EFFECT OF A PROTEIN REDUCED DIET WITH AND WITHOUT HIGH CONTENTS OF INDUSTRIAL BY-PRODUCTS, ON ZOOTECHNICAL PERFORMANCE AND SLAUGHTER PARAMETERS OF FATTENING PIGS

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Abstract. For a calculation of diets covering the pig's requirement and to avoid the waste of valuable nutrients without impact on zootechnical performance, the knowledge about the nutrient contents and their availability of the used feedstuffs, is a prerequisite. From the perspective of sustainability, higher usage of industrial by-products would be desirable to reduce the strong competition for food between human and pig nutrition. Hence, the aim of the present study was to test the effect of high amounts of wheat middlings in pig diets under consideration of the net energy system on zootechnical and slaughter performance of fattening pigs.

Four dietary treatments differing in energy- (corn / barley / wheat middlings) and protein source (soybean meal / rapeseed meal / DDGS) were conducted, resulting in one high dietary crude protein treatment (soybean meal) and three reduced dietary crude protein treatments (rapeseed meal, low wheat middlings and high wheat middlings). Animals receiving the high wheat middlings diet showed a significantly lower daily feed intake (-13.6%) compared to the diet including rapeseed meal ($p<0.0001$). The rapeseed meal diet declined the feed to gain ratio (+8.6%) compared to the other treatments ($p<0.05$). The average daily gain was numerically greater for pigs receiving the high protein diet (+6.4%; $p<0.1$) compared to the other treatments. No differences between treatments were recorded for the investigated slaughter parameters. Specific slaughter parameters showed the highest Pearson correlation coefficient with the daily net energy intake.

The observed differences regarding zootechnical performance parameters can be explained by unbalanced nutrient contents between the different experimental diets. The net energy system appears to be the most precise tool for an energy estimation of fattening pig diets. An accurate knowledge of the nutrient contents and availability of the feedstuffs is a prerequisite to optimize balanced diets for fattening pigs.

Keywords: fattening pigs, protein reduced diets, performance, industrial by-products, net energy

Introduction. The production of foodstuffs of animal origin consumes a large amount of cereals. Above all, monogastric livestock such as swine has strong competition for food to the humans (Schedle, 2016). Wheat can be regarded as the most frequently produced grain worldwide, after corn. However, besides its primary aim, the fabrication of flour, the agricultural production of wheat generates a major by-product: wheat middlings. Industrial by-products like wheat middlings contain a high amount of non starch polysaccharides (NSP) which adversely affect the digestibility of nutrients and as a result the energy content is decreased (Schedle, 2016). For this reasons, only small inclusion of such industrial by-products is possible in diets for fattening pigs. Nevertheless, low protein diets and the system of standardised ileal digestible amino acids (SID AA) offers the possibility to increase the use of industrial by-products (low in protein content) like wheat middlings, in diets for fattening pigs (Schedle et al. 2012; Schedle et al. 2013; Kraler et al. 2015).

To take full advantage of low protein diets, the energy supply must also be taken into account. With high protein diets, excess absorbed AA are converted into nitrogenous waste which is excreted through urine and faeces into the environment. This process uses up valuable energy, consequently, when the protein level is reduced, less energy is required in the feed (Noblet et al. 1987). However, the more efficient utilisation of dietary energy with low protein diets is not taken into account in all energy systems.

Hence, the aim of the present study was to test the effect of high amounts of wheat middlings in low protein pig diets under consideration of the net energy (NE) system on zootechnical and slaughter performance of fattening pigs.

Material and Methods. The study employed a total of 60 female pigs OEHYB: Crossbred F1 sow (Large White * German Landrace) * Pietrain, with 32.6 ± 0.4 kg at the onset of the study. Pigs were equally distributed among four dietary treatments, considering litter and initial body weight (BW) and, were housed in 12 pens (i.e. five animals per pen, three pens per treatment). The four dietary treatments differ in energy and protein source (Tables 1 and 2) resulting in one high crude protein (CP) treatment (TG 1) and three treatments with a reduced CP content (TG 2 to TG 4). The treatments TG 2 and TG 4 differed by the protein/energy feedstuffs that were used: TG 2 contained rapeseed meal (RSM), TG 3, 20% of wheat middlings and TG 4, 40% of wheat middlings. Each pen was equipped with an automatic dry-feeding-system and a nipple drinking system. Animals had free access to feed and water over the whole fattening period.
The animals received a grower diet (Table 1) from start of the experiment up to a BW of about 74.7 ± 0.8 kg (mean of a pen). Then, animals were fed a finisher diet until the end of the experiment (116.6 ± 0.4 kg) (Table 2).

Table 1: Components of diets for pigs

Pig fattining PH1 Uni*, %	20.00	20.00	20.00	20.00
Trial feed, %	80.00	80.00	80.00	80.00
Feedstuffs (Trial feed), %	**TG 1**	**TG 2**	**TG 3**	**TG 4**
Corn	47.90	61.50	56.30	36.70
Barley	24.50	10.00		
Soybean meal (without hulls)	20.90	7.10		
Rape seed meal		15.00		
DDGS (Actiprot ®)			21.00	15.10
Wheat middlings			20.00	40.00
Wheat bran	4.30	4.10		
Vegetable oil				5.60
Ca-carbonate	1.10	0.90	1.50	1.50
Monocalcium-P	0.70	0.60		
Salt	0.200	0.200		
L-lysine-HCl	0.200	0.410	0.690	0.670
DL-methionine	0.050	0.030	0.110	0.130
L-threonine	0.080	0.140	0.240	0.250
L-tryptophan		0.040	0.070	0.070
L-isoleucine			0.070	0.090
L-valine			0.040	0.070
Vitamin and trace element premix	0.500	0.500	0.500	0.500

*Per kg: 12.9 MJ ME, 16.7% CP, 1.02% Lys, 0.60% Met + Cys, 0.61% Thr, 0.20% Trp, 0.78% Val, 0.64% Ile

Table 2: Components of finisher diets

Pig fattining PH1 Uni*, %	15.00	15.00	15.00	15.00
Trial feed, %	85.00	85.00	85.00	85.00
Feedstuffs (Trial feed), %	**TG 1**	**TG 2**	**TG 3**	**TG 4**
Corn	51.70	66.20	61.60	43.30
Barley	25.90	10.00		
Soybean meal (without hulls)	15.70	1.90		
Rape seed meal		15.00		
DDGS (Actiprot ®)			16.50	9.40
Wheat middlings			20.00	40.00
Wheat bran	5.00	5.10		
Vegetable oil				5.30
Ca-carbonate	0.90	0.70	1.20	1.10
Monocalcium-P	0.50	0.40		
Salt	0.200	0.200		0.100
L-lysine-HCl	0.150	0.360	0.510	0.490
DL-methionine			0.040	0.060
L-threonine	0.040	0.100	0.160	0.180
L-tryptophan		0.040	0.050	0.040
L-isoleucine			0.010	0.040
L-valine				
Vitamin and trace element premix	0.500	0.500	0.500	0.500

*Per kg: 12.9 MJ ME, 16.7% CP, 1.02% Lys, 0.60% Met + Cys, 0.61% Thr, 0.20% Trp, 0.78% Val, 0.64% Ile

Experimental data were statistically analysed by the GLM procedure of SAS (SAS Inst., Inc., Cary, NC, USA). Any data observation which was more than 2-fold standard deviation from the group mean was considered as outlier. Outliers were removed from statistical evaluation. For all results of the growth performance and carcass characteristics, least square means (LS-means) of dietary treatments were compared using the Tukey-Kramer-Test for each variable. The following tables present the LS-means of the dietary treatments as well as the pooled standard error of means (SEM). Significant differences among means ($p<0.05$) are indicated by superscripts. For performance parameters, the initial BW of each phase, as well as for analysis of carcass characteristics, the final BW were used as covariate, if the effect of covariate was significant ($p<0.05$).

Model for statistical analysis $Y_{ijk} = \mu + TG_i + Rep_j + e_{ijk}$

Y_{ijk} = Tested parameter

μ = Overall means

TG_i = Trial group i, i = 1, 4

Rep_j = Replicates j, j = 1, 3

e_{ijk} = Residual error

Results. The analyzed nutrient contents of the diets (dry matter, CP, ether extracts, starch, sugar, crude fibre, and crude ash) are listed in Table 3. Despite the 20% (grower phase) and 15% (finisher phase) inclusion rate of a pelleted universal fattening feed (Pig fattining PH 1 Uni) to grant the flowability in the automatic dry feeding system, the CP values and the AA contents were similar to the targeted nutrient values of diets. As expected, the calculated energy values (whatever the system) were within analytical ranges for the 4 treatments (Table 3). Nevertheless, the highest difference regarding energy content was recorded between the rapeseed meal diet (TG 2) and the high wheat middlings diets (TG 4).

Table 3: Analyzed nutrient contents of grower and finisher diets (in g/kg fresh matter)

Traits	**TG 1**	**TG 2**	**TG 3**	**TG 4**	**TG 1**	**TG 2**	**TG 3**	**TG 4**
	grower				finisher			
MJ ME (GfE 2008), MJ/kg	13.8	13.6	13.8	14.0	13.7	13.6	13.9	14.4
MJ NE [1)], MJ/kg	10.3	10.2	10.4	10.5	10.4	10.3	10.5	11.0
Dry matter, g/kg	899	897	901	908	893	893	900	904
Crude protein, g/kg	165	156	154	149	149	140	140	137
Ether extracts, g/kg	27	31	46	93	27	32	44	87
Crude fibre, g/kg	30	36	37	48	29	36	35	45
Ash, g/kg	50	46	44	46	45	41	40	52
Starch, g/kg	474	484	434	359	501	510	465	392
Sugar, g/kg	38	39	24	40	40	36	35	41
Lysine, g/kg	10.1	10.2	9.8	10.0	8.4	8.7	8.1	8.5
SID Lysine, g/kg	*9.0*	*8.9*	*8.7*	*8.8*	*7.4*	*7.4*	*7.1*	*7.3*
Methionine + Cysteine, g/kg	5.6	5.6	5.7	5.9	4.9	5.2	5.0	5.1
Threonine, g/kg	6.8	6.8	6.6	6.7	5.7	5.9	5.6	5.7
Tryptophan, g/kg	2.1	2.1	2.1	2.3	1.8	1.8	1.8	1.8
Valine, g/kg	7.8	7.2	7.0	7.0	7.0	6.6	6.2	6.0
Isoleucine, g/kg	6.6	5.7	5.5	5.4	5.8	5.0	4.7	4.7
Leucine, g/kg	13.2	12.3	11.8	10.8	12.0	11.2	11.1	9.9
Phenylalanine, g/kg	8.0	6.9	6.3	6.0	7.1	6.0	5.8	5.5
Histidine, g/kg	4.2	3.9	3.5	3.5	3.7	3.5	3.3	3.3
Lysine:MJ ME	0.73	0.75	0.71	0.71	0.61	0.64	0.58	0.59
SID Lysine:MJ ME	***0.65***	***0.65***	***0.63***	***0.62***	***0.54***	***0.54***	***0.51***	***0.51***
Lysine:MJ NE	0.98	1.00	0.94	0.95	0.81	0.85	0.77	0.77
SID Lysine:MJ NE[1)]	***0.87***	***0.87***	***0.84***	***0.84***	***0.71***	***0.72***	***0.68***	***0.66***

[1)] Noblet et al. 1994: Table 6: Linear regression model No. 7

Two animals were removed from the experiment during the grower phase (TG 3, accident and TG 4, rectal prolapse). During the finisher phase, two further animals were removed from the trial (TG 1, cannibalism and leg violation, and TG 2, rectal prolapse and cannibalism).

Zootechnical performance data are presented in Table 4. During the grower period (32.6 ± 0.4 kg to 74.7 ± 0.8 kg), animals receiving the high wheat middlings diet (TG 4) showed a significantly lower daily feed intake (dFI) (-13.7%) compared to the diet including RSM (TG 2) ($p<0.05$). Furthermore, the RSM diet (TG 2) impaired the feed to gain ratio (F:G) (+10.2) and the energy to gain ratio compared to the other treatments ($p<0.05$).

In the finisher period (74.7 ± 0.8 kg to 116.6 ± 0.4 kg), the high wheat middlings diet (TG 4) decreased dFI compared to the high protein (TG 1) and the RSM diet (TG 2) ($p<0.05$). Furthermore, the two wheat middlings diets (TG 3 and TG 4) decreased daily energy intake compared to the RSM diet (TG 2) ($p<0.05$).

Over the whole fattening period (32.6 ± 0.4 kg to 116.6 ± 0.4 kg), animals receiving the high wheat middlings diet (TG 4) showed a significantly lower dFI (-13.6%) compared to the diet including RSM (TG 2) ($p<0.0001$). The RSM diet (TG 2) declined the F:G (+8.6%) compared to the other treatments ($p<0.05$). The average daily gain (ADG) was numerically higher for pigs receiving the high protein diet (+6.4%; $p<0.1$) compared to the other treatments.

Carcass composition and meat quality parameters are presented in Table 5. Values were within normal ranges. No differences between treatments were recorded for the investigated parameters ($p>0.1$). The parameters lean, fat: meat ratio, back fat depth, and meat depthness respectively showed the highest Pearson correlation coefficient with the parameter daily NE intake followed by the daily ME intake (data not shown).

Table 4: Results of zootechnical performance

Traits	TG 1	TG 2	TG 3	TG 4	SEM	p-value
Grower period						
Animals, n	15	15	14	14		
Initial BW, kg	32.6	33.5	31.1	33.0	0.4	0.1602
Middle BW, kg	75.2	74.0	74.6	75.1	0.8	0.9515
ADG, g	834	778	795	765	11	0.0939
dFI, g	1732^{ab}	1804^{a}	1665^{ab}	1556^{b}	30	0.0054
dME, MJ	23.9	24.1	22.9	21.9	0.4	0.0809
dNE, MJ	17.8	18.1	17.3	16.4	0.3	0.0978
F:G, kg/kg	2.06^{b}	2.29^{a}	2.10^{b}	2.01^{b}	0.03	0.0002
ME:G, MJ/kg	28.4^{b}	31.2^{a}	28.9^{b}	28.1^{b}	0.3	0.0025
NE:G, MJ/kg	21.2^{b}	23.4^{a}	21.8^{ab}	21.1^{b}	0.3	0.0021
Finisher period						
Animals, n	14	14	14	14		
Middle BW, kg	75.2	74.0	74.6	75.1	0.8	0.9515
Final BW, kg	116.0	117.5	116.1	117.0	0.4	0.5624
ADG, g	819	790	772	754	11	0.1606
dFI, g	2223^{a}	2282^{a}	2115^{ab}	2012^{b}	33	0.0071
dME, MJ	26.9^{ab}	27.9^{a}	25.9^{b}	25.7^{b}	0.3	0.0327
dNE, MJ	20.4^{ab}	21.1^{a}	19.6^{b}	19.7^{b}	0.3	0.0420
F:G, kg/kg	2.73^{ab}	2.90^{a}	2.69^{b}	2.67^{b}	0.03	0.0135
ME:G, MJ/kg	32.9^{b}	35.5^{a}	32.8^{b}	33.7^{ab}	0.4	0.0250
NE:G, MJ/kg	25.0^{ab}	27.0^{a}	24.8^{b}	25.8^{ab}	0.8	0.0236
Total fattening period						
Initial BW, kg	32.6	33.5	31.1	33.0	0.4	0.1602
Final BW, kg	116.0	117.3	116.1	117.1	0.4	0.7545
ADG, g	821	785	774	757	10	0.0602
dFI, g	1961^{ab}	2066^{a}	1890^{ab}	1786^{b}	30	<0.0001
F:G, kg/kg	2.40^{b}	2.60^{a}	2.41^{b}	2.37^{b}	0.02	0.0033

Table 5: Carcass characteristics and meat quality

Traits	TG 1	TG 2	TG 3	TG 4	SEM	p-value
Carcass weight, kg	94.4	94.8	93.6	94.2	0.4	0.7653
Dressing, %	81.3	80.6	80.8	80.5	0.2	0.1566
Lean, %	62.6	62.6	62.7	61.9	0.3	0.7818
Valuable cuts, %	53.3	53.1	52.9	52.7	0.2	0.7419
Fat:Meat, 1: …	9.11	9.05	9.28	9.02	0.21	0.9721
Back fat depth, mm	17.4	17.1	17.6	18.6	0.4	0.4824
Meat depthness, mm	78.6	77.9	77.2	78.4	0.5	0.8117
pH1 loin muscle	5.91	6.02	6.16	6.06	0.04	0.1729
pH1 ham	6.24	6.27	6.25	6.20	0.06	0.9796
LF[†)]1 loin muscle, ms/cm	5.52	4.76	4.73	5.57	0.31	0.6461
LF1 ham, ms/cm	3.56	3.61	4.84	5.82	0.41	0.1810
LF24 loin muscle, ms/cm	4.98	4.95	4.72	4.97	0.24	0.9789
LF24ham, ms/cm	8.59	6.81	7.45	6.66	0.47	0.4078
Loin lightness[‡)] (U)	65.5	66.5	66.5	64.7	0.7	0.7824
Drip losses, %	7.74	7.51	7.28	7.24	0.30	0.9252
Intramuscular fat, %	1.08	1.21	1.04	1.08	0.04	0.3010

[†)]LF = conductance; ms = milli siemens, [‡)]„Göttinger Farbhelligkeitsmesser“ <45 U = PSE; >80 U = DFD (U = Units)

Discussion. According to Quiniou and Noblet (2012), pigs are able to regulate their feed intake according to the NE supply for values between 8.7 and 10.5 MJ NE/kg. This statement is supported by the results of the present study, where the NE and fibre-rich diets containing high quantity of wheat middling (TG 4) reduced the dFI compared to the RSM diet

(TG 2). Furthermore, the response of the pigs to the dietary energy concentration depends on the fibre sources used in the diets (Montagne et al. 2003; Quiniou & Noblet 2012).

The declined F:G ratio in RSM diet (TG 2) could be due to an underestimation of SID AA values in this diet or an overestimated available energy content. The nutrient availability in the feedstuffs for pigs varies in a wide range (Sauvant et al. 2004). Possible reasons for such a high degree of fluctuation are various factors that interfere with the utilisation of nutrients like NSP and or other anti-nutritional factors, thus limiting their use particularly in the nutrition of pigs. Additionally, feed additives or treatment techniques have the potential to modify nutrient density and energy content in feedstuffs.

In order to optimize pig diets covering the animal's requirements without impacting zootechnical performance, the knowledge about the nutrient contents and their availability of the used feedstuffs, is a prerequisite (Opapeju et al. 2006; Ayoade et al. 2012; Schedle et al. 2013). Nevertheless, a large incorporation of fibre-rich industrial by-products may result in increased N output, and increased bulk is associated with an increased volume of feed, which has to be transported from the feed mill to the farm. However, because of the competitive costs of fibre-rich industrial by-products compared with the cost of traditional grain and protein sources, fibre-rich industrial by-products may be more common in pig diets in the future (Quiniou & Noblet 2012).

The stronger Pearson correlation of dNE compared to dME, with important carcass characteristic parameters, might indicate that the NE content evaluated with equation No. 7 (Noblet et al. 1994) is the most precise tool for an energy estimation of fattening pig diets.

Conclusion. In summary, to optimize diets covering the pig's requirement, without impact on zootechnical performance, the knowledge about the nutrient contents and their availability of the used feedstuffs, is a prerequisite. Hence, the observed differences regarding zootechnical performance parameters can be explained by unbalanced nutrient contents between the different experimental diets. The usage of high amounts of industrial by-products in fattening pig diets will not affect animal performance as soon as the energy and nutrient contents are accurately estimated. The NE system appears to be the most precise tool for an energy estimation of fattening pig diets. Nevertheless, ongoing studies on this topic are necessary, to specify the nutrient values of our feedstuffs.

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