 years.

Fattening performance and carcass evaluation:
Daily gains: approx. 737g on average
Feed absorption: 2.1kg per day
Feed conversion: 2.8kg per 1 kg growth
Lean meat content: 57.6%

Problems with rye in feed:
There is no problem among the animals. It is only when more than 45% is used in the diet that the mixture begins to foam and problems can arise with the liquid feeding equipment.

Benedikt Biermann, Gut Karow, Karow, Germany

Number of animals:
240 Angus suckler cows plus their offspring

Rye in concentrated feed of calves:
By the 4th week after birth alongside hay and silage the calves are given on-farm mixed concentrated feed with a rye ratio of 29% to be consumed at will.
In the rearing period of 8 – 10 months the rearing calves consume 300 kg concentrated feed. If necessary the ratio of rye can be increased to over 50% without affecting the livestock performed.

I/S Cathrineholm, Fuglebjerg, Denmark

Number of pigs fattened annually: 13500 units

Rye ratio in pig feed: 13% rye (liquid feed)

Time rye has been in use: For two months now

Fattening performance and carcass evaluation: No relevant data is available.

Problems with rye in feed: No problems to date

I/S Fuglsang, Aars, Sjøstrup, Denmark

Number of milking cows: 600 Jersey dairy cows

Rye utilisation per cow and day: 2 – 3kg rye (soda grain)

Milk yield per year: 9,300kg ECM

Cell count: 180,000 – 200,000ml milk

Utilization period: Rye has been in use for two years now.
But wheat has been used now and again during this time.

Problems with rye in feed:
No problems were encountered while using rye in feed.
No difference between rye and wheat.

Łukasz Popowicz, Brodnica, Poland

Number of pigs fattened annually:
approx. 800 units

Rye ratio in feed:
Starting feed and final feed 10% rye

Fattening performance and carcass evaluation:
Daily gains: 930g, lean meat content: 58.2%

Problems with rye in feed:
No worrying symptoms were observed among the animals that could be traceable back to the addition of rye in the feed.

Marek Stelmaszyk, Pszczew, Poland

Animal stock:
500 sows plus pig fattening in closed system

Rye ratio in pig feed:
Depending on feeding phase between 20 – 60% rye is used.

Fattening performance and carcass evaluation:
Daily gains: 860 – 880g on average

Feed conversion: 2.75 kg per 1 kg growth
Lean meat content: 59 – 61%

Problems with rye in feed:
No detrimental effects have been observed that could be traced back to the use of rye in pig feed.

Krzysztof Komorowski, Lubosz, Poland

Number of pigs fattened annually:
approx. 2.500 units

Rye ratio in feed:
up to 40% rye

Fattening performance and carcass evaluation:
Daily gains: 850 – 870g
Lean meat content: approx. 56%
Feed conversion: 2.90kg per 1kg growth

Problems with rye in feed:
No worrying symptoms were observed among the animals that could be traced back to rye.

Józef Szczepaniak, Rostarzewo, Poland

Animal stock:
65 sows (PIC) plus pig fattening in closed system

Rye ratio in feed:
up to 40% rye

Fattening performance and carcass evaluation:
Lean meat content: approx. 59.3%
Feed conversion: 2.80kg per 1kg growth

Problems with rye in feed:
No worrying symptoms were observed among the animals that could be traced back to rye.
In his view it makes no difference if hybrid rye or triticale is used in the pig feed.

5 Pigs and Cattle Feed Value Table

Pigs feed value table

	1.000g original substance												
	dry matter g	Fesv	Feso	crude protein %	Lysine % of crude protein	digestible Lysine g	Methionine % of crude protein	digestable Methionine g per kg	crude fiber (soluble/unsoluble) g	Starch g	Calcium g	Phos-phourus g	digestible Phos-phourus* g
Fat 92_15	995	3.81	3.66	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Palm oil	995	3.81	3.66	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Peas	85,2	1.01	1.02	20.4	6.99	11.95	1.61	266	383	0.77	0.77	3.92	45
Rape cake 11,4% fat	895	0.92	0.99	29.2	5.50	12.33	5.06	335	17	7.25	7.25	10.70	27
RYE 2011	850	1.12	1.12	7.6	3.70	2.10	1.03	137	521	0.40	0.40	2.70	50
Soybean meal, dehulled	885	0.96	0.98	46.9	6.14	25.85	5.81	0	65	3.10	3.10	6.20	39
Spring barley 2011	850	1.05	1.05	8.9	3.87	2.45	1.26	188	513	0.50	0.50	3.10	43
Spring barley 2011 + xylanase	850	1.06	1.06	8.9	3.87	2.46	1.27	188	513	0.50	0.50	3.10	43
Wheat 2011	850	1.15	1.13	9.1	3.05	2.12	1.19	138	569,5	0.40	0.40	2.70	50
Wheat 2011 + xylanase	850	1.16	1.14	9.1	3.05	2.15	1.20	138	570	0.40	0.40	2.70	50
Wheat bran	870	0.62	0.69	14.5	3.90	3.54	1.60	391	193	0.96	0.96	10.40	20
Winter barley	850	1.03	1.04	9.1	3.84	2.46	1.27	188	513	0.50	0.50	3.10	39
Winter barley + xylanase	850	1.04	1.04	9.1	3.84	2.48	1.27	188	513	0.50	0.50	3.10	39

* without Phytase supplementation

VIDENCENTER OF SVINEPRODUCTION, Denmark

Cattle feed value table

Description	Parameter	Unit	Rye	Rape seed cake, 10,5% fat	Soy bean meal, dehulled	Sugar beet pulp, dried	Clover grass silage, mid. OMD, 40% clover	Corn silage, mid. OMD
Attributes								
	Group		1	2	2	4	6	6
	Code		11	44	54	20	230	308
General								
	Dry matter	g/kg	850	885	885	890	418	348
	Ash	g/kg DM	19	71	68	70	96	33
	OMD	% af OM	89	78.5	90.8	88	76	77.2
Protein								
	Crude protein	g/kg Dry matter	93	333	528	96	161	77
	soluble crude protein	g/kg crude protein	400	264	144	177	570	459
	NH3-N	g N/kg N	0	0	0	0	61	46
	Potentially degradable crude protein	g/kg crude protein	560	659	856	823	381	437
	indigestible crude protein	g/kg crude protein	43	96	18	198	94	140
	Degradation rate of potentially degradable crude protein	%/hour	14.5	12.4	7.5	7.7	9.2	4.6
Fat								
	Crude fat	g/kg Dry matter	20	122	24	12	44	22
	Fatty acids	g/kg crude fat	700	800	700	650	390	650
NDF								
	NDF	g/kg Dry matter	146	268	102	382	398	359
	Potentially degradable NDF	g/kg NDF	801	489	939	911	843	820
	Indigestible NDF	g/kg NDF	199	511	61	89	157	180
	Degradation rate of potentially degradable NDF	%/hour	6.6	10.4	5	9.6	4	3.2
Starch								
	Starch	g/kg Dry matter	640	25	49	0	15	331
	Soluble starch	g/kg starch	500	490	490	0	500	500
	Potentially degradable starch	g/kg starch	500	510	510	0	500	500
	Indigestible starch	g/kg starch	10	20	20	0	10	10
	Degradation rate of potentially degradable starch	%/hour	40	12	12	0	40	40
Other carbohydrates								
	Crude fibre	g/kg Dry matter	25	148	47	201	237	187
	Sugar	g/kg Dry matter	70	101	121	59	73	20
Minerals								
	Ca	g/kg Dry matter	0.5	8.2	3.5	11.7	6.6	1.6
	P	g/kg Dry matter	3.3	11.1	7.1	1	3.5	2
	Mg	g/kg Dry matter	1.1	4.9	3.3	2.2	1.9	1
	K	g/kg Dry matter	5.4	14	24.1	3.6	25.8	9.3
	Na	g/kg Dry matter	0.3	0.1	0.1	0.6	2	0.2
	Cl	g/kg Dry matter	0.7	0.5	0.2	0.3	14	2.3
	S	g/kg Dry matter	1.3	6.2	3.8	2.7	2.2	0.9
	CAB	meq/kg Dry matter	50	-39	377	-59	214	126
Structure/fill value								
	Particle size	mm	2.1	2	2	4	20	10
	Chewing time index	min./kg Dry matter	8	4	4	22	53	44
	Fill value	FV/kg Dry matter	0.22	0.22	0.22	0.22	0.44	0.41
Standard feed value								
	AAT20	g/kg Dry matter	106	111	228	96	77	86
	PBV20	g/kg Dry matter	-64	157	239	-63	34	-58
	NEL20	MJ/kg Dry matter	7.73	7.31	8.55	6.26	6.01	6.46

Barley straw	Spring barley	Winter barley	Oat	Wheat	Corn (kernel)	Triticale	Brewer's grain, fresh	Brewer's grain, dried	Beet pulp, pressed, ensiled, 5% molasses	Clover grass hay, high OMD	Clover grass hay, low OMD
6	1	1	1	1	1	1	1	1	4	6	6
386	8	9	10	13	14	15	100	103	33	403	404
850	850	850	850	850	875	850	256	250	265	836	867
60	21	21	26	18	15	21	48	42	65	87	74
44.1	85	85	73	90	89	89.5	66.5	65.2	89	73.6	65.9
51	106	106	103	105	96	110	231	263	94	145	106
306	224	224	310	308	114	362	43	44	340	317	317
0	0	0	0	0	0	0	0	0	63	0	0
579	724	724	629	671	886	606	800	799	651	596	596
616	59	59	33	31	200	28	127	127	113	213	213
2.6	17.3	17.3	35	16	2.5	16	6.8	6.8	8.8	5	5
13	28	31	54	23	46	25	100	123	15	24	21
250	700	700	800	700	900	700	790	790	650	480	480
771	180	180	340	117	111	142	542	520	319	451	542
616	842	842	608	813	913	813	676	676	910	818	770
384	158	158	392	187	87	187	324	324	90	182	230
2.3	3.7	3.7	2	3.5	3	3.5	3.3	3.3	9.6	4	3.2
0	609	601	478	680	712	658	50	0	7	15	15
0	500	500	500	500	230	500	500	500	500	500	500
0	500	500	500	500	770	500	500	0	500	500	500
0	10	10	10	10	30	10	10	10	10	10	10
0	40	40	40	40	9	40	40	40	40	40	40
438	56	54	135	28	23	29	158	186	186	250	287
0	20	20	18	32	17	32	20	0	20	112	107
4.6	0.6	0.6	0.9	0.5	0.1	0.5	3.7	3.7	8.4	5.4	5.4
0.9	3.4	3.4	3.5	3.1	3.2	3.5	7.2	7.2	0.8	2.9	2.9
0.9	1.2	1.1	1.2	1.2	1.2	1.3	2.7	2.7	1.7	1.4	1.4
20	5.4	5.9	5.3	5.5	4	5.4	1	1	8.2	24.3	24.3
1.4	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	2.1	1.4	1.4
17	1.5	1.4	1.2	1	0.7	0.7	1.1	1.1	0.8	12	12
1.1	1.1	1.3	1.4	1.3	1.2	1.3	3	3	1.7	1.7	1.7
25	40	43	28	44	21	50	-180	-180	172	238	238
50	2.1	0	2.1	2.1	2	2.1	4	4	7.9	50	50
126	9	4	15	7	4	8	36	35	34	65	80
0.68	0.22	0.22	0.22	0.22	0.22	02..	0.22	0.22	0.34	0.48	0.55
44	104	104	81	107	104	106	120	125	91	88	81
-34	-48	-48	-12	-52	-63	-45	51	75	-51	-12	-30
2.47	7.53	7.55	6.2	7.84	8.04	7.72	5.53	5.98	7.13	5.42	4.86

Notes

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