Impact of acetic acid concentration of fermented liquid feed on growth performance of piglets☆

Nuria Canibe a,⁎, Anni Øyan Pedersen b, Bent Borg Jensen a

a University of Aarhus, Faculty of Agricultural Sciences, Dept. of Animal Health, Welfare and Nutrition, Blichers Allé 20, P.O. BOX 50, DK-8830 Tjele, Denmark
b Pig Research Center, Danish Agriculture and Food Council, Axelborg, Axeltorv 3, DK 1609 København V, Denmark

A R T I C L E   I N F O

Keywords:
Acetic acid
Fermented liquid feed
Growth performance
Piglets

A B S T R A C T

Feeding fermented liquid feed (FLF) to pigs has proven to benefit gastrointestinal health of the animals. However, growth performance data of piglets and growing pigs fed FLF are variable and often a lower feed intake compared to feeding non-FLF or dry feed has been observed. Accumulation of microbial metabolites, namely acetic acid, possibly in combination with low feed pH, has been suggested to be determinant in reducing feed intake by impairing palatability. However, this hypothesis has never been investigated. A study was carried out to determine the impact of increasing levels of acetic acid in FLF on feed intake of weaners. Three experimental FLF diets were prepared to contain varying levels of acetic acid (30, 60, and 120 mM). Twenty piglets per treatment, weaned at 4 weeks of age and housed individually, were fed the experimental diets during six weeks starting at weaning. Feed intake and body weight were registered weekly. The results showed that high acetic acid concentration in FLF, accompanied by a slight lower pH level, tended to decrease feed intake without affecting body weight gain. This discrepancy could partly be explained by the difficulty in measuring accurately feed intake on dry matter basis when feeding liquid feed to pigs. In conclusion, concentrations of acetic acid, at the levels normally measured in FLF, are not expected to affect markedly growth performance of piglets.

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1. Introduction

Fermentation of liquid feed can be advisable from a health point of view. Feeding FLF reduces the seroprevalence of Salmonella in growing pigs (van der Wolf et al., 2001) and infected pigs with Brachyspira hyodysenteriae or Lawsonia intracellularis showed lower incidence of clinical disease and of faecal excretion of the pathogen than those fed with the same dry feed (Lindecrona et al., 2003; Boesen et al., 2004). The counts of Enterobacteriaceae along the gastrointestinal tract (GI-tract) can also be reduced by feeding FLF (Mikkelsen and Jensen, 2000; van Winsen et al., 2001; Canibe and Jensen, 2003).

However, the effects of FLF on growth performance are more variable (Russell et al., 1996; Jensen and Mikkelsen, 1998; Pedersen, 2001; Lawlor et al., 2002; Canibe and Jensen, 2003; Canibe et al., 2007). Pigs fed FLF have shown lower feed intake compared to those fed non-FLF or dry feed (Pedersen, 2001; Canibe and Jensen, 2003), which has been speculated to be due to low palatability of FLF. High levels of acetic acid have been suggested as main factors impairing palatability of FLF (Brooks et al., 2001; Beal et al., 2005). However, to our knowledge, this hypothesis has not been investigated.

An experiment was carried out to investigate the impact of acetic acid concentration in FLF on growth performance of weaners.

2. Materials and methods

This experiment was carried out at the University of Aarhus, Denmark. The Danish Ethical Commission approved the experimental protocol and the animals were handled in accordance with guidelines established by this Commission.
2.1. Animals and housing

Sixty piglets (Danish Landrace × Yorkshire × Duroc) from 20 litters were used. Piglets were weaned at 28 ± 1 d of age and a body weight of 8.7 kg (SD = 1.01) and moved to pens (184 cm × 82 cm, of which 82 cm × 82 cm was slatted) where they were individually housed during the whole study. The animals were allotted on the basis of litter, sex, and initial body weight to each of the dietary treatments. Temperature of the nursery was maintained at 28 °C during the first two weeks, 24 °C during the following two weeks, and 20 °C during the last two weeks of the experiment.

2.2. Diets and feeding

2.2.1. Pre-experimental period

Three dietary treatments were prepared using a non-pelleted, non-heated weaner diet ground in a roller mill (g/kg): wheat, 311.8; barley, 311.7; dehulled toasted soybean meal, 217.0; fish meal, 80.0; animal fat, 50.0; calcium carbonate, 9.2; monocalcium phosphate, 9.1; vitamin and mineral premix, 4.0; t-Lysine HCl, 40.0; 3,9; sodium chloride, 2.9; DL-Methionine, 40.0; 0.4. Feed and water (at a temperature of approx. 16 °C) were mixed in the ratio 1:2.5 (w/w) in a tank with a capacity of 100 kg. The mixture was agitated during 5 min every hour. Every 24 h, 60% of the mixture stored in the tank was removed and then replaced with an equal amount of fresh feed and water. This procedure was followed during one week before the FLF was fed to the animals. When the animals were introduced to the experiment the same procedure was followed.

Three experimental diets with varying concentrations of acetic acid were prepared by adding acetic acid to the experimental diet: Diet ‘30 mM’; Diet ‘60 mM’; and Diet ‘120 mM’. An appropriate amount of FLF was removed from the tank and transferred to three buckets. The concentration of acetic acid was adjusted by adding acetic acid every morning immediately before feeding to each bucket.

All animals were allowed *ad libitum* access to feed from 0800 to 1445. Additional fresh water was permanently available for all piglets from nipple drinkers.

2.3. Experimental procedure

A total of 16 FLF samples from each bucket were taken weekly in the morning immediately before feeding. The pH, microbial composition, and the concentration of organic acids and of ethanol were measured.

Individual feed intake was recorded weekly by weighing the offered feed and refusals and determining their dry matter content. Individual body weight was recorded weekly. The animals were introduced to the study in three series of 24, 18, and 18 animals each.

2.4. Analytical methods

The diet used to prepare the FLF treatments was analyzed for dry matter, energy, nitrogen and fat as described by Canibe and Jensen (2003). The concentration of SCFA, as well as, lactic acid and succinic acid and ethanol was measured as described by Canibe et al. (2007). Dry matter percentage of feed refusals was determined by drying the samples at 103 °C to constant weight. For microbiological enumeration, procedures described by Canibe et al. (2007) were followed. Clostridium perfringens were enumerated using the pour-plate technique on tryptose sulfate agar (Merck 1.11972) supplemented with cycloserine (Oxoid SR088E) following anaerobic incubation at 20 °C for 3 d.

2.5. Calculations and statistical methods

The effect of diet on daily weight gain, daily feed intake and gain/feed was estimated using the Proc Mixed procedure of SAS with diet and series as fixed effects and litter as random effect. The initial body weight was used as a covariate when analyzing daily weight gain and daily feed intake. Because the interaction between diet and series was not significant, it was taken out of the model. The analyses were performed with SAS for Windows version 8.2 (SAS Institute, Cary, NC). When there was an overall effect of diet, at an alpha of P = 0.05, differences between means were compared pairwise using an F-test.

3. Results

The pH, microbial composition and concentration of organic acids in the three experimental diets are shown in Table 1. The pH decreased from 4.38 to 4.16 with increasing levels of acetic acid in the diets. The concentration of acetic acid was very close to the expected values, 28, 57, and 111 mM in the ‘30 mM’, ‘60 mM’, and ‘120 mM’ diet, respectively. The microbial composition and the level of the other organic acids measured were very similar in the three dietary treatments.

The daily weight gain was not affected by the dietary treatment in any of the three periods considered (P ≤ 0.48) (Table 2). The daily feed intake during the first two weeks post-weaning was also very similar in the three dietary groups (P = 0.57). During the last four weeks of the study and when the whole period was considered, a tendency to lower feed intake with increasing dietary acetic acid was observed (P ≤ 0.09). The gain/feed ratio was not affected by diet during any of the periods considered (P ≥ 0.41).

<table>
<thead>
<tr>
<th>Item</th>
<th>30 mM</th>
<th>60 mM</th>
<th>120 mM</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>4.38 ± 0.06</td>
<td>4.28 ± 0.08</td>
<td>4.16 ± 0.04</td>
</tr>
<tr>
<td>Enterobacteriaceae</td>
<td>3.34 (2) ± 0.48</td>
<td>3.40 (2) ± 0.39</td>
<td>3.25 (7) ± 0.55</td>
</tr>
<tr>
<td>Lactic acid bacteria</td>
<td>9.63 ± 0.07</td>
<td>9.64 ± 0.08</td>
<td>9.61 ± 0.10</td>
</tr>
<tr>
<td>Yeasts</td>
<td>6.89 ± 0.26</td>
<td>6.87 ± 0.30</td>
<td>6.81 ± 0.28</td>
</tr>
<tr>
<td>Moulds</td>
<td>3.24 (3) ± 0.40</td>
<td>3.54 (1) ± 0.47</td>
<td>3.30 (2) ± 0.38</td>
</tr>
<tr>
<td>Clostridium perfringens</td>
<td>2.42 (4) ± 0.54</td>
<td>2.62 (3) ± 0.67</td>
<td>2.35 (3) ± 0.48</td>
</tr>
<tr>
<td>Formic acid</td>
<td>3.6 ± 1.64</td>
<td>3.6 ± 1.57</td>
<td>3.1 ± 1.00</td>
</tr>
<tr>
<td>Acetic acid</td>
<td>27.8 ± 2.19</td>
<td>56.7 ± 3.33</td>
<td>110.8 ± 6.10</td>
</tr>
<tr>
<td>Propionic acid</td>
<td>1.0 ± 0.15</td>
<td>1.0 ± 0.16</td>
<td>0.8 ± 0.35</td>
</tr>
<tr>
<td>Lactic acid</td>
<td>180.4 ± 9.23</td>
<td>180.5 ± 10.28</td>
<td>179.5 ± 7.38</td>
</tr>
<tr>
<td>Succinic acid</td>
<td>1.6 ± 0.06</td>
<td>1.6 ± 0.04</td>
<td>1.6 ± 0.05</td>
</tr>
<tr>
<td>Ethanol</td>
<td>8.1 ± 2.96</td>
<td>8.2 ± 2.91</td>
<td>7.2 ± 2.79</td>
</tr>
</tbody>
</table>

* Values are means (n = 16; the remaining items, n = 9) and standard deviation. Values in brackets indicate the number of samples with values below detection levels. Detection level was log cfu/g = 3 for all microorganisms, except for Clostridium perfringens (log cfu/g = 2).

b 30 mM, diet containing 30 mM acetic acid; 60 mM, diet containing 60 mM acetic acid; 120 mM, diet containing 120 mM acetic acid.
Table 2
Growth performance of piglets fed the experimental diets.*

<table>
<thead>
<tr>
<th>Diet**</th>
<th>SEM</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>30 mM</td>
<td>60 mM</td>
<td>120 mM</td>
</tr>
<tr>
<td>Daily weight gain, g</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1–14 days</td>
<td>142</td>
<td>126</td>
</tr>
<tr>
<td>14–42 days</td>
<td>636</td>
<td>613</td>
</tr>
<tr>
<td>1–42 days</td>
<td>472</td>
<td>455</td>
</tr>
<tr>
<td>Daily feed intake, g DM</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1–14 days</td>
<td>257</td>
<td>244</td>
</tr>
<tr>
<td>14–42 days</td>
<td>1035</td>
<td>967</td>
</tr>
<tr>
<td>1–42 days</td>
<td>776</td>
<td>726</td>
</tr>
<tr>
<td>Gain/feed, kg</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1–14 days</td>
<td>539</td>
<td>513</td>
</tr>
<tr>
<td>14–42 days</td>
<td>622</td>
<td>649</td>
</tr>
<tr>
<td>1–42 days</td>
<td>613</td>
<td>631</td>
</tr>
</tbody>
</table>

* Values are least square means (n = 20).
** 30 mM, diet containing 30 mM acetic acid; 60 mM, diet containing 60 mM acetic acid; 120 mM, diet containing 120 mM acetic acid.
*** Some animals lost weight during this period, which results in incorrect feed conversion ratio values, therefore gain/feed calculated as sum of gain/sum of feed for each diet.

4. Discussion

The microbial composition of the three FLF diets was within the levels previously measured in FLF prepared following a similar procedure (Canibe and Jensen, 2003; Canibe et al. 2007).

The numerically lower feed intake with increasing levels of acetic acid measured indicates that high levels of acetic acid in FLF can impair palatability. However, in order to interpret these data correctly it has to be kept in mind that the typical concentration of acetic acid in FLF prepared with compound pig feed ranges between ~20 and 40 mM (Mikkelsen and Jensen, 2000; Scholten et al., 2001; van Winsen et al., 2001; Canibe and Jensen, 2003; Canibe et al., 2007). Levels of ~54 mM have been reported, though (Pedersen, 2001).

Therefore, the current data suggest that the levels of acetic acid typically measured in FLF prepared with standard compound feed would not profoundly affect its palatability, and thereby feed intake by piglets. This is supported by the similar daily weight gain observed in the three experimental groups. Because the diet fed to the three animal groups was the same and the only difference was the addition of acetic acid prior to feeding, differences in feed intake among groups would be expected to result in a corresponding difference in weight gain. The discrepancy between the feed intake and the weight gain data could be explained by the difficulty in measuring accurately feed intake on dry matter basis when feeding liquid feed. In order to calculate the weekly feed intake on dry matter basis, feed refusals were removed and weighed every day and pooled in a bucket per pig. At the end of each week, a sample (approx. 150 g) was taken from each bucket and the dry matter percentage was determined. This procedure can give some inaccuracies when taking a sample from the buckets for dry matter analysis.

The data also indicate that certain ingredients (e.g., liquid co-products) with very high levels of acetic acid (Scholten et al., 2001; Lyberg et al., 2008) or that contribute to a very high production of acetic acid during fermentation may negatively affect feed intake of the mixture by the animals.

In conclusion, the present data indicate that acetic acid, at the concentrations measured in FLF prepared with ‘traditional’ ingredients, do not markedly affect growth performance. However, inclusion of ingredients with high levels of acetic acid or that promote high production of acetic acid during fermentation (e.g., liquid co-products) could impair growth performance of piglets.

Conflict of interest

There is no conflict of interest regarding the short paper.

References


Russell, P.J., Geary, T.M., Brooks, P.H., Campbell, A., 1996. Performance, water use and effluent output of weaner pigs fed ad libium with either dry pellets or liquid feed or the role of microbial activity in the liquid feed. J. Sci. Food Agric. 72, 8–16.

