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Water inclusion in piglet diet after weaning

Inclusão de água em dietas de leitões após o desmame

Felipe Ceolin[1], Aline Felix Schneider Bedin[2], Clóvis Eliseu Gewehr[3]*

[1] Programa de Pós-graduação em Ciência Animal, Centro de Ciências Agroveterinárias (CAV), Universidade Federal do Estado de Santa Catarina (UDESC), Lages, SC, Brasil
[2] Universidade Federal de Santa Catarina, Lages, SC, Brasil
[3] Departamento de Produção Animal e Alimentos, CAV, UDESC, Lages, SC, Brasil
* Correspondence to: clovis.gewehr@udesc.br

ABSTRACT The performance and morphometry of intestinal villi were evaluated in piglets fed liquid diets with different water levels compared to dry diets during the first week after weaning. The experiments were using 48 piglets around 7 kg, weaned at 25 days of age, and housed in 24 bays for seven days. A completely randomized design was adopted with six treatments: dry feed (control) provided in the feeder and water provided in the drinker; control diet moistened with water in a 1:1 ratio (feed/water) and access to the drinker (1:1+water); control diet moistened with water in a 1:2 ratio (feed/water) and access to the drinker (1:2+water); control diet moistened with water in a 1:3 ratio (feed/water) and access to the drinker (1:3+water); control diet moistened with water in a ratio of 1:2 (feed/water) without access to the drinker (diet 1:2/no water); control diet moistened with water in a ratio of 1:3 (feed/water) without access to the drinker (diet 1:3/no water). In the 1:2+water and 1:3+water diets, there was an improvement in piglet performance compared to the dry diet. The 1:2+water diet improved the duodenal villus/crypt ratio and the 1:2+water and 1:3+water diets improved the jejunal villus/crypt ratio compared to the dry diet.

Keywords Feeding piglets, liquid diet, pig ration, villous, crypt

RESUMO Avaliou-se o desempenho e morfometria das vilosidades intestinais em leitões alimentados com dietas líquidas com diferentes níveis de água comparando com dieta seca durante a primeira semana pós desmame. Foram usados 48 leitões de +/- 7 kg, desmamados aos 25 dias de idade, alojados em 24 baias durante sete dias. Adotou-se um delineamento inteiramente casualizado com seis tratamentos: ração seca (controle) fornecida no comedouro e água fornecida em bebedouro, dieta de controle umedecida com água na proporção 1:1 (ração/água) e acesso à agua no bebdouro (dieta 1:1+água); dieta controle umedecida com água na proporção de 1:2 (ração/água) e acesso ao bebedouro (dieta 1:2+água); dieta controle umedecida com água na proporção de 1:3 (ração/água) e acesso ao bebedouro (dieta 1:3+água); dieta controle umedecida com água na proporção de 1:2 (ração/água) sem acesso ao bebedouro (dieta 1:2/sem água); dieta controle umedecida com água na proporção de 1:3 (ração/água) sem acesso ao bebedouro (dieta 1:3/sem água). Nas dietas 1:2+água e 1:3+água observou-se melhora no desempenho dos leitões em comparação com a dieta seca. A dieta 1:2+água melhorou a proporção vilo/cripta do duodeno e dietas 1:2+água e 1:3+água melhoraram a relação vilo/cripta no jejuno em relação a dieta seca.

Palavras-chave Alimentação de leitões, dieta líquida, ração de suínos, vilosidades, cripta

1. Introduction

The use of liquid diets in Brazil has yet to gain popularity. Only 2% of the animals are finished with liquid diets, but significant returns are observed with an economy of 10 to 15% per kilogram of weight gain (Yagüe, 2007). According to the same author, many European countries practice liquid feeding in more than half the practices of fattening animals. In North America, the use of liquid feed systems has escalated because of the high prices for conventional solid foods, their increasing availability, and lower costs of liquid co-products (Yang & Liao, 2019).

Liquid feed has been observed as an interesting alternative to reduce pig feed costs (Cullen et al., 2021), as it improves intestinal health and well-being, taking advantage of unused liquid food products, minimizing feed waste, boosting the feed intake and nutrient digestibility, thus improving animal performance (Han et al., 2006). It also helps to provide a healthier environment through the reduction of dust (Cullen et al., 2021) and manpower, as well as by raising the diet (Missotten et al., 2010). Further, liquid feeding of weaned pigs encourages higher feed intake, thus circumventing the

post-weaning growth lag normally observed after weaning, as well as facilitating the transition from sow milk to solid feed (Missotten et al., 2015; Jiang et al., 2019).

The weaning period in pigs is an indicator of a growth pause, which causes significant economic losses (Yang & Liao, 2019). The low performance during this period is attributed to the low consumption of feed (Cullen et al., 2021), and the drop in the post-weaning growth rate can precipitate growth depression in the later stages (Jiang et al., 2019). There is a common and high correlation noted between weaning stress and chronic inflammatory intestine diseases (McLamb et al., 2013), as well as reduced feed intake in newly weaned animals (Paula, 2018).

A positive relationship is observed between feed intake after weaning and intestinal morphological quality (Wang et al., 2020). Stimulating feed intake at this point may lower villous atrophy, prevent diarrhea, and stimulate animal growth (Dong & Pluske, 2007). An adequate degree of feeding level after weaning can stop the intestinal barrier function loss, which prevents the animal from having an antigen overload (Wijtten et al., 2011).

The objective of this study, therefore, was to assess the performance and morphometry of the intestinal villi during the first week after weaning the piglets fed with diets containing different levels of water compared to the dry diet, with and without access to the drinking fountain.

2. Material and methods

This research utilizing 48 animals was conducted according to the institutional committee on animal use number 1.71.13, CEUA by CAV-UDESC. The experiment was conducted for seven days in an open shed shielded with plastic curtains on all sides, including the first week after weaning. In these experiments, 48 newly weaned, 25-day-old piglets of commercial lineage were used (male Agroceres 337 and female Topigs C20) drawn from a Pig Production Unit (PPU) of agroindustry in western Santa Catarina state, with the coordinates of 27º 05' 47" S latitude, and 52º37'06" W longitude, at 674 meters elevation. During the lactation phase, from the 7th day of life, the animals received water and feed at will, formulated according to the lineage requirement. On arrival at the nursery, a group of 300 animals was selected, with an average weight of 7 kg (± 0.250), weighed individually on a digital scale, and randomly distributed in pairs in 24 bays, each 1 square meter in area.

The bays were provided with wooden separators, a slatted plastic floor, and a feeder. A drinking fountain (when needed in the treatment) is included, made of a plastic pipe 200 mm in diameter, cut in half, and coupled to a wooden base with silicone sealing of the iron edges. Each feeder or drinking fountain had 40 cm of access and was fixed to the floor, thus preventing waste.

The experiments comprised six treatments, namely: dry meal fed in the feeder and water available through a drinking fountain (control); control diet moistened with water in the ratio of 1:1 (feed⁄water ratio) and access to water (diet 1 is to 1 + water); control diet moistened with water in the proportion of 1:2 (feed⁄water ratio) and access to water (diet 1:2 + water); control diet moistened with water in the ratio of 1:3 (feed⁄water ratio) and access to water (diet 1:3 + water); control diet moistened with water in the proportion of 1:2 (feed⁄water ratio) without access to water (1:2 diet without water); control diet moistened with water in the proportion of 1:3 (feed⁄water ratio) without access to water (1:3 diet without water).

In all the different treatments, the feed used was similar (Table 1), formulated according to the recommendations of Rostagno et al. (2011). The diets were available to the piglets in appropriate feeders, and were provided twice a day, at 8:00 a.m. and 4:00 p.m. Water was provided ad libitum, according to the determined treatments, originating from an artesian well and chlorinated in the water tanks located in the shed.

Table 1 – Nutritional and calculated composition of the experimental diet in natural matter.

Ingredients	g/kg as feed
Grain maize	321
Pregelatinized maize	200
Soybean oil	8.50
Soybean meal 46%	195
Whey 71%	143
Pig plasma	40
Limestone 38%	2
Dicalcium phosphate	17
Crystal sugar	5
White salt	1.70
DL-Methionine 99%	3
L-Lysine 78%	5.95
Threonine 98%	2.75
Tryptophan 98%	0.50
Aromatic/Palatabilizing	0.20
Zinc oxide 72%	3.65
Copper sulphate 25%	0.75
Premix vitamin/mineral*	5.00
Total	1000
Calculated composition	**g/kg as feed**
Metabolizable energy (kcal/kg)	3,452
Protein	19
Gross fiber	23
Calcium	7
Phosphorus	5
Lysine digestible	14
Methionine digestible	5
Threonine digestible	9
Tryptophan digestible	2.50
Lactose	100
Sodium total	3

*Vitamin A 12.6 KUI, vitamin D3 2.1 KUI, vitamin E 57.2 mg, vitamin K3 3.1 mg, thiamine 4.2 mg, riboflavin 6.3 mg, pyridoxine 7.3 mg, cyanocobalamin 23.5 mcg, niacin 55.7 mg, pantothenic acid 23.7 mg, folic acid 1.14 mg, biotin 240 mcg, choline 828 mg, magnesium 353 mg, iron 266.3 mg. Copper 194.3 mg. Zinc 3020 mg, manganese 31.3 mg, selenium 0.43 mg, cobalt 0.065 mg, iodine 0.44 mg, growth promoter 120 mg, antioxidant 1 mg.

The diets were prepared fresh immediately before supplying them; the ration was then placed in a jar and weighed on a digital scale, after which water was added to the amount determined for the treatment. The diet was homogenized using a stick for about 30 seconds before it was served

immediately to the animals. Using electric curtains and heaters, the warehouse temperature was controlled and maintained between 86 ºF and 89.6 ºF.

The zootechnical performance was obtained through the consumption of accumulated ration (kg/animal), subtracting the leftovers (water and feed) from a predetermined amount provided so that diet in the feeders was always available between the replenishments. Measurements were taken using a digital scale with 5 g precision. The final weight was obtained by the mean of the box and expressed in kg/animal. The daily weight gain was obtained by subtracting the initial weight from the final weight and divided by the experimental time, expressed in kg/animal. Feed conversion was determined by the feed intake (kg) reason for weight gain (kg) during the evaluation period, ignoring the amount of water added.

For the histological analyses of the duodenum and jejunum, on the last day of the experimental period, one animal was slaughtered by a randomly selected repetition. First, it was submitted to a 12-h fast, then desensitized by cerebral concussion, and then sacrificed by bleeding the jugular and carotid cervical vessels. Fragment samples of around 2 cm in length were obtained. The duodenal samples were sectioned 10 cm from the pyloric antrum, and those from the jejunum were taken from them idle third. The samples were washed internally and externally using mild soaks of fixative solution (10% buffered formaldehyde; pH 7.2 to 7.4) and placed in individual plastic bottles containing 50 ml of the fixative solution. All the samples were routinely processed and stained with Hematoxylin and Eosin. The readings were taken in an Opticam ocular microscope (objective and 10x eyepiece), captured by a digital camera coupled under a microscope, and analyzed using the previously calibrated ToupTek ToupView software (version x64, 3.7.2270). Measurements of three crypts and three whole villi were taken per slide and expressed in micrometers (μm). The villus height was measured from the apex to the base of each villus, the latter corresponding to the opening of the crypts. The crypt depth was measured from the crypt opening to its lower portion, limited by the muscular mucosa. The analyses were determined through the relationship noted between the villi and crypts.

A completely randomized design with six treatments and four replicates was adopted, in which the experimental unit included two animals. The results were submitted to the analysis of variance, and the differences were compared by the Duncan test ($\alpha = 0.05$) through the SAS software (SAS Institute Inc.).

3. Results

The accumulated feed intake (Table 2) of the piglets submitted to the 1:2 + water diet was higher ($P > 0.05$) than the ones on the other diets and 15% higher than those on the dry diet. The other diets presented no difference ($P < 0.05$) between them. The consumption of the animals in the 1: 3 + diet with water access did not differ ($P < 0.05$) from the control diet. The final weights (Table 2) of the piglets fed with 1:2 + water and 1:3 + water were similar ($P > 0.05$) to each other but higher ($P < 0.05$) than those submitted to the other diets. Piglets fed on diets 1:1 + water and 1:3 without water showed weights ($P > 0.05$) similar to those given the dry diet. However, the piglets treated with the 1:2 diet without access to water presented lower final weights ($P < 0.05$) than those on the other diets.

A higher daily gain ($P < 0.05$) was observed in the 1:2 + water diet of the piglets compared to the other diets (Table 2), followed by those who received the 1:3 + water diet, which was higher ($P < 0.05$) in comparison to the diets with no water in the drinker, and the dry diet, which revealed similar weights ($P > 0.05$). The daily weight gain was 30 and 14% higher for diets 1:2 + water and 1:3 + water, compared to the dry diet.

The feed conversion (Table 2) in piglets receiving 1:2 + water and 1:3 + water diets was better ($P < 0.05$) than the ones given the 1:3 diet without water but similar ($P > 0.05$) to the others.

The 1:2 + water diet presented a higher (P < 0.05) villous/crypt ratio in the duodenal portion compared to the control diet (Table 2). The villus/crypt relationship in the jejunum was higher (P < 0.05) in the animals fed on diets 1:2 + water and 1:3 + water compared to the control diet (Table 2).

Table 2 – Accumulated feed intake (AFI), final weight (FW), average daily weight gain (ADW), feed conversion (FC), and villous/crypt ratio of the duodenum and jejunum of piglets feed for seven days after weaning with diets with different levels of inclusion of water.

Diets	AFI (kg)	FW (kg)	ADW (kg)	FC (kg/kg)	Villus/crypt duodenum	Villus/crypt jejunum
Dry (control)	1.48 [b]	8.38 [b]	0.19 [c]	1.10 [ab]	1.96 [c]	1.33 [b]
1:1 + water	1.43 [b]	8.30 [b]	0.19 [c]	1.10 [ab]	2.27 [bc]	1.84 [ab]
1:2 + water	1.70 [a]	8.63 [a]	0.25 [a]	0.98 [b]	3.08 [a]	2.22 [a]
1:3 + water	1.53 [b]	8.57 [a]	0.22 [b]	1.02 [b]	2.28 [bc]	2.10 [a]
1:2 without water	1.41 [b]	8.10 [c]	0.19 [c]	1.10 [ab]	2.01 [c]	1.87 [ab]
1:3 without water	1.44 [b]	8.23 [bc]	0.17 [c]	1.21 [a]	2.97 [ab]	1.63 [ab]
CV (%)	7.25	2.04	8.99	11.6	17.2	25.2
Probability	0.0001	0.0001	0.0001	0.0152	0.013	0.137

[a] Unequal letters between the means of the column differ significantly by the Duncan test (P < 0.05).

4. Discussion

The higher consumption observed in the animals that received the 1:2 + water diet may be related to the similarity of the liquid diet to the sow milk, as suggested by Goihl (2009).

The consumption of the animals in the 1:3 diet+water access did not differ, contrary to Han et al. (2006), which indicated a higher consumption in the piglets fed on the liquid diet in this proportion, from the first 10 to 20 days after weaning, when compared to the piglets given a dry diet. The excess water used in this mixture could have probably been the limiting factor, along with the physical capacity of the digestive tract, that is, excess water and only a little ration given in the treatment. Godbout and Pouliot (2002) reported superior consumption in piglets during the day-care phase, fed on rations that were moistened automatically and without any ration to defined water proportion, compared to the ones put on the dry ration; this consumption remained higher for the next 20 days on the dry diet alone. Kim et al. (2001) obtained 18% higher consumption during the first 14 days after weaning in the piglets fed on the 1:5 liquid diet (feed/water ratio) compared to those fed on the dry diet. Later, O'Meara et al. (2020) investigated the optimal feed delivery method and the feed form for the grower-finisher piglets. They observed that the liquid-fed meal increased the body weight in the piglets and weight game compared to feeding them the dry meal or wet/dry feeding meal.

On the other hand, Silva et al. (2002) found no difference in the piglets given the dry diet when compared to the piglets given the 2:1 liquid diet in the day-care animals, which concurred with the findings of Hurst et al. (2008). Their study found no difference in the feed intake during the growth phase of the pigs fed on dry and liquid diets in the 1:3 ratio. The lack of access to water through the drinking fountains failed to raise the consumption of the liquid diets compared to the control diet. Dong and Pluske (2007) also observed lower feed intake in pigs placed on the water-restriction diet.

The results of the final weight of the piglets were possibly due to consumption of the feed and better utilization of the moist diets. The lower results were linked to the water restriction and low levels of water inclusion, which were insufficient to meet the requirements of maintenance. The piglets fed on the 1:2 + water, and 1:3 + water diets revealed weights that were 3.0% and 2.3% higher than those fed on the dry diet. Kim et al. (2001) obtained better results with the liquid diets, although the final weight was 21% higher for the piglets treated with a 1:5 liquid diet (feed⁄water ratio) than a dry pelleted diet during the first 14 days after weaning, and this difference was maintained until the pigs were slaughtered at 150 days of age. In a similar work, Hurst et al. (2008) presented higher weight at the end of the growth phase (from 40 to 80 kg), where they used a liquid diet in an 1:3 proportion (feed⁄water ratio) compared to the one on a dry ration.

However, Silva et al. (2011) did not report any difference in the final weights in their experiment performed with piglets in the day-care phase, both males and females, that were fed on the 2:1 (ration is to water) diets, compared to being fed a dry diet.

The best result obtained with a 1:2 + water diet can be related to the ration intake, combined with its better use. Similar results were presented by Han et al. (2006), in which the piglets fed for 10 and 20 days on the liquid diet 1:3 (feed⁄water ratio) after weaning also revealed greater weight gain than the piglets fed on a dry diet. A similar result was obtained by Kim et al. (2001) during the first 14 days after weaning, with the piglets being fed on a 1:5 liquid diet (feed⁄water ratio) on a dry diet.

Furthermore, Hurst et al. (2008) observed a difference in the weight gain of the piglets treated with a liquid diet (ratio 1:3), from 40 to 80 kg live weight, during the pig growth phase. On the other hand, Godbout and Pouliot (2002), working with the piglets in the nursery phase, found no difference in weight gain between the dry and moist rations, regardless of the ratios of feed to defined water. This result corresponds to the findings of Silva et al. (2011), who also reported no difference in the weight gain of the day-care piglets fed on a 2:1 net diet (feed⁄water ratio) compared to being given a dry diet. A similar result was obtained in terms of weight gain in pigs fed on both the dry and wet diets, 2:1 (feed⁄water ratio) from weaning at 90 kg live weight, without any significant differences (Silva et al., 2002). The same authors also found no difference in the weight gain between the dry and wet diets of 2:1 (feed⁄water ratio) from weaning at 90 kg live weight.

The better feed conversion obtained from piglets receiving 1:2 + water and 1:3 + water diets is contrary to the one obtained by Silva et al. (2011), where there were no differences in the conversion of day-old piglets fed on dry and liquid diets in the ratio of 2:1 (feed⁄water ratio) to those found by Han et al. (2006), where there was no difference in conversion during the first 20 days of day-care between the dry and liquid diets of 1:3 (feed⁄water ratio). These results corroborate those of Kim et al. (2001), who found no differences for the first 14 days after weaning between feeding the piglets the dry and liquid diets in the 1:5 ratio (ration is to water).

However, in the experimental study by Han et al. (2006), when considering the entire nursery period (40 days), the conversion was much better for the animal group that received a dry diet. For growing pigs fed on a dry or liquid diet of 1:3 ratio (feed⁄water ratio), no differences were observed in the feed conversion (Hurst et al., 2008). On the other hand, the feed conversion rate was higher for the pig group fed on the dry ration than on the dry ration (Goddard & Pouliot, 2002). Further, O'Meara et al. (2020) found that liquid-fed pigs showed worsened feed efficiency compared to the ones fed on the dry meal or wet/dry feeding meal.

In general, a lower zootechnical performance was observed in the piglets that received diets with the inclusion of water and without the availability of drinkers. Pinheiro and Dallanora (2014) emphasizes that the low consumption of water at this stage, besides causing dehydration, contributes to a drop both in feed intake and weight gain. Dong and Pluske (2007) cite that water

consumption is one of the factors affecting the feed intake and growth rate in pigs and that the eating and drinking habits of freshly weaned piglets are positively related.

The higher villus/crypt ratio in the duodenal region, taken from piglets receiving the 1:2 + water diet, suggests a better duodenal histological structure of these animals, which, according to Pluske et al. (1997), could be related to the higher intake of dry matter, as observed in this diet.

The results found regarding the relationship of the villus/crypt ratio in the jejunum was higher in the animals fed on the diets of 1:2 + water and 1:3 + water compared to the control diet. This result concurs with the results obtained by Deprez et al. (1987), where the animals submitted to a liquid diet revealed a higher ($P < 0.05$) villus/crypt ratio for six, eight, and ten days after weaning compared to the animals fed on a dry diet. The higher villus/crypt ratio may indicate better nutritional adaptation during the post-weaning period. Thus, the results obtained for both the duodenal and jejunal portions indicate that animals submitted to the 1:2 and 1:3 diets with access to water in the first week after weaning utilize the diet well, resulting in better zootechnical performance. Villous height is one of the crucial morphological indicators for overall health and bowel function (Feng et al., 2015). The greater the height of the villi, the higher the absorptive capacity of the nutrients available, whereas the shorter the villi, the lower the metabolic cost for epithelial renewal (Yang et al., 2016; Yang & Liao, 2019), and the growth performance of the piglets increased in direct proportion to the increase in the villous height (Wang et al., 2020).

Besides the improved dry mather intake and growth rates observed in the pigs given liquid feeding (Missotten et al., 2015), several practical benefits are noted over dry feeding, which include the ability to optimize the microbial and nutritional quality through the addition of feed additives such as starter cultures for controlled fermentation, enzyme preparations to advance nutrient digestibility, and direct acidification of the feed using organic acids (Rudbäck, 2013).

5. Conclusions

The liquid diet of 1:2 and 1:3 ratio (feed/water ratio) with access to water in the feeder improve the growth performance of the piglets during the first week after weaning when compared to traditional dry diet. Piglets in the post-weaning phase which received the 1:2 and 1:3 liquid diets without access to the drinking fountain, presented performances similar to the traditional dry diet. The villi to crypt ratio in the jejunal portion improves with the 1:2 and 1:3 diets (feed/water ratio) with access to water in the drinking fountains.

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Declaration of Conflict of Interest

The authors declared no conflicts of interest.

Authorship Contribution Statement

Felipe Ceolin: Funding acquisition, Investigation, Methodology, Project administration, Writing – original draft; **Aline Félix Schneider Bedin**: Conceptualization, Formal analysis, Supervision, Validation, Writing – original draft, Writing – review & editing; **Clóvis Eliseu Gewehr**: Validation, Visualization, Writing – original draft, Writing – review & editing.

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