

Weaned piglets prefer feed with hydroxychloride trace minerals to feed with sulfate minerals

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ABSTRACT: The aim of this study was to determine whether newly weaned piglets had a preference for diets containing hydroxychloride trace minerals (HTM). To test this, two preference tests were set up. In Exp. 1, the piglets could choose between HTM or inorganic, originating from sulfate trace minerals (STM) in the form of sulfates. Two treatments were applied with high Cu levels (160 ppm Cu added) or low Cu levels (15 ppm Cu added). All diets contained 110 ppm added Zn from the same source as Cu in the respective diet. The pigs could choose between a diet with hydroxychloride Cu and Zn or with Cu and Zn originating from sulfates at the same mineral levels. The piglets were included in the study from weaning until 34 d after weaning. In Exp. 2, the piglets could also choose between HTM and STM. However, automated feeding stations were used to collect individual feed intake data.

Similarly two treatments were applied, one with high Cu levels (160 ppm added Cu) and one with slightly lower Cu levels (140 ppm added Cu until 28 d after weaning, thereafter 15 ppm added Cu). All diets contained 110 ppm added Zn from the same source as Cu in the respective diet. The piglets were followed until 35 d after weaning. The current studies showed that when piglets were given a choice, they preferred diets with HTM. This effect resulted only in a significant ($P < 0.05$) preference for HTM at high dietary Cu levels (160 ppm) ranging from 76% to 81% in the first and second week of Exp. 1 to between 53.4% and 57.8% in the overall experiment period of Exp. 2. This preference was less pronounced at levels of 140 ppm added or less. Individual feed intake and gain measurements did not show any link between the preference and the performance.

Key words: hydroxychloride trace minerals, preference test, sulfate trace minerals, weaned pigs

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INTRODUCTION

The weaning process is a difficult period during a piglets life involving a lot of changes, such as separation from the mother, mixing with other litters, and change in diet (Lalles et al., 2007). The

transition from the highly digestible mother's milk to the less digestible solid feed has a great impact to a newly weaned piglet. The piglets have to get used to the new form of feed and often have a lower feed intake after weaning. A low feed intake is a major risk factor for impaired gut structure and function (Dong and Pluske, 2007; Jayaraman and Nyachoti, 2017). As a result of the damaged gut, malabsorption of nutrients from the feed will occur and a lower growth performance is encountered, together with diarrhea. Therefore, it is very important to get

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the feed intake up to the normal level as soon as possible after weaning. The feed intake after weaning is among others determined by diseases, weaning age, environmental factors, nutrients levels, form of the feed, and palatability (Dong and Pluske, 2007).

One way that the commercial pig producers already know to increase feed intake and reduce weaner diarrhea is the addition of high copper levels in the diets (Bikker et al., 2015). In commercial diets in Europe high copper levels up to 170 ppm are used (Bikker et al., 2015; EC, 2018). It is well known that at these Cu levels an increased performance is observed (Bikker et al. 2015). The mechanisms behind this are attributed to the impact on the microbes in the intestine (Hojberg et al., 2005; Jensen, 2016). However, Zhou et al. (1994) describe that intravenous injection of Cu, so bypassing the gut, also improved performance by directly improving feed intake. When applied via the feed, Cu is proven to have an effect on hormone production related to appetite in the hypothalamus in pigs (Yang et al., 2011).

In commercial practice, Cu is often added in the form of highly soluble inorganic CuSO_4 . It is known in humans that CuSO_4 has a metallic taste (Epke et al., 2009). Pigs have three to four times more taste buds on their tongue than humans (Hellekant and Danilova, 1999). Even though pigs have a different taste experience than humans as demonstrated with several sweetener compounds (Hellekant and Danilova, 1999), the larger number of taste buds indicates that CuSO_4 could also give a metallic taste in pigs, resulting in feed refusal or reduction. On the basis of studies with a human tasting panel it is known that soluble Cu is readily tasted, whereas complexed or insoluble Cu was poorly tasted in water (Cuppert et al., 2006). It is hypothesized that the same is true for pigs. This means that pigs cannot taste a low soluble Cu source, whereas they would still benefit from the feed intake stimulating and thus growth promoting properties of Cu. An example of such a Cu source is hydroxychloride trace minerals (HTM) that are insoluble in water (Miles et al., 1998). These minerals are not soluble above a pH of 4. Therefore they will remain in their original form in the feed, tasteless, nor react to other components in the feed (Lu et al., 2010; Luo et al., 2005).

The objective of this study was to determine whether newly weaned piglets had a preference for diets containing HTM compared to sulfate minerals. Therefore, two repeating experiments were performed in which the preference was tested. In

Exp. 1 the pigs could choose between two feeds within their pen. In Exp. 2 the pigs could do the same from the automated feeding stations, thus allowing individual monitoring. Both experiments included the European commercial levels of higher Cu and a lower level of Cu.

MATERIAL AND METHODS

Two experiments are described in this study, both performed at the Swine Research Centre of Trouw Nutrition (St. Anthonis, the Netherlands). The piglets used in both experiments originated from the same internal sow herd, but different farrowing rounds. The experiments were approved by the internal animal welfare body and performed in accordance with the local Dutch law regarding animal experiments.

Experiment 1

In Exp. 1, total 144 piglets (Maxter*Hypor Libra) were divided into pens with six piglets each, three males and three females. The piglets were placed in their experimental pens directly after weaning at around 24 d of age with an initial body weight (BW) of 8 kg. The piglets were blocked based on initial BW. Each pen contained two feeders, with a different feed in each feeder. One feeder contained feed with Cu and Zn from sulfates and the other feeder contained feed with Cu and Zn from HTM. Two different treatments were applied in 12 pens per treatment, with two difference mineral sources within a treatment. In treatment 1 feed containing 160 ppm Cu from CuSO_4 (Eurotrade, Steenwijk, the Netherlands) and 110 ppm Zn from ZnSO_4 (Grillo, Duisburg, Germany) was compared to feed containing 160 ppm Cu from hydroxychloride copper (IntelliBond Cu, Trouw Nutrition, the Netherlands) and 110 ppm Zn from hydroxychloride zinc (IntelliBond Zn, Trouw Nutrition, the Netherlands). In treatment 2 feed containing 15 ppm Cu from CuSO_4 and 110 ppm Zn from ZnSO_4 was compared to feed containing 15 ppm Cu from hydroxychloride copper and 110 ppm Zn from hydroxychloride zinc.

The two feeders in each pen were switched twice weekly to prevent that the preference of feeder side interfered with preference of diet. The study was conducted until 34 d after weaning. The feed intake was measured weekly per feeder per pen and the BW was measured at the start and the end of each phase per pen. A three-phase feed program was used with phase 1 from day 0 to 14, phase 2 from day 14 to 28, and phase 3 from day 28 to 35.

The same mineral contents were used throughout the entire study period. The minerals were added via the premix to the complete feed. All diets were fed in pelleted form. The dietary composition of the feed is shown in Table 1. The feed intake and BW were used to calculate the average daily gain (ADG) and average daily feed intake. The preference of the animals for a certain feed was expressed as the percentage feed intake of one feed compared to the total feed intake.

Experiment 2

In total 120 piglets (Maxter*Hypor Libra) were housed in pens with 20 piglets each, 10 males and 10 females. The piglets were placed in their experimental pens directly after weaning at around 24 d of age and an average BW of

7.9 kg. Each pen contained two electronic feeding stations (Schauer Agrotronic GmbH, Austria), allowing measurement of the individual feed intake. During the setup of this study European Food Safety Authority (EFSA) published an opinion about the suggested Cu levels to be used in the future in Europe (EC, 2018). The high Cu group in Exp. 2 was the same as in Exp. 1 and represented the commercial levels of minerals used at that time in the European Union (end 2016). Three pens received treatment 1 in which a feed containing 160 ppm Cu from CuSO₄ (Eurotrade, Steenwijk, the Netherlands) and 110 ppm Zn from ZnSO₄ (Ecozinder, Trezzo d'Adda, Italy) was compared to a feed containing 160 ppm Cu from hydroxychloride copper and 110 ppm Zn from hydroxychloride zinc. The same mineral levels were fed throughout the entire study period in treatment

Table 1. Feed formulation per phase in each experiment shown as a percent of total

Ingredient	Experiment 1			Experiment 2		
	Phase 1	Phase 2	Phase 3	Phase 1	Phase 2	Phase 3
Barley	15.000	15.000	15.000	15.000	15.000	15.000
Wheat	40.000	40.000	40.000	40.000	40.000	40.000
Maize	7.135	7.303	12.304	6.290	7.900	11.520
Wheat bran	2.000	3.000	3.000	2.000	3.000	4.000
Soybean meal	15.000	15.000	15.000	15.000	15.500	16.500
Potato protein	1.709	3.322	2.763	3.930	3.210	2.140
Phytase	0.010 ¹	0.010 ¹	0.010 ¹	0.040 ²	0.040 ²	0.040 ²
DL-methionine (99%)	0.254	0.180	0.180	0.160	0.170	0.140
L-lysine HCL (98%)	0.719	0.540	0.567	0.500	0.520	0.480
L-threonine (98%)	0.280	0.184	0.194	0.140	0.150	0.130
L-tryptophan (98%)	0.067	0.041	0.044	0.030	0.030	0.020
L-valine (96.5%)	0.212	0.096	0.106	0.060	0.080	0.050
Na bicarbonate	0.512	0.380	0.370	0.390	0.340	0.240
Ca carbonate	0.235	0.286	0.540	0.190	0.230	0.490
Monocalcium phosphate	1.104	0.971	0.963	0.890	0.760	0.740
Salt (NaCl)	0.390	0.481	0.489	0.480	0.510	0.580
Lactose	6.369	4.246	—	6.460	4.310	—
Sugar	2.500	2.000	1.000	2.500	2.000	1.000
Soya oil	5.234	5.689	6.200	4.790	5.100	5.780
Vitamin E	0.240 ³	0.240 ³	0.240 ³	0.120 ⁴	0.120 ⁴	0.120 ⁴
Choline chloride	0.030	0.030	0.030	0.030	0.030	0.030
Premix	1.000 ⁵	1.000 ⁵	1.000 ⁵	0.500 ⁶	0.500 ⁶	0.500 ⁶

¹Phytase in Exp. 1: 5000 FTU, final concentration in the feed 500 FTU.

²Phytase in Exp. 2: 0.025%.

³Vitamin E in Exp. 1: 50% adsorbate.

⁴Vitamin E Exp. 2: 0.025%.

⁵Premix Exp. 1 (per kg final feed): 2 g sepiolite, 8,000 IE vitamin A, 2,000 IE vitamin D3, 30 IE vitamin E, 1.5 mg vitamin K3, 1 mg vitamin B1, 4 mg vitamin B2, 13 mg calcium-D-Pantothenate, 20 mg niacinamide, 1 mg vitamin B6, 0.3 mg folic acid, 30 mcg vitamin B12, 50 mg water-free betaine, 100 mg iron sulfate monohydrate, 1.0 mg calcium iodine, 30 mg manganese(II)oxide, 0.3 mg sodium selenium. Cu and Zn were added to the premix according to the corresponding treatments.

⁶Premix Exp. 2 (per kg final feed): 2 g sepiolite, 10,000 IE vitamin A, 1,750 IE vitamin D3, 30 IE vitamin E, 1 mg vitamin K3, 1 mg vitamin B1, 6 mg vitamin B2, 16.3 mg calcium-D-pantothenaat, 25 mg niacinamide, 1.5 mg vitamin B6, 0.5 mg folic acid, 30 mcg vitamin B12, 50 mcg biotin, 50 mg water-free betaine, 100 mg iron sulfate monohydrate, 1.0 mg calcium iodine, 30 mg manganese(II)oxide, 0.4 mg sodium selenium. Cu and Zn were added to the premix according to the corresponding treatments.

1. The low Cu levels were based on the opinion published by EC (2018). The low levels would be 140 ppm added to the feed until 4 wk after weaning, thereafter 100 ppm until 12 wk of age. To create a larger contrast in this study and show a direct effect of lowering the Cu level 4 weeks after weaning it was decided to test a more dramatic drop in Cu level to 15 ppm added in the fifth week after weaning. Three pens received treatment 2 in which a feed containing 140 ppm Cu until day 28 and thereafter 15 ppm Cu from CuSO_4 and 110 ppm Zn from ZnSO_4 was compared to a feed containing 140 ppm Cu until day 28 and thereafter 15 ppm Cu from hydroxychloride copper and 110 ppm Zn from hydroxychloride zinc. The feeds within a pen were switched twice weekly between the feeding stations to correct for a preference for feeding station side. The study was conducted until 35 d after weaning. A three-phase diet was used with the first phase from day 0 to 14, second phase from day 14 to 28, and the last phase from day 28 to 35. The minerals were added via the premix to the complete feed. All diets were fed in pelleted form. A similar diet formulation as in Exp. 1 was used (Table 1). The feed intake was measured continuously for each individual piglet. The BW of the piglets was measured weekly for each individual pig separately.

Statistical Analysis

In Exp. 1 the pen was the experimental unit. The amount of feed intake and the growth performance data were analyzed using the MIXED model procedure in SAS. The model included the fixed effects of treatment, and random effects of block and time were included as repeated measure. The percentage feed intake compared to the total feed intake was analyzed using the GLIMMIX procedure in SAS.

In Exp. 2 the individual feed intake was summarized per pig per week. Each piglet was regarded as the experimental unit. The preference was analyzed with a time series analysis using the GLIMMIX procedure in SAS. To link the preference data to the performance data, the feed intake results were averaged per day for each week and analyzed using the MIXED procedure in SAS.

The effects were regarded as significantly different if $P < 0.05$.

RESULTS AND DISCUSSION

Experiment 1

The growth performance results of Exp. 1 are shown in Table 2. The total feed intake per pen in Exp. 1 was higher in the groups that received the high levels of Cu compared to the groups that

Table 2. Growth performance of the piglets in Exp. 1

<i>n</i>	High copper	Low copper	SE	<i>P</i> -value
	12	12		
Body weight, kg				
Start (D0)	8.0	8.0	0.44	0.9839
End phase 1 (D14)	11.1	10.4	0.46	0.4108
End phase 2 (D28)	18.3	16.1	0.58	0.0506
End phase 3 (D34)	22.4	19.7	0.65	0.0548
ADG, g				
Phase 1 (D0-14)	217.4 ^a	166.2 ^b	10.16	0.0212
Phase 2 (D14-28)	505.6 ^a	399.9 ^b	22.89	0.0312
Phase 3 (D28-34)	684.6	595.2	36.00	0.4842
Total (D0-34)	423.4 ^a	342.0 ^b	47.30	<0.0001
ADF, g				
Phase 1 (D0-14)	253.8 ^a	209.5 ^b	12.16	0.0052
Phase 2 (D14-28)	644.3 ^a	538.9 ^b	22.45	0.0104
Phase 3 (D28-34)	866.1	785.2	33.91	0.3572
Total (D0-34)	524.3 ^a	447.8 ^b	60.16	<0.0001
Gain:feed				
Phase 1 (D0-14)	0.861	0.802	0.0322	0.7772
Phase 2 (D14-28)	0.788	0.745	0.0199	0.6045
Phase 3 (D28-34)	0.794	0.767	0.0283	0.9806
Total (D0-34)	0.808 ^a	0.765 ^b	0.0353	<0.0001

^{a, b}Different superscripts within a row represent significant differences ($P < 0.05$).

ADF = average daily feed intake.

received the low levels of Cu. This confirms the feed intake stimulating effects of Cu as described by Bikker et al. (2015), Zhou et al. (1994) and Yang et al. (2011). For this reason, the preference is calculated as percentage of the feed compared to the total feed intake per pen to correct for variation in total intake between pens (Fig. 1). When high levels of Cu were fed to the piglets a significant ($P < 0.05$) preference of 76% for HTM was observed in the first week and of 81% in the second week (Fig. 1). Although the preference for HTM became less clear, this was still significantly higher until 28 d. In the last week, the piglets did not have a significant preference for any of the feeds in the high Cu groups. In the low Cu groups the piglets had a preference ($P < 0.05$) for sulfate trace mineral (STM) until 21 d of age. In the last 2 wk, there was no significant difference anymore. It is not expected that these animals developed a Cu deficiency, because 15 ppm added Cu is still above the requirements of

6 ppm (NRC, 2012). The copper status of the animals does not seem to interfere with the preference, and cannot explain the preference for STM at low dietary Cu levels. Also the lack of differences at the end of the study, regardless of mineral levels fed, cannot be explained.

The BW and therefore the growth performance was measured on pen average at the start and the end of each phase. As the individual feed intake was not measured in this experiment no correlations can be calculated between the preference of mineral source and the performance. However, the two different treatments, i.e., high and low Cu levels, can be compared. The groups receiving the low Cu diets seemed to have a lower BW from day 28 onwards (Table 3) ($P < 0.1$). The ADG and average daily feed intake were lower ($P < 0.05$) for the low Cu groups until 28 d and in the overall study. In the different feeding phases there were no significant differences in gain:feed, however in the overall study the low Cu groups had a lower ($P < 0.05$) gain:feed than the high Cu groups. The lower performance observed in the low Cu groups confirm the feed intake driven effect of Cu as discussed in studies of Bikker et al. (2015), Zhou et al. (1994) and Yang et al. (2011).

Experiment 2

The results in Exp. 1 confirmed the preference for HTM by the piglets. As the feed intake and proportion of each type of feed was not measured on an individual basis it could not be related to performance of the piglets. Therefore, Exp. 2 was conducted in which the feed intake was followed continuously using automated feeding stations. In this experiment, both the feed intake and performance were measured per individual pig. In Exp. 2 also two treatments were applied.

The results of Exp. 2 are shown in Fig. 2, and similar to Exp. 1 the preference was expressed as percentage feed intake as the total. The piglets in the high Cu groups had a significant ($P < 0.05$) preference for feed with minerals from HTM during the entire experimental period, ranging from 53.4% to 57.8% ($P < 0.05$). These percentages of preference were lower than observed in Exp. 1. This could be attributed by the more complicated feeding stations. Newly weaned piglets seem to have more difficulties learning to eat from the feeding stations than from common feeders. It was noticed in this study that some piglets did not find the feeding stations the first days, as no feed intake was recorded for those animals (data not shown). It seemed to take them

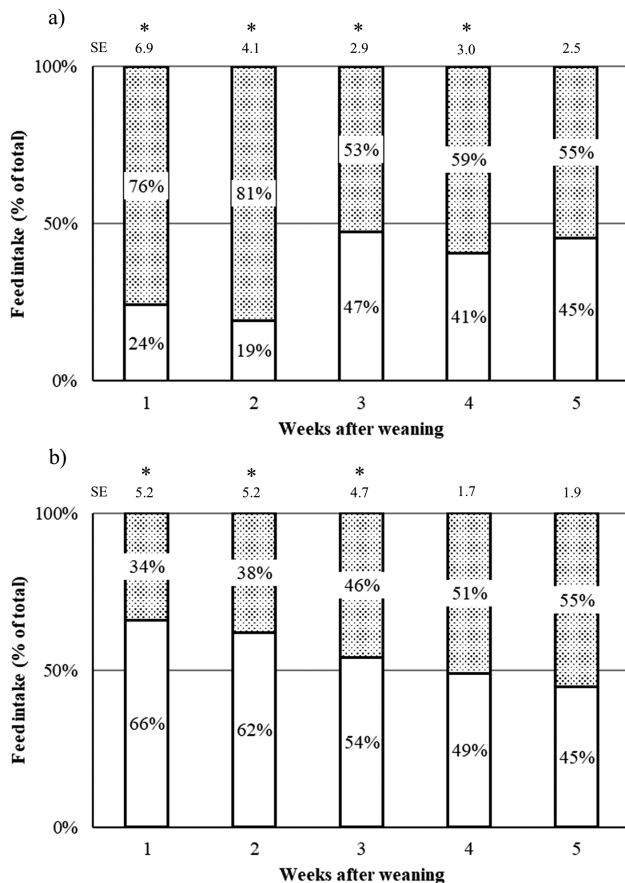


Figure 1. Preference of the piglets per week in Exp. 1. (a) The preference of the pigs fed diets with high Cu levels (160 ppm added); (b) the preference of the pigs fed diets with low Cu levels (15 ppm added). The white clear bars represent the percentage of feed with sulfate minerals consumed and the dotted bars represent the percentage of feed with hydroxychloride minerals consumed. The data are expressed as percentage of the total feed intake in that week. * represents the week in which a significant ($P < 0.05$) difference was observed. SE = standard error of the mean.

Table 3. Growth performance of the piglets in Exp. 2

<i>n</i>	High copper	Low copper	SE	<i>P</i> -value
	60	60		
Body weight, kg				
Week 1	8.9 ^b	9.4 ^a	0.15	0.0004
Week 2	10.9	11.1	0.19	0.3064
Week 3	12.6	12.6	0.29	0.9513
Week 4	16.4	15.7	0.42	0.1018
Week 5	19.9	18.9	0.55	0.0771
ADG, g/pig/d				
Week 1	150.8 ^b	235.1 ^a	26.77	0.0017
Week 2	285.2 ^a	228.1 ^b	26.92	0.0346
Week 3	256.4	222.2	26.77	0.2021
Week 4	550.6 ^a	440.1 ^b	26.77	<0.0001
Week 5	494.4	455.4	26.77	0.1458
Total	344.9	317.4	10.77	0.0705
ADF, g/pig/d				
Week 1	175.2 ^b	216.7 ^a	13.3	0.0285
Week 2	324.2	327.6	11.1	0.8245
Week 3	362.9	365.6	16.1	0.9026
Week 4	680.8 ^a	580.7 ^b	22.3	0.0017
Week 5	690.6 ^a	628.6 ^b	22.1	0.0473
Total	446.7	417.1	12.2	0.0864
Gain:feed				
Week 1	0.588 ^a	0.396 ^b	0.0857	0.0252
Week 2	0.779	0.818	0.0862	0.6521
Week 3	0.822	0.955	0.0867	0.1253
Week 4	0.678	0.660	0.0857	0.8356
Week 5	0.840	0.682	0.0857	0.0658
Total	0.770	0.751	0.0085	0.1106

^{a, b}Different superscripts within a row represent significant differences ($P < 0.05$).

more effort to both learn the mechanisms of a feeding station and to learn that there were two feeding stations present in a pen with different feeds. During the analysis it was clear that some piglets had a preference for one feeder and (almost) never ate from the other feeder throughout the entire study period (data not shown). In the experimental design the feeds in the feeders were switched to prevent a false preference for a feed. However, as a result these piglets with a feeder preference ate 50% of both feeds, reducing the impact on preference. This behavior is also expected under commercial circumstances, and therefore these piglets were not removed from the data analysis. Even when this was taken into account, a significant preference for HTM was observed. Removing those piglets that preferred a side rather than a certain diet would drive the data even more toward a preference for HTM. With including these piglets, the natural variation between animals is included in the data analysis. This suggests that the preference of the piglets eating from both feeders was even stronger than the results indicate.

Lowering the Cu content with 20 ppm already dilutes the preference for HTM, where the low Cu groups only showed a significant ($P < 0.05$) preference of 54.2% in the third week after weaning for HTM. In week one, two, and four of the study the animals also received 140 ppm Cu in their diet, but during those weeks no significant preference was observed. In the last week of the experiment when the low Cu diets only contained 15 ppm Cu, the piglets preferred the diets with STM. This confirmed the findings of the low Cu groups in Exp. 1. This switch in preference toward the other mineral source, suggested that the piglets were able to select diets within a pen. It suggested that the experiments were designed successfully to demonstrate feed preferences.

Similar to Exp. 1 the performance was expressed comparing high and low Cu groups. In the first week after weaning the low Cu groups grew more than the high Cu groups, resulting in an increased BW and ADG. However, the higher feed intake in that group resulted in a decreased gain:feed ratio in the first week. Even though the mineral levels are

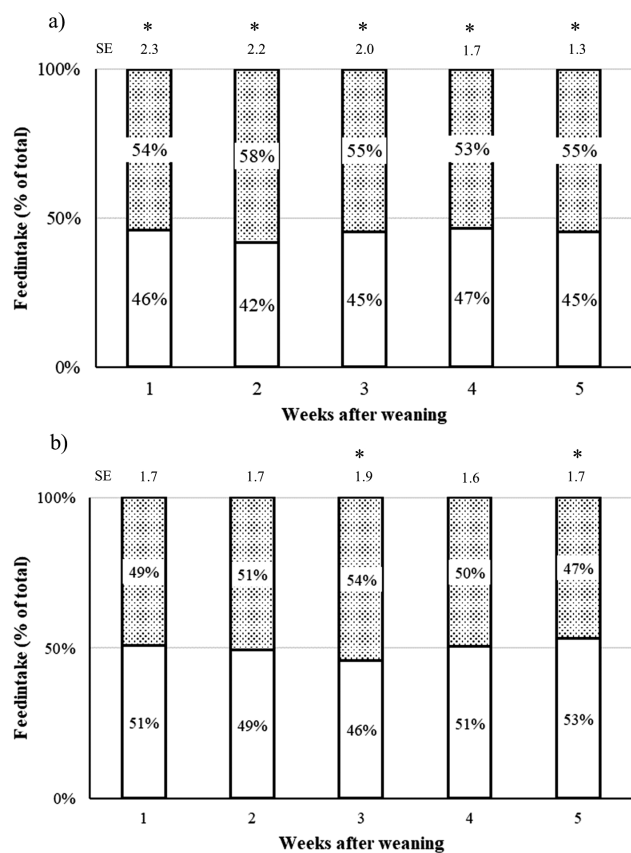


Figure 2. Preference of the piglets per week in Exp. 2. (a) The preference of the pigs fed diets with high Cu levels (160 ppm added); (b) the preference of the pigs fed diets with low Cu levels (140 ppm in the first 4 wk, last week 15 ppm Cu added). The white clear bars represent the percentage of feed with sulfate minerals consumed and the dotted bars represent the percentage of feed with hydroxychloride minerals consumed. The data are expressed as percentage of the total feed intake in that week. * represents the week in which a significant ($P < 0.05$) difference was observed. SE = standard error of the mean.

only slightly lower in the low Cu group during the first 28 d of the study, a lower ADG was observed between 7 and 14 d and between 21 and 28 d. The individual measurements of gain and feed intake done in Exp. 2 allow finding links between preference and performance. The preference for HTM did not affect BW ($P = 0.2226$), ADG ($P = 0.1213$) or gain:feed ratio ($P = 0.2457$). Although the piglets were housed in groups of 20 pigs per pen, which might bias the individual measurements, each pig was considered individually. The low amount of pens influencing the outcomes might cause the lack of significant correlations between preference and growth performance. A larger study measuring individual gain and feed intakes including more replicates should be done to study the link between preference and growth performance.

The preference for HTM in the high Cu diets confirmed the findings of Coble et al. (2013). They observed a clear preference of 65% for hydroxychloride copper compared to inorganic copper in pigs

in the grower and finisher phase. The diets in that study contained higher levels of Cu, up to 243 ppm. On the basis of the current study, the effect of preference should be more clear at higher Cu levels. It should be noted that Coble et al. (2013) tested the preference in grower/finisher pigs, whereas in the current study the preference in piglets was measured. In this study, the piglets were not followed into the grower/finisher phase after both experiments studies were ended. The short-term preference of piglets to HTM could not be confirmed to last until the grower/finisher phase.

Although this study was not set up to show an increased intake when piglets have no choice, the preference observed in this study indicates a possible higher feed intake when only a diet with HTM is provided. This is not only taste driven, but also because of the systemic effect of Cu on feed intake (Zhou et al., 1994; Yang et al., 2011). The higher feed intake was confirmed by the data presented by Fry et al. (2012), who showed a numerical increased average daily feed intake in the first 33 d after weaning in pigs fed 225 ppm Cu from HTM compared to 225 ppm Cu from STM. A higher feed intake was thought to be related to less weaner diarrhea because of sufficient stimulation of the gut (Dong and Pluske, 2007). Diarrhea scoring was not part of any of the described experiments. The diarrhea scoring would have been based on pen scores whereas the intake per mineral source differed between animals.

An increased performance with HTM had been expected based on the numerical higher ADG described in Fry et al. (2012) and the improved feed conversion ratio described in Winkler et al. (2013). The average preference for diets with HTM in Exp. 2 was just above 50%, possibly explaining the lack of correlation between preference and performance. This means that the pigs not only ate from diets containing HTM, but also from the diets with STM, diluting the possible growth beneficial effects of HTM. In general, the performance of the piglets was lower in Exp. 2 compared to Exp. 1. The reason for this is unknown. A future study should be performed to show effects of HTM on growth performance, feed intake, and diarrhea of newly weaned piglets.

Taste in pigs and its influence on feed intake was already studied late 19th century (Roura and Fu, 2017). The main research summarized by Roura and Fu (2017) concerned the taste of sweeteners and later umami taste. For sweet compounds it is known that the taste experience is different between humans and pigs (Hellekant and Danilova, 1999).

Not much is known whether the taste of CuSO_4 is also perceived as metallic in pigs as it is in humans (Epke et al., 2009). The current study suggests that the metallic taste of CuSO_4 was also tasted by newly weaned piglets resulting in a preference for HTM. This effect resulted only in a clear preference at high dietary Cu levels (160 ppm), and was less pronounced at levels of 140 ppm added.

Conflict of interest statement. None declared.

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