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Evaluation of Technical Glycerols from "Biodiesel" Production as a Feed Component in Fattening of Pigs

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The utilization of two different technical glycerols from "Biodiesel" production as a feed component was investigated in a feeding experiment using 6 × 6 barrows (Pietrain × F1). Glycerol was included into the diets in amounts of 5 and 10% (Diets 3-6). The control diet [1] contained no glycerol, whereas diet 2 was supplemented with 10% pure glycerol. The contents of dry matter of the two technical glycerols were 77.6% and 99.7%, respectively. The contents of ash were 18.7% and 4.8%, respectively. The feeding performance of the pigs in the growing period was elevated by 7.5% in all groups which received glycerol compared to control group 1. The improvement of the daily gain depended strongly on the actual intake of glycerol in this growing period. This effect could not be observed in the finishing period. The dietary treatments did not have any significant effects on meat quality. Glycerol reduced the water content in tendency. There were no differences between technical and pure glycerol concerning the feeding performance. A possible contamination with ash and a dilution with water should be considered in regards to the nutritive value in pigs.

Bewertung von technischem Glycerol aus der „Biodiesel"-Produktion für die Schweinemast. In einem Fütterungsversuch mit 6 × 6 Börgen (Pietrain × F1) wurde die Einsatzmöglichkeit von zwei verschiedenen technischen Glycerinen aus der Biodieselproduktion während einer Mastperiode als Rationskomponente in Höhe von 5 bzw. 10% Glycerin im Vergleich zu einer Kontrollgruppe 1 (ohne Glycerin) und einer Kontrollgruppe 2 (10% reines Glycerin) geprüft. Der Trockenmassegehalt (TS) der technischen Glycerine lag bei 77,6% bzw. 99,7%, und die Rohaschegehalte betrugen 18,7% bzw. 4,8%. Unabhängig von der Qualität der Glycerine war die Mastleistung in der Vormastperiode gegenüber der Kontrollgruppe 1 in allen Glyceringruppen um durchschnittlich 7,5% erhöht. Dabei bestand in dieser Periode ein enger Zusammenhang zwischen der tatsächlichen Glycerinaufnahme und der täglichen Lebendmassezunahme. In der Hauptmastperiode wurde dieser Effekt trotz ebenfalls tendenziell erhöhter Futteraufnahme nicht bestätigt. Die Fleischbeschaffenheit wurde nicht signifikant verändert. In der Tendenz ergaben sich geringere Wassergehalte im Fleisch nach Glyceringabe. Zwischen reinem und technischem Glycerin gab es keine Unterschiede in der erzielten Mastleistung. Bei Einsatz von technischen Glycerinen als Futterkomponente muß hinsichtlich der Einsatzempfehlungen der Mineralstoff- und Wassergehalt berücksichtigt werden.

1 Introduction

In previous investigations we showed the benefit of glycerol as a feed component in fattening of pigs [1, 2]. *Mourot* [3] found positive effects of glycerol on water holding capacity of muscles and other parameters of meat quality. For feeding only technical qualities of glycerol can be used, because pure glycerol would be too expensive for animal nutrition. The purpose of the investigations of glycerol as a feed component was an expected high glycerol production with an increasing cultivation of rapeseed as plant for industrial use. Glycerol is a byproduct of the production of "Biodiesel". An amount of about 10% glycerol originates from the production of rapeseed oil. There are no legal restrictions for the use of glycerol in animal feeding. Rapeseed was produced on an area of 330,000 ha in Germany in 1995 and the total area on which industrial crops were produced was 500,000 ha. If the total amount of rapeseed oil would be esterified for industrial use, there would be a yield of 33,000 t of glycerol. The production of "Biodiesel" may be estimated to be 1.2 m t in Europe in 1996. The resulting amount of glycerol from rapeseed is equal to 2/3 of the European industrial glycerol production per year. The utilization of rapeseed glycerol is expected to be of great interest because of the corresponding dropping prices. At present, the costs of glycerol are stable and high as capacities for esterification of rapeseed oil are missing in Germany. Therefore, a large amount of the rapeseed oil must be exported for processing. The glycerol used for the feeding experiment in the current study was purchased from Germany (Gly 1) and Italy (Gly 2). Technical glycerols were investigated with respect to their value as a feed component for growing-finishing pigs.

2 Technical Glycerols

The hydrolysis of fat yields glycerol and fatty acids. The reaction is reversible and the splitting reagents can be water (hydrolysis), alcohols (transesterification), sodiumhydroxide (saponification) or amines (aminolysis). At present, industrial glycerol is produced by hydrolysis and transesterification, as through these methods the produced glycerol is not contaminated with any other reagents. The reactants used in hydrolysis of fat form a heterogeneous reaction system consisting

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Tab. 1. Composition of technical glycerols from different „Biodiesel" production facilities.

Name	%DM	% in DM			in orginal matter	
		ash	crude fat	crude protein	glycerol/%	arsenic µg/l
Gly 1	77.6	18.7 (24% P, 27,5% Na)	0.2	0.01	54.8	23
Gly 2	99.7	4.8 (40.6% Na)	0.2	0.01	88.7	34
Gly 3	80.5	9.0	49.2	0.10	25.2	n.d.
Gly 4	98.5	5.4	6.1	0.01	81.3	n.d.
Gly 5	89.5	8.9	n.d.	0.01	77.8	12
Gly 6	51.7	7.7	n.d.	n.d.	46.3	60
Gly 7	99.6	6.5	n.d.	n.d.	84.9	n.d.

of two liquid phases. One is the disperse aqueous phase consisting mainly of water which will be enriched by glycerol during hydrolysis. The second phase is the homogeneous lipid phase, which is composed of glycerides (tri-, di- and mono-) and fatty acids. The progress of the reaction is characterized by a decreasing water content and an increasing glycerol content because of the hydrolysis. It is very important for the process to optimize the conditions for the reaction. The reaction rate depends strongly on the temperature. At 100°C it is very slow. A splitting of about 20% of fats would last approximately for 10 days under these conditions.

The use of catalysts and hydrolysis under pressure is a common practice [4]. According to the production process, the composition of the glycerol containing aqueous phases varies greatly. Using saponification, the soap lye consists of 82–84% of glycerol and 8–9.5% of inorganic salts after water dehydration. Ash free glycerol is formed using pressure hydrolysis. When esterification with methanol is applied, glycerol is produced in amounts of 90–92%. Arsenic can be found in trace concentrations in all glycerol products regardless to the productive conditions [5]. Esterification of small amounts of rapeseed oil, which is a common practice in oil mills, yields a wide variety of glycerol products. Table 1 shows the glycerols tested in the current study.

The glycerol varieties Gly 1 and Gly 2 were investigated in a fattening experiment. The glycerols have been characterized accordingly as follows: Glycerol 1 was a dark brown/black viscous liquid, which smelt like lubricating grease and tasted sweet and salty. Glycerol 2 was light brown to red brown and of creamy consistence. It smelt aromatically of almonds and tasted sweet and strongly salty, too. A high ash content can be found in most glycerols. Therefore, sponification, or at least a combination of different processes, must be applied for the production procedure in oil mills. The quality of the glycerols is very different as shown in Tab. 1. For Gly 3 the hydrolysis was incomplete, indicated by the high fat content. The ash of Gly 1 consists mainly of phosphates of sodium and in Gly 2 of sodiumchloride. The content of arsenic calculated on a mg/kg feed basis was 0.004 - 0.002 when 10% glycerol is used in the diet. This concentration of arsenic in the feed would be below the tolerated maximum levels allowed by the legislation, which are 2–10 mg/kg [6].

Tab.2. Composition of the experimental diets in % of original matter.

Group	1 control 1	2 control 2 10% glycerol[1]	3 5% technical glycerol Gly 1	4 10% technical glycerol Gly 1	5 5% technical glycerol Gly 2	6 10% technical glycerol Gly 2
growing period						
barley meal	83.64	71.27	77.04	71.27	77.04	71.27
soybean meal	14.35	17.92	16.56	17.92	16.56	17.92
technical glycerol Gly 1	–	–	6.60	13.33	–	–
technical glycerol Gly 2	–	–	–	–	4.63	9.28
pure glycerol; Fa. Henkel	–	8.80	4.39	8.80	4.39	8.80
minerals	2	2	2	2	2	2
lysine	0.01	0.01	0.01	0.01	0.01	0.01
finishing period						
barley meal	92.37	80.30	86.59	80.30	86.59	80.30
soybean meal	5.55	8.90	7.00	8.90	7.00	8.90
technical glycerol Gly 1	–	–	6.38	12.58	–	–
technical glycerol Gly 2	–	–	–	–	4.54	9.15
pure glycerol; Henkel	–	8.73	4.34	8.73	4.34	8.73
minerals[2]	2	2	2	2	2	2
lysine[3]	0.08	0.07	0.07	0.07	0.07	0.07

[1] The pure glycerol had a water content of 13.5%. The values in the table are the added amounts of 100% glycerol.
[2] Minerals: In diets 1 and 2: Troumix 14; containing : 5.8% Na, 23.5% Ca, 7% P, 1.6% Mg, Vitamins and trace element concentration supply meeting the requirements of a dosage of 2%.
In diets 3 to 6: Troumix 4; containing 0% Na,. 27.5% Ca, 6% P, 1.6% Mg, all other components as in Troumix 14.
[3] Lysine: The amounts are lysinehydrochloride with a lysine content of 73.25%.

3 Fattening Experiment with Technical Glycerols

3.1 Materials and methods

3.1.1 Animals and housing conditions

6 × 6 barrows (pietrain × F1, landrace × German breed) were used for the investigation. At the beginning of the experiment the average body weight was 24.1±0.34 kg. At this time the pigs were in good condition. The fattening experiment was conducted at the experimental station of the Humboldt-University of Berlin. The pigs were housed in fully conditioned single pens. The pens were divided in a feed/lying area and a grid floor for manure removal with semiliquid manure technology. In the pens a selfwaterer and a bolted feed trough were installed. The lateral limitation was a lattice, which allowed sight and touch of the animals. Each animal had an area of 2.3 m^2.

3.1.2 Diets and feeding

The formulation of the diets was done for two fattening periods. The supply of energy and protein was calculated for 700 g daily live weight gain in the first experimental period and for 800g in the finishing period at normal feed intake. The control diet 1 consisted of barley meal, soybean meal and minerals. In the control diet 2, 10% of the diet were replaced by glycerol (pure glycerol, 86%; Henkel, Düsseldorf, Germany). The exchange was done against barley meal. The amount of soybean meal was increased accordingly to achieve the same protein content in the diets.

For groups 3-6 two different glycerols were mixed at amounts of 5 and 10% glycerol, respectively. Groups 3 and 4 received Gly 1 from the Oil Mill Leer (Germany), whereas groups 5 and 6 obtained Gly 2 from Novaol (Italy). The composition of the glycerols is shown in Tab. 1. For all diets the amount of soybean meal was adjusted to achieve the same protein content (see Tab. 2). The addition of lysine was done according to the different amounts of soybean meal in the diet. The composition of the diets is shown in Tab. 2 and the content of nutrients and glycerol is presented in Tab. 3. As shown in Tab. 3, the theoretically assumed content of glycerol in the diets was not always exactly attained. The supply with minerals and vitamins complied with the nutrient requirements. For the two control diets the mineral premix "Troumix 14" for pigs was used. Because of the high sodium content in the technical glycerols, a mineral premix without sodium (Troumix 5) was added in groups 3 to 6 (see Tab. 2). Similar to previous experiments, the consistency of the feed improved when glycerol was added, because it received a light, crumbly structure and it reduced the feed dust. The feeding level was semi *ad libitum* (with full saturation at the 3 feeding times, but without some residues), feeding times were at 7.00 a.m, 1.00 p.m. and 7.00 p.m. The animals had free access to water.

3.1.3 Experimental design, performance test and analysis

After an adaptation period of 8 days to the control diet, the experiment began December 22, 1994. The pigs were weighed after an overnight fast and received the experimental diets. During the fattening experiment the pigs were weighed every two weeks after a 12 hour fasting time. At the same time the feed intake was determined.

After a period of 40 days and a live weight of 50 to 60 kg, the diet was altered from the growing period to the finishing period. The body weight and feed balance of each pig were determined at this time as well. When a live weight of approximately 95 kg was achieved, the pigs were slaughtered in the Experimental Station for Animal Breeding and Animal Nutrition in Ruhlsdorf, Brandenburg. Parameters of carcass characteristics and meat quality (see Tab. 6) were established. Parts of liver, kidney and blood were taken from the pigs. The blood was collected in test tubes containing heparin; the plasma was separated in a centrifuge (10 min at 3500 g) and glycerol was determined using a test kit of Boehringer, Mannheim.

During the whole experiment the content of dry matter of the diets was determined. The values were rather constant and the variation was considered in regards to the daily dry matter intake. The crude nutrients of the diets were analyzed using Weender analysis. The crude fat was calculated after HCl-hydrolysis. The glycerol content in the diet was determined in the supernatant after extraction with warm water (37°C) for 1.5 hours in a shaking water bath and following fil-

Tab. 3. Dry matter (DM) content (mean values of 3-6 estimations) and content of crude nutrients of the diets in % of DM.

Group	1 control 1	2 control 2 10% glycerol	3 5% technical glycerol Gly 1	4 10% technical glycerol Gly 1	5 5% technical glycerol Gly 2	6 10% technical glycerol Gly 2
growing period						
DM	88.56	87.98	87.45	86.20	88.02	87.79
crude protein	15.33	16.90	16.22	16.19	16.16	16.44
crude fat	3.22	2.85	2.86	2.66	2.81	2.86
crude fibre	6.86	5.35	6.42	5.78	6.24	5.97
crude ash	4.72	5.03	6.89	7.54	5.81	5.61
ME [MJ/kg DM]	17.36	17.33	16.96	16.83	17.14	17.20
glycerol	–	8.78	4.21	7.50	3.67	10.98
finishing period						
DM	88.72	87.79	87.43	86.50	88.24	87.35
crude protein	12.89	13.68	13.35	12.75	13.33	13.76
crude fat	3.08	2.42	2.95	2.90	2.80	2.64
crude fibre	6.80	6.02	6.04	5.25	5.88	5.74
crude ash	4.82	4.88	5.70	8.06	5.52	5.04
ME [MJ/kg DM]	17.22	16.59	16.34	16.12	16.49	16.52
glycerol	–	10.03	2.88	8.31	4.91	7.57

tration through a folded filter. After dilution the concentration was determined with an enzymatical test kit.

3.1.4 Statistics

The values shown in the tables are presented as means with standard errors (S_E). Homegeneity of the variations was tested applying the COCHRAN- and BARTLETTS-Tests, and Tukey's multiple range test was used to identify differences among means when significant ($P<0.05$).

3.2 Results and discussion

3.2.1 General condition of animals

During the first three days of the investigation some animals of groups 3 to 6 (technical glycerol) had insignificant diarrhoea. This could have been due to the change of diets. The animals which received dietary glycerol, especially in the groups which received technical glycerols, showed symptoms of polyuria. The examination of the organs did not show any pathological lesions caused by a higher water turnover or the glycerol intake. Two pigs had to be taken out of the experiment because of a chronic pneumonia. Thus, treatments 2 and 5 consisted only of 5 pigs per group. The condition of the remaining pigs was good over the whole experiment.

3.2.2 Growth performance

The results of the fattening investigation are summarized in Tab. 4. The feed intake increased in groups 2–6 with glycerol in comparison to control group 1. Feed intake improved at an average to 106% in the growing period and of 104% in the finishing period, which was similar in all glycerol fed groups. The higher feed intake could be due to the sweet and saline taste of the diets, which is a preferred flavour for pigs as well as the improved consistency of the diets containing glycerol. In previous fattening experiments [1, 2] a higher feed intake due to the addition of glycerol could be observed. The higher feed intake caused a higher live weight gain in the growing period. It was elevated to 108% in comparison to the control group 1. In the finishing period there were no effects on the live weight gain even though there was a higher feed intake due to glycerol in the diets. In group 1 the content of crude protein in the diet was 1% lower than in diets 2–6. Because of this, there might have been a suboptimal supply of these animals in group 1. The increased weight gain might have been the result of a higher supply with protein in groups 2–6 compared to group 1. On the other hand, there exists a close correlation between the amount of glycerol intake and the daily live weight gain (Fig. 1). The difference between the theoretical and the achieved glycerol contents of the diets and the different feed intake between the groups caused a different glycerol intake during the fattening experiment. Fig. 1 shows the relationship between glycerol intake and daily live weight gain with a coefficient of regression $r = 0.90$. There is a strong correlation between glycerol intake and live weight gain up to 10% of glycerol in diet, regardless of the purity of glycerol. This could be seen only during the growing period, whereas there were no effects in the finishing period.

Tab. 4. Results of fattening and feed conversion ratio during the fattening periods.

Group	1 control 1	2 control 2 10% glycerol	3 5% technical glycerol Gly 1	4 10% technical glycerol Gly 1	5 5% technical glycerol Gly 2	6 10% technical glycerol Gly 2
growing period; 40 days						
body weight at beginning [kg]	24.02± 0.88	24.20± 0.83	24.00± 0.84	23.94± 0.88	24.26± 1.22	24.38± 0.76
feed intake [kg DM/animal and day]	1.76± 0.10	1.86± 0.06	1.87± 0.08	1.93± 0.04	1.88± 0.07	1.82± 0.04
daily gain [g/animal and day]	702 ±57	770 ±51	729 ±47	764 ±28	761 ±43	782 ±22
feed conversion ratio [kg DM/kg gain]	2.53± 0.06b	2.44± 0.11ab	2.60± 0.08b	2.53± 0.04ab	2.48± 0.05ab	2.33± 0.03a
finishing period; 48/52 days						
BW at beginning of finishing period [kg]	52.08± 2.87	54.98± 1.63	53.10± 2.43	54.49± 0.85	54.78± 2.65	55.66± 1.19
feed intake [kg DM/animal and day]	2.38± 0.14	2.43± 0.09	2.58± 0.08	2.50± 0.08	2.51± 0.15	2.37± 0.05
daily gain [g/animal and day]	818 ±55	800 ±37	843 ±31	800 ±40	801 ±53	778 ±14
feed conversion ratio [kg DM/kg gain]	2.93± 0.07a	3.05± 0.08ab	3.06± 0.04ab	3.14± 0.11ab	3.15± 0.06b	3.05± 0.07ab
Whole fattening period; 88/92 days						
average experimental time [d]	89.3	92.0	90.0	91.3	89.6	92
BW at experimental end	92.18± 4.89	96.56± 1.91	95.12± 2.91	95.32± 2.20	94.32± 4.30	96.08± 0.76
feed intake [kg DM/animal and day]	2.10± 0.12	2.18± 0.05	2.26± 0.07	2.24± 0.06	2.23± 0.11	2.12± 0.04
daily gain [g/animal and day]	766 ±55	786 ±24	792 ±33	784 ±33	783 ±47	779 ± 9
feed conversion ratio [kg DM/kg gain]	2.77± 0.06	2.78± 0.05	2.86± 0.04	2.87± 0.08	2.85± 0.05	2.73± 0.03

mean values ± S_E; different letters in one row indicate significant differences of $P \leq 0.05$.

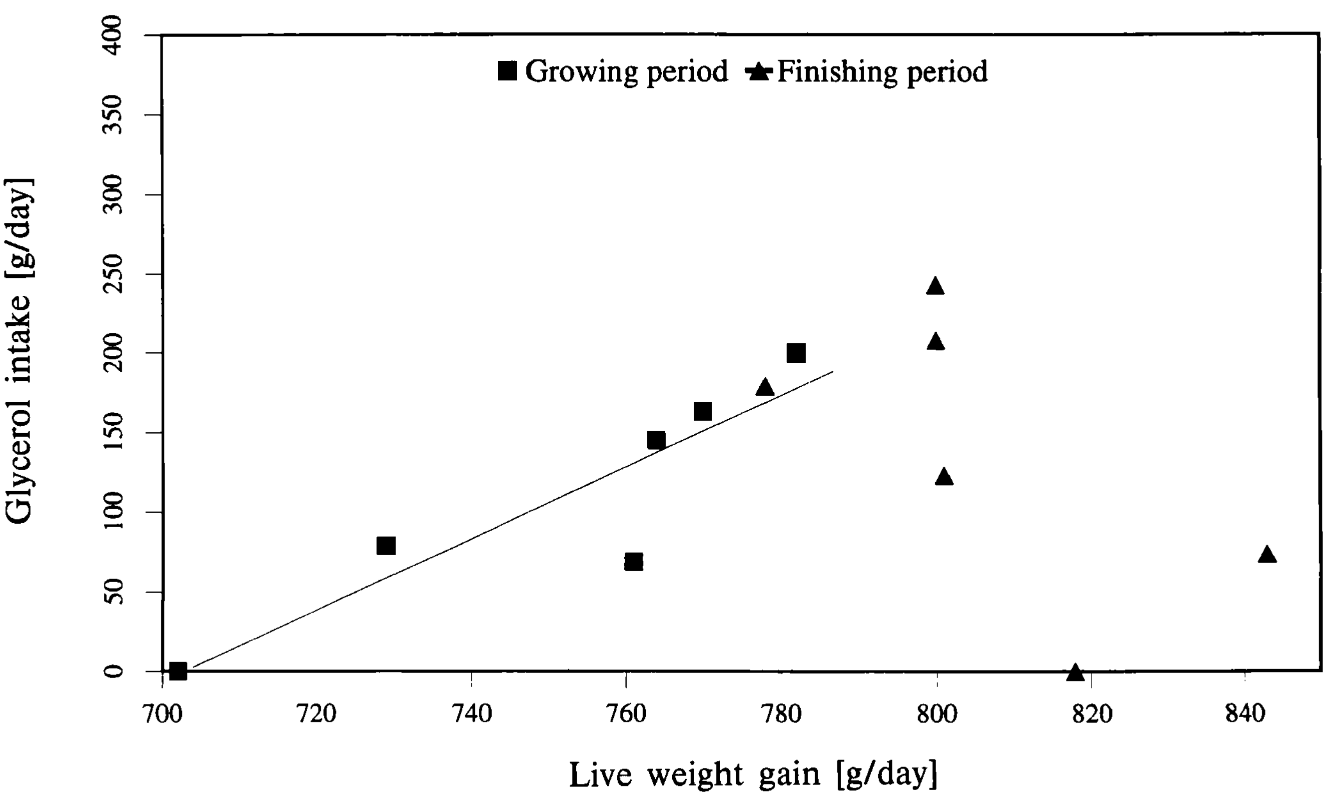

Fig. 1 Glycerol intake and live weight gain in the two fattening periods.

The proportion of fat synthesis as part of live weight gain in the finishing period is much higher than in the growing period. The formation of fat from glycerol and fatty acids in the fat tissue did not occur directly with glycerol, because there is no glycerokinase activity in the fat tissue. The fat formation is realized in fatty tissue exclusively by using glucose as the glycerol precursor. Glycerol in storage tissue can only be metabolized by gluconeogenesis, which is an energy-dependent process. Apart from this, the substitution of barley by glycerol decreased the fat content in the diets and more fat had to be synthesized (see Tab. 3). Especially Gly 1 had a very high ash content. Tab. 5 shows the average daily intake of sodium and phosphorus. The requirement of sodium for growing pigs fed *ad libitum* is 0.1% [NRC, 7]. Calculated on the daily basis, that would be a sodium requirement of about 1.9 g in the growing period and of 3.1 g in the finishing period. The maximum upper tolerance for sodium is considered to be 8% in diets [8] on condition that water intake is *ad libitum*. With limited water consumption the toxic amount is much lower. The application of sodium free mineral mixture in groups 3-6 led to a maximal dose of threefold the sodium requirements in group 4, which was not critical. The phosphorus requirement is considered to be 0.5% (20-50 kg BW) and 0.4% (50-100 kg BW) in the diet [7] and was exceeded significantly in group 4. But this concentration was not critical either, as the concentration of more than three times the requirement can have a negative influence on the metabolism of calcium. In the groups receiving glycerol the feed conversion ratio in the finishing period was increased, because of the higher feed intake and decreased gain. There were significant effects of the dietary treatment on

Tab. 5. Average intake of sodium and phosphorus during the two experimental periods (content in barley and soybean meal calculated from literature).

Group	1 control 1	2 control 2 10% glycerol	3 5% technical glycerol Gly 1	4 10% technical glycerol Gly 1	5 5% technical glycerol Gly 2	6 10% technical glycerol Gly 2
growing period						
sodium intake g/animal and day	2.3	2.4	4.6	8.6	1.42	4.2
% in DM content	0.13	0.13	0.25	0.45	0.08	0.23
phosphorus intake g/animal and day	10.7	11.0	13.0	15.3	8.0	11.3
% in DM content	0.61	0.59	0.70	0.79	0.43	0.62
finishing period						
sodium intake g/animal and day	3.1	3.2	4.1	11.7	2.5	3.6
% in DM content	0.13	0.13	0.16	0.47	0.10	0.15
phosphorus intake g/animal and day	14.5	13.6	10.1	20.8	13.4	9.6
% in DM content	0.61	0.56	0.39	0.83	0.53	0.41

The intake with glycerol was calculated of the estimated glycerol content in the diets. DM – dry matter.

Tab. 6. Results of carcass evaluation, meat quality parameters and concentration of glycerol in blood after slaughtering.

	1 control 1	2 control 2 10% glycerol	3 5% technical glycerol Gly 1	4 10% technical glycerol Gly 1	5 5% technical glycerol Gly 2	6 10% technical glycerol Gly 2
carcass weight/kg	76.92±2.28a	82.40±0.93b	79.33±1.08ab	78.60±1.86ab	77.70±1.61ab	81.00±1.34ab
lean fraction/%	48.43±1.41a	50.70±1.38ab	47.87±0.55a	51.10±0.76ab	49.82±1.44ab	53.08±0.83b
back fat thickness/cm	2.93±0.18ab*	3.13±0.14b*	3.10±0.09b*	2.72±0.16a*	2.85±0.16ab*	2.89±0.07ab*
side-fat thickness/cm	3.32±0.29ab*	3.22±0.27ab*	3.63±0.18b*	3.02±0.29a*	3.24±0.31ab*	3.38±0.11ab*
Meat-fat ratio	0.57±0.05	0.55±0.05	0.62±0.03	0.49±0.03	0.57±0.05	0.48±0.02
marbling (subjectively)	2.00±0.37a	2.80±0.20abc	3.17±0.17c	2.80±0.37abc	3.00±0.32bc	2.33±0.21ab
pH-value; 45min in chop	6.09±0.19	6.25±0.18	6.27±0.08	6.36±0.07	5.93±0.15	6.33±0.17
conductivity of loin; 24 h in chop	4.82±1.57	4.85±0.77	3.88±0.72	4.92±0.82	3.78±0.70	4.17±0.72
reflectance value	33.83±3.34b*	27.60±0.75a*	31.17±2.15ab	32.00±2.61ab*	34.40±2.60b*	29.00±2.58ab*
meat colour	65.67±2.84	66.40±3.56	68.50±1.34	69.33±1.43	68.40±1.25	67.83±3.82
slaught dripping loss/%	7.07±0.81	6.27±0.83	6.54±0.73	6.24±0.71	7.03±0.68	6.09±0.57
press water loss/%	45.94±0.87	45.74±1.58	45.51±1.54	44.69±1.88	44.70±1.24	45.09±1.32
DM of meat/%	25.69±0.39	25.73±0.25	25.83±0.36	25.57±0.47	26.34±0.41	25.80±0.41
glycerol mmol/l plasma	0.292±0.027a	0.590±0.033c	0.377±0.018b	0.662±0.040cd	0.406±0.029b	0.732±0.053d

mean values ± S_E; different letters in one row indicate significant differences $P \leq 0.05$ and * $P < 0.1$.

the feed conversion. The feed conversion ratio was much better in groups 2, 5 and 6 compared to groups 3 and 4 which received a technical glycerol with a high water- and ash content. The dry matter of the diet in group 4 with 10% glycerol was under the required limit of about 88% due to the high water content in Gly1 (see Tab. 3). With respect to utilization of technical glycerol the contamination and water content must be taken into account.

3.2.4 Carcass yield and meat quality

Parameters of carcass yield and meat quality are shown in Tab. 6. The highest ratio of lean was observed in group 6 with the highest gain in the growing period and a lower gain in the finishing period. In comparison to groups 1 and 3 the difference is significant. These two groups showed the highest gain in the finishing period. The highest fatness showed group 3 with highest feed intake and live weight gain in the finishing period. These results agree with the known fact of the consequence of different gain intensity in the fattening periods and are primary not a result of the glycerol intake.

The lower fat content in glycerol diets did not cause a decreased fat content in the meat. Partly an increased fat ratio in meat was obtained. The concentration of glycerol in blood plasma was elevated significantly in the glycerol groups even after a 12 hour starvation period (see Tab.6). This could influence the fat metabolism in pigs. *Abe* [9] estimated a higher fat content in blood after glycerol feeding in rats. The higher content was not a result of a higher synthesis of fat, but of a decreased activity of lipase due to the high glycerol plasma level. The occurrence of reduced fat catabolism is more probable than increased synthesis by administered glycerol, because glycerol is not directly used by the fatty tissue as described above. The results of the data on the meat quality indicate a decreased water deposit after glycerol intake (slaught dripping loss, meat DM and press water loss). It can be concluded, that glycerol as well as technical glycerol does not have any effects on meat quality.

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Literature

[1] *Bergner, H., C. Kijora,* Freie Fettsäuren und Glycerin in der Fütterung von Mastschweinen, Fat Sci. Technol. **95** (1993), 526-529.

[2] *Kijora, C., H. Bergner, R.-D. Kupsch, L. Hagemann,* Glycerin als Futterkomponente in der Schweinemast, Arch. Anim. Nutr. **47** (1995), 345-360.

[3] *Mourot, J., A. Aumaitre, A. Mournier, P. Peiniau, A. C. Francois,* Nutritional and physiological effects of dietary glycerol in the growing pig. Consequences on fatty tissues and post mortem muscular parameters, Livestock Production Sci. **38** (1994), 237-244.

[4] *Brockmann, W., G. Demmering, U. Kreutzer, H. Lindemann, J. Pladenka, U. Steinberger:* Fatty acids in Ullmann's Encyclopädie of Industrial Chemistry Vol. 10A, VCH Verlagsgesellschaft 1987, pp 254-257.

[5] *Borivoj, R.* and, *S. Franco-Filipasic:* Glycerin in Ullmanns Enzyklopädie der technischen Chemie, 4. Aufl. Band 12, Verlag Chemie Weinheim, 1976.

[6] *Entel, H. J., N. Förster, E. Hinckers (Ed):* Futtermittelrecht, Verlag Paul Parey - Berlin und Hamburg, Stand 1996.

[7] NRC – Nutritional requirements of swine, 9. Ed. (1988), National Academy Press, Washington, D.C. 1988, 50-51.

[8] NRC - Mineral Tolerance of domestic animals, National Academy of Sci, Washington, D.C., 1980, 364-370, 441-447.

[9] *Abe, R., I. Macdonald, Y. Maruhama, Y. Goto,* Effect of glycerol on Triglyceride metabolism in the rat. Metabolism. **28** (1979), 97-99.

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