Italian Journal of Animal Science

ISSN: (Print) 1828-051X (Online) Journal homepage: https://www.tandfonline.com/loi/tjas20

Developing and testing a new feed block for the gut health and welfare of the weaning pig

Paolo Trevisi, Micol Bertocchi, Diana Luise, Maurizio Mazzoni, Leonardo Nanni Costa & Paolo Bosi

To cite this article: Paolo Trevisi, Micol Bertocchi, Diana Luise, Maurizio Mazzoni, Leonardo Nanni Costa & Paolo Bosi (2019) Developing and testing a new feed block for the gut health and welfare of the weaning pig, Italian Journal of Animal Science, 18:1, 1117-1125, DOI: 10.1080/1828051X.2019.1621215

To link to this article: https://doi.org/10.1080/1828051X.2019.1621215

ITALIAN JOURNAL OF ANIMAL SCIENCE
2019, VOL. 18, NO. 1, 1117–1125
https://doi.org/10.1080/1828051X.2019.1621215

Taylor & Francis
Taylor & Francis Group

PAPER

OPEN ACCESS Check for updates

Developing and testing a new feed block for the gut health and welfare of the weaning pig

Paolo Trevisi[a], Micol Bertocchi[a], Diana Luise[a], Maurizio Mazzoni[b], Leonardo Nanni Costa[a] and Paolo Bosi[a]

[a]Dipartimento di Scienze e Tecnologie Agroalimentari, University of Bologna, Bologna, Italy; [b]Dipartimento di Scienze Mediche Veterinarie, University of Bologna, Ozzano Emilia, Italy

ABSTRACT

Pig weaning cause transient stress and reduction of feed intake and intestinal villi. Providing feed with solid texture could stimulate explorative interest, relieving weaning drawbacks and improving welfare. Feed blocks (0.8 kg each) were produced and 8 formulas were preliminarily tested for consumption on a pig farm (ingredients: wheat by-products, dried milk whey, calcium carbonate, oil, molasses). Feed consumption and growth within 3 days after weaning were assessed on penned litters fed the normal feed ad libitum, and one of the 3 best block formulas or a control (wooden pieces). Block consumption was relevant, but growth and carcase quality on a sub-sample reared to commercial maturation were not changed. These formulations were also tested against control on 72 weaned pigs on which behaviour related to feeding and social activities was evaluated by means of surveys using cameras. After 4 days, pigs were slaughtered and the small intestines were sampled for mucosa morphology. In general, block consumption was additive with the consumption of normal feed. Growth was not affected. One formulation (major ingredients: wheat middlings, cane molasses, milk whey and coconut oil) increased the mucosal surface area of the intestinal villi by 7.9% ($p < .05$) and the length of time the pigs slept ($p < .01$), of the activities detected by cameras. The presence of some ingredient in the formula may have influenced feed block consumption with a potential reduction in the negative impact of weaning on the growth of the intestinal villi and an improvement of some behavioural parameters.

HIGHLIGHTS

- Ingredient composition may influence the disappearance of the feed block, as a variable combination of disaggregation and intake by the piglets.
- The formulation based on wheat middlings, cane molasses, milk whey and coconut oil may improve growth and favour better welfare
- Block supplementation may increase the absorbent surface of the proximal jejunum.

ARTICLE HISTORY
Received 23 December 2018
Revised 3 May 2019
Accepted 16 May 2019

KEYWORDS
Eating behaviour; feed blocks; intestinal mucosa; pig; welfare

Introduction

On 18 December 2008, European Union COUNCIL DIRECTIVE 2008/120/EC which laid down minimum standards for the protection of pigs became effective. The Directive highlighted key points to ensure an adequate level of welfare for pigs reared in confined conditions. In particular, this Directive stressed the need for permanent access of the animals to a sufficient quantity of material to enable their proper investigation and manipulation activities, without compromising health, and this represented a challenge for the production system, especially for weaning pigs. On the other hand, this obligation represented an opportunity to join the need to stimulate the explorative behaviour of the piglets and the need to sustain the feed intake of piglets during the first week post-weaning. Infact, weaning is associated with transient anorexia which causes an increase in the main signals of inflammation in the intestinal mucosa, alteration of the integrity of the mucosa, digestive disorders, increased risk of

CONTACT Prof. Paolo Bosi paolo.bosi@unibo.it Department of Agricultural and Food Sciences, University of Bologna, Viale G. Fanin 46, Bologna 40127, Italy

Supplemental data for this article can be accessed here.

disease, worsened growth performance, economic losses which above all, can result in the so-called post-weaning diarrhoea syndrome.

A modest ingestion of solid feed can stimulate saliva secretion. Saliva contains an array of growth factors synthesised and secreted by the salivary glands (Zelles et al. 1995). In mice, raising submandibular saliva secretion increased the height of the small intestinal villi and the nucleic-acid content of the mucosal cells (Li et al. 1983). Stimulating salivation, even by chewing crunchy feeds, could prevent the transient reduction of villus height (Boudry et al. 2004) and upregulation of the inflammatory markers (Pié et al. 2004) observed in the immediate postweaning period. Abruptly weaned pigs penned in a new environment express an explorative behaviour (Wood-Gush and Vestrgaard 1989) and may be attracted by unusual types of feed presentations with which they can interact. This is what can be supposed to happen when piglets are kept in an unconfined environment and can find roots or other vegetable products to interact with. It was hypothesised that feed blocks (smaller than those frequently used for ruminants) such as cookies, could satisfy, multiple functions: stimulate the instinct of play, and reduce competition and aggressive behaviour, stimulate early intake of solid feed (piglets like gnawing and rooting – Studnitz et al. 2007) and favour the post-weaning maintenance of a well-shaped gut mucosa. Feed blocks have already been tested in weaning pigs (Nannoni et al. 2016; Winfield et al. 2017) and in grouped sows (Muller et al. 2015). However, in these cases no specific attention was paid to the formulation of the feed blocks. In one case, the feed blocks were formulated to contain lucerne meal, molasses and minerals (Nannoni et al. 2016). Winfield et al. (2017), focussed on the importance of different shapes of the block. Thus, the first aim of the present study was to evaluate, by means of an acceptance test, the attractiveness of several formulations of supplemental feed blocks in pigs at weaning. The lack of research respect to pig performance was also evidenced regarding supplementation using specifically designed supplementary feed blocks provided to weaning pigs. The second aim was to test, under field conditions, the best formulations identified during the palatability test on the productive performance of the pigs and the characteristics of the carcase at slaughter from weaning until the end of the production cycle of the pigs. Finally, no data were found regarding the possible impact of feed blocks on the morphology of the small intestine, while the data found concerning the behaviour of the piglets in the presence of feed blocks were limited to one single feed block formulation. The third aim was then to provide experimental data in order to better verify the entity of the physical interaction of the piglets with the blocks, and the physical piglet to piglet interaction, in the presence of the blocks also depending on their composition. At the same time, one aim was to test whether the early consumption of different feed blocks could affect the characteristics of the intestinal mucosa in the post-weaning phase.

Material and methods

Preliminary preparation of the supplementary feed blocks

The production of blocks having a compact and rubbery consistency, which did not crumble and could stimulate mastication by the piglets, was organised working at two levels: (1) technical – design and assembly of a pilot production line, including mixing of the raw materials, compression of the mixture into moulds, followed by drying, and (2) technological – basic formulation of the blocks in order to obtain the right consistency.

For the pilot production, steel moulds were designed to be partially perforated to favour ventilation during the drying process, and to be opened at the end of the production process to release the blocks. The blocks were brick-shaped and of average size: 13 cm × 10 cm × 7 cm. This shape was considered to favour the simultaneous physical interaction of more than one piglet, because it presented a wider surface than the other shapes (Winfield et al. 2017). The blocks were dried in a stove using forced ventilation for 24 hours at 37 °C.

The formulation of the mixtures was based on the idea that, upon heating, molasses and calcium carbonate could provide the ideal product to provide consistency, as confirmed by their frequent use in formulations for ruminants (Salem and Nefzaoui 2003). Milk whey was added to provide nutrients and taste, but also to take advantage of its property of crystalising. One formula was planned to contain a typical appetiser (sodium glutamate, F2). In the initial formulas, very low doses of wheat by-products were added. Conversely, to reduce the crystal consistency of the blocks and increase the roughness of the latter formulas, more wheat by-products (wheat middlings and wheat bran) were added. On the contrary, calcium carbonate was progressively reduced and finally totally excluded. In all, at the end of the preliminary phase, eight formulations were obtained which differed in

Table 1. Trial 1. Composition of the tested feed blocks.

	Feed block							
Ingredients, %	F1	F2	F3	F4	F5	F6	F7	F8
Milk whey	44.00	44.00	48.00	45.00	23.00	15.00	18.00	20.00
Molasses, cane	15.00	15.00	17.00	17.00	25.00	15.00	20.00	20.00
Wheat middlings	5.50	5.50	3.00	4.00	–	60.00	55.00	–
Wheat bran	–	–	–	10.00	35.00	–	–	50.00
Coconut oil	–	–	–	–	–	9.00	6.00	9.00
Calcium carbonate	30.00	30.00	30.00	23.00	13.00	–	–	–
Sodium chloride	2.75	2.62	1.00	–	2.00	0.50	0.50	0.50
Monocalcium phosphate	2.75	2.63	1.00	1.00	2.00	0.50	0.50	0.50
Sodium glutamate	–	0.25	–	–	–	–	–	–
Chemical composition, % as fed[a]								
Dry matter	93.75	93.74	93.41	92.05	87.91	87.66	86.89	87.32
Ash	41.08	40.84	38.04	30.3	23.27	6.25	6.82	7.22
Crude protein	7.01	7.23	7.21	8.45	9.03	11.76	11.57	10.65
Crude fat	1.33	1.34	1.33	1.75	2.31	12.04	8.94	11.85
NDF	1.74	1.74	0.95	5.59	15.12	18.98	17.40	21.61
ADF	0.51	0.51	0.28	1.68	4.58	5.58	5.11	6.54
ADL	0.15	0.15	0.08	0.48	1.30	1.62	1.48	1.86

[a]Calculated.
NDF: neutral detergent fibre; ADF: acid detergent fibre; ADL: acid detergent lignin.

the inclusion of wheat middlings, wheat bran, milk whey, vegetable oil, and flavouring (Table 1).

Trial 1

The trial was conducted on a commercial pig breeding farm. The experimental design was organised into 8 block treatments × 3 pens = 24 pens, with an average of 30 to 40 piglets/pen. The experiment was completed in 8 consecutive runs, lasting four days each, with 3 treatments per run and 1 pen per treatment and per run. For the statistical analysis, the first five runs were grouped into period 1, and the last three runs were grouped into period 2. A total of 898 piglets, 24 ± 2 d of age, were used. The characteristics of the 8 blocks are given in Table 1.

The palatability tests were carried out as follows. In the suckling period, the pigs received a standard creep feed from 14 days of age; on the day of weaning, in each pen, in addition to the normal weaning feed administered, the blocks (≈0.8 kg each) were introduced directly on the cage floor in the ratio of 1 block every to 4 piglets. Before inserting the blocks in the pens, the weight of the blocks was recorded. On the fourth day post-weaning, the residues of the blocks were taken from the pens and weighed in order to calculate the block consumption.

Trial 2

The tests were carried out on a commercial pig breeding farm, using the three formulations (F6, F7, F8) of the blocks which provided the best ingestion data during the palatability tests (Trial 1). The experimental design was organised according to the following scheme: 4 runs x 4 block treatments for a total of 16 pens (35 ± 4.6 piglets/pen). Thus, in each run, all the 4 block treatments were tested with 1 pen per run and per formula. A total of 566 piglets (PIC hybrids) weaned at 24 ± 2 d of age was used. Each run lasted 4 days. The four block formula treatments corresponded to the three formulations F6, F7, and F8, and a control group receiving a wood placebo.

On the day of weaning (day 0), the piglets of each farrowing crate were identified by numbered ear tags; the live weight and gender were then recorded. Subsequent to these operations, the separations between four contiguous farrowing crates were removed, the four litters were mixed, and the sows were separated from the piglets and moved to the appropriate heat-fertilisation waiting rooms. The weight of the eight blocks for each of the three formulas were recorded and these blocks were then placed in the corresponding pen. Moreover, eight bricks of wood similar to the blocks regarding shape and weight (environmental enrichment) were added to the pens of the control group. The use of wood blocks has already been established as a tool to stimulate favourable interaction between pigs during early post-weaning (Barbari et al. 2017). Furthermore, all the experimental groups received the same weaning feed (in flour). The blocks were left in the pens during the first three days post-weaning. Every test day, additional blocks were added in case they had been finished, recording their weight. After four days, the residual blocks were weighed, and the food consumption of each pen was calculated (standard feed plus blocks); moreover, the body weight of all the subjects of the four experimental groups (post-block final weight) was recorded.

Twenty-five subjects were randomly selected from each of the four block treatments of the first run and were followed throughout the production cycle until slaughter (Italian heavy pig type). The subjects from each treatment were penned together in the same dedicated pen and received the same growing-finishing diet in the same amount until slaughtering. For these subjects, individual body weight was recorded at 51 days post-weaning and on the day of slaughtering. The pigs were slaughtered in a commercial abattoir, the weight of the carcases and the carcase lean percentage were recorded using a Fat-O-Meater (FOM, Carometec, Soeborg, Denmark). The carcase lean percentage was automatically computed on the slaughtering line from the measurements of back-fat thickness and loin depth (European Union 2014a, 2014b).

Trial 3

The trial was carried out in the experimental facilities of the Department of Agricultural and Food Sciences of the University of Bologna. For the trial, 72 piglets (PIC hybrids) obtained from a commercial farm at weaning and weaned at 24-±2 days of age were used. The piglets were ear-tagged for the identification of litter of origin. Upon arrival, gender and body weight were recorded for each animal. The piglets were then assigned to one of the four experimental groups (18 subjects/group), balanced for weight and litter of origin: a control group (Control) which received, as enrichment material, three bricks of wood of the same shape and size as the blocks which were the object of the test, and groups F6, F7 and F8 to which the respective block formulas already used in Trial 2 had been assigned. In addition to the blocks, each group was given ad a standard weaning diet (ad libitum) in the form of flour (Supplementary Table 1). The subjects were placed in groups of three subjects per cage; each cage constituted an experimental unit. The temperature of the room was kept at 30 °C for the duration of the test and, in addition, an infra-red lamp was placed above each cage. Both the wooden bricks and the feed blocks, were inserted into the cages from the start (day 0), three for each formula and their weight was recorded before placing them in the cages. Each test day, blocks were added in case they had been finished, recording their weight. After 4 d of treatment the piglets were sacrificed, the weight of the residual blocks was measured, and the feed consumption of each pen was calculated (standard feed plus blocks). Moreover, by means of a camera system positioned above each cage during the entire experimental period, video recordings were made of each group for 30 min repeated 5 times per day for each day of the test, in order to evaluate the following mutually exclusive behaviour: eating, drinking, biting the block, playing with the block, sleeping, fighting and inactivity, all expressed in percentage of total time spent.

After 4 days of treatment the pigs were sacrificed after sedation. The proximal (25%) and caudal (75%) jejunum segments from each pig, were sampled, opened longitudinally and prepared for intestinal morphometry analysis, as described by Trevisi et al. (2017). Briefly, each sample was opened, rinsed with sterile ice-cold phosphate buffer saline solution (pH 7.3) and a specimen of $\sim$1 cm^2 was collected, pinned tautly on balsa wood and then immersed in a 10% buffered formalin solution for 24 h. Formalin-fixed and paraffin-wax-embedded samples were deparaffinised in xylene and stained with haematoxylin and eosin. For each sample, the height of 10 villi and the depth of 10 crypts were measured. The mucosal-to-serosal amplification ratio (M) in the jejunum was calculated as indicated by Kisielinski et al. (2002). This ratio is based on mean values of the villous surface (calculated using the length and width of the villous), mucosal unit bottom (determined by villous and crypt width) and villous bottom (determined by villous width): M = (villous surface + unit bottom − villous bottom)/unit bottom, where villous surface = π (villous length $\times$ villous width), unit bottom = π (villous width/2 + crypt width/2)^2 and villous bottom = π (villous width/2)^2.

Statistical analysis

Trial 1: The data were elaborated using the analysis of variance by the PROC GLM of SAS (release 9.4, SAS Inst. Inc., Cary, NC, USA), considering the pen as the experimental unit, the type of supplemented block (1, … 7) as the fixed factor and the experimental period (1, 2) as a random factor. The contrast between different block supplementations was tested using the Tukey test.

Trial 2: The data were elaborated using the PROC GLM; the experimental factors were block treatment (fixed factor: 1,.4) and replication (random factor: 1,.4).

However, for growth performance and slaughtering data, the individual pig was the experimental unit and block treatment, and gender (female, barrow) and replication (not for slaughtering data) were the experimental factors.

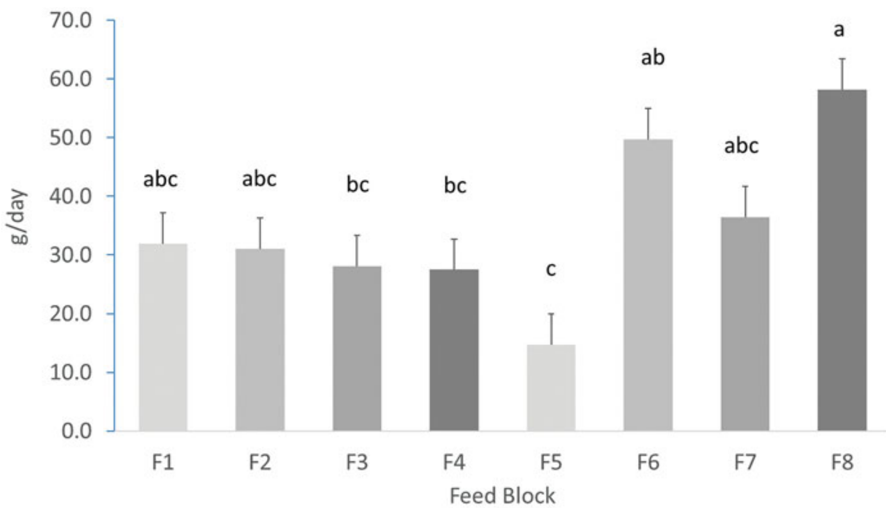

Figure 1. Trial 1. Average daily consumption of the different feed block formulations used in the acceptance tests (least square means ± standard error). Main three ingredients of the formulations, in decreasing order: F1, milk whey, calcium carbonate, molasses; F2, as F1, but with sodium glutamate; F3 and F4, milk whey, calcium carbonate, molasses; F5, wheat bran, molasses, milk whey; F6, wheat middlings, molasses and milk whey and F7, wheat middlings, molasses, milk whey; F8, wheat bran, molasses and milk whey.

Trial 3: Experimental factors were considered: block treatment (1,.4, fixed), and replication (1, … 4, random).

Effects were considered significant at $p < .05$ and as a trend at $p < .10 \geq .05$.

As regards the behavioural data analysis, the percentages of time spent on each occurrence were normalised by natural log transformation and analysed using PROC GLIMMIX of SAS, using the pen as the experimental unit. The model included the fixed effects of block treatment, the replication and the random effect of test day.

Ethical approval

All the procedures complied with EU Directive 2010/63/EU for animal experiments, were approved by the Ethical-Scientific Committee of the University of Bologna and were sent to the National Health Ministry (protocol number 47357-X/10) by this Institution.

Results and discussion

Trial 1

In Figure 1, the average daily consumption data of the blocks with different formulations are reported. The formulas F1, F2, F3, F4, F5, F6, F7 and F8 were tested on 107, 100, 106, 79, 76, 135,144 and 151 piglets, respectively. The results showed that the feed blocks with the F8 formula were consumed more than those with the F3, F4 and F5 formulas ($p < .05$, Figure 1). Furthermore, the consumption of the F6 blocks was higher than that of F5 ($p < .05$). Overall, F6, F7 and F8 had the highest acceptance. This result could be explained by two parameters which were modified in the formulation. The first and perhaps the most important, concerned the consistency of the blocks. In fact, in the formulas F1, F2, F3, F4, F5, the presence of elevated quantities of whey and calcium carbonate and the low percentage of fibre from wheat by products, gave the blocks a very compact consistency. Conversely, in formulas F6, F7 and F8, the presence of a high fibrous component, the reduction of whey and the absence of calcium carbonate, gave the blocks greater friability.

The second difference concerned the addition of coconut oil to the F6, F7 and F8 formulas in order to increase the energy ingested with the blocks. Coconut oil was chosen because the bibliography indicated a good palatability in weaning pigs (Jin et al. 1998). In addition, its medium-chain fatty acid composition made coconut oil well digestible even in young animals. The use of an appetiser (sodium glutamate, F2) did not improve the consumption of the blocks.

Trial 2

During the trial, the health status of the piglets was always good; there were no diarrhoea or respiratory problems. No subject died during the experimental period. Table 2 shows the growth performance of the piglets, raised under field conditions, in the first 4 days post-weaning. The live weight at weaning did not differ between the four experimental groups. Of the three test formulas, no differences were observed

Table 2. Trial 2. Growth performance in field condition, in the first four post-weaning days.

	Control	F6[a]	F7[a]	F8[a]	SEM	p[b]
Pigs, *n*	128	149	147	142		
Starting LW[c], kg	7.540a	7.200ab	7.000b	6.940b	0.145	.054
ADG[d], g	99b	126a	79b	98b	9.100	.003
Consumption, g/day						
Feed blocks	–	58	56	57	3.000	.866[e]
Feed compound	261a	230ab	218b	228ab	11.600	.323
Total	261	288	274	286	11.200	.261
Feed to gain	2.780	2.270	3.470	2.900	0.240	.455

[a]Treatments obtained adding the blocks of the respective composition reported in Table 1.
[b]Means with different letters in the same line differ for $p < .05$.
[c]At weaning. LW = live weight.
[d]4 days later, ADG = average daily gain.
[e]C group was not considered for statistical test for feed block consumption.

Table 3. Trial 3. Performance of the piglets in the experimental farm condition.

	Control	F6[a]	F7[a]	F8[a]	SEM	p[b]
Starting LW[c], kg	6.600	6.600	6.700	6.700	0.300	1.000
LW[c] at 4 days, kg	7.000	6.900	7.100	7.000	0.300	.962
ADG[d], g	86.300	66.300	114.400	88.200	14.800	.171
Consumption, g/day						
Feed compound	136	116	126	114	13.500	.650
Feed block	–	469	388	473	46.100	.457[e]
Total	136B	585A	514A	587A	34.700	<.001

[a]Treatments obtained adding the blocks of the respective composition reported in Table 1.
[b]Means with different letters in the same line differ for $p<.001$.
[c]At weaning, LW = live weight.
[d]4 days later, ADG = average daily gain.
[e]C group was not considered for statistical test for feed block consumption.

in the quantity of feed blocks ingested daily by the subjects of the different groups. For the F6 and F8 groups, the consumption observed was similar to that observed during the Trial 1, while, for the F7 group, there was a greater consumption of the blocks (55%) with respect to the values obtained for the same formula in Trial 1, confirming the good palatability of the three formulations chosen. Furthermore, the total daily consumption (feed + supplemental feed block) and the feed to gain ratio (F:G) showed no significant differences between the experimental groups; although, numerically, the F6 group showed a reduced, and thus better F:G than the other groups.

On the other hand, the data showed a lower daily consumption of feed in the F7 group as compared to the Control group ($p < .05$). The lower feed consumption affected the average daily gain (ADG) of the F7 group which was numerically lower than that of the F8 group while the ADG of the F6 group was greater than that found in the Control group and in the other treated groups ($p < .05$). The greatest ADG of the F6 group could be ascribed to the best F:G which, although not reaching statistical significance, was lower than that of the other experimental groups. In addition, the higher content of coconut oil as compared to the F7 formula and the use of wheat middlings instead of the wheat bran in formula F6 could explain the better ADG of the F6 group. Nevertheless, general variations with the three block formulas were not consistent; thus it could also be assumed that the modest variations in the ingredients used or in their quantities, were not expected to impact the piglet performance in the immediate post-weaning phase in a relevant way.

Furthermore, the treatment did not affect the growth performance of the piglets monitored until slaughtering. The pooled values were for the weight at weaning 6.55 kg (SEM = 0.22) at 51 days post weaning, 29.68 kg (SEM = 0.76) and at slaughtering, 160.5 kg (SEM = 3.0); the pooled total ADG was 594 g (SEM = 13). The moderate ADG is not unusual for the Italian heavy pig production due to the feed restriction applied to a batch of slaughtering pigs to comply with the requirements of minimum age at slaughtering (nine months) and the standard weight requested by the abattoir, as it is imposed by the Parma and the San Daniele PDO consortia for typical 'dry' cured hams (Bosi and Russo 2004). The carcase weight and the lean meat percentage were not changed by the treatment at weaning; pooled carcase weight and the percentage of lean meat obtained by FOM were 136.5 kg (SEM = 0.86) and 54.9% (SEM = 1.69), respectively. The carcase lean percentage was, on the average, high for the typical Italian heavy pig production (Bosi and Russo 2004) and this could have been related to the feed restriction and the pig genotype (PIC hybrid, based on the Hampshire breed), which would not be suitable for typical Italian heavy pig production.

Trial 3

During the trial, the health status of the piglets was good. Table 3 shows the production performance of the pigs supplemented with the feed blocks or the wooden bricks. At the end of the trial (day 4), there were no significant differences in weight gain and feed consumption in the pigs in the four experimental groups. Furthermore, there was no difference in the consumption of feed blocks between the F6, F7 and F8 groups. The absence of better growth performance, despite the difference in total ingestion of feeds in favour of the F6, F7 and F8 groups as compared to the Control group ($p < .001$), was probably due to the fact that the majority of the blocks were not ingested, but rather crumbled after an intense interaction of the piglets with them. This was confirmed by occasional

Table 4. Trial 3. Behaviour analysis of piglets in the experimental farm condition.

Behaviour paremeter[a]	Control	F6[b]	F7[b]	F8[b]	SEM	p[c]
Eating feed	2.5900	2.6100	2.5500	2.6600	0.1870	.9770
Drinking	0.7700	0.7800	0.9700	0.8900	0.1240	.5970
Biting the block	2.0500ab	1.8700ab	2.4500a	1.4900b	0.2380	.0160
Playing with the block	0.8900	0.7100	1.2100	0.8300	0.2250	.4200
Sleeping	4.0300b	4.3000a	3.9700b	4.1200ab	0.0580	<.0001
Fighting	2.0200	2.0320	2.0900	1.5700	0.2220	.3320
Not active	2.4300	2.3200	2.4900	2.3100	0.0915	.4420

[a]Values expressed as natural log.
[b]Treatments obtained adding the blocks of the respective composition reported in Table 1.
[c]Means with different letters in the same line differ for $p<.05$.

observations carried out during the experiment. In fact, the average daily consumption of the blocks increased from 57 g per pig in trial 2 to 443 g per pig in this trial. This difference was presumably due to the smaller total space available to the piglets in the experimental farm of the University of Bologna as compared to the commercial farm, which meant that the piglets were more in contact with the blocks, increasing their interaction with them and also the waste. Furthermore, in the experimental farm, the piglets encountered a new environment at the moment of enrichment with the blocks while, when the supplementation was given in the commercial farm, the weaning piglets remained in the same environment (farrowing crates). Different behaviours regarding the response to novel object or unfamiliar human had previously been observed when pigs were placed or not in an enriched environment (Backus et al. 2017).

Table 4 shows the behavioural parameters, detected during the first four days post-weaning by means of the cameras positioned above the pens. The pigs showed no behavioural differences regarding the parameters ‘eat food’, ‘drink’, ‘play with the block’, ‘fight’ and ‘inactive’ while significant differences were observed for the parameters ‘bite block’ (p=.02) and ‘sleep’ ($p < .0001$). The subjects of the F7 group bit more blocks than the F8 group for a greater number of minutes while no differences were found with the Control and F6 groups. The differences between the feed blocks could be ascribed to a different time to adaptation to the different formulations. In general, it has been seen that brick-shaped blocks disappear more in suckling piglets than cube- shaped blocks (Winfield et al. 2017) and that the oro-nasal interactions are more intense the first day of provision of the blocks (Winfield et al. 2017). Regarding the ‘sleep’ parameter, the subjects of the F6 groups rested for a percentage of time significantly higher than those of the control and of the F7 groups, while the value of the F8 group did not differ significantly from that of the other three groups. The longer time dedicated to sleep by the F6 group was not related to the different

Table 5. Trial 3. Histological morphometry of the jejunum mucosa of the piglets (5 d post-weaning).

	Control	F6[a]	F7[a]	F8[a]	SEM	p[b]
Jejunum, at 25% of the length						
Villus height, μm	255	267	254	245	9	.427
Villus width , μm	96	95	94	95	3	.948
Crypth width, μm	35	34	35	36	0.8	.861
Crypth depth, μm	113	114	119	114	4	.364
M index[c]	6.2b	6.7a	6.3ab	6.0b	0.1	.080
Jejunum, at 75% of the length						
Villus height, μm	252	244	245	241	9	.884
Villus width , μm	86	86	88	81	3	.267
Crypth width, μm	36	35	36	34	0.9	.720
Crypth depth, μm	113	105	111	109	5	.321
M index[c]	6.3	6.3	6.1	6.4	0.2	.682

[a]Treatments obtained adding the blocks of the respective composition reported in Table 1.
[b]Means with different letters in the same line differ significantly ($p<.05$).
[c]Mucosal surface area, calculated from the presented measures with the method of Kisielinski et al. (2002).

fibre quantity of the blocks because the NDF of the F6 blocks was intermediate between F7 and F8 and also to total feed consumption, which did not differ among the groups. Regarding aggressive behaviour, the work of Nowicki and Klocek (2012) has shown that the introduction of an enrichment into the weaning pen at weaning significantly reduced the struggles as compared to groups without environmental enrichment. In our trial, the control group received the supply of wooden bricks. Thus, in the present study, the absence of statistically significant differences concerning the ‘fighting’ behaviour between the groups supplemented by blocks and the control group (wood bricks) indicated that eating enrichment did not have an additional influence on aggressive behaviour. This agreed with the results obtained in weaning pigs when comparing edible blocks with other types of non-eating enrichment (Chains or wood briquettes, Nannoni et al. 2016), when the environmental conditions were optimal.

Table 5 shows the data regarding the intestinal morphometry of the piglets. No significant differences were found for the morphometric parameters of the jejunal 25% and 75% segments, except that the absorbent surface of the proximal jejunal portion was found to be greater for the F6 group than in the control and the F8 groups ($p < .05$) while there was no significant difference with the F7 group. This result could have been related to the behavioural data which showed that the F6 group slept more than the Control group, a sign of lower psychological stress caused by weaning and, therefore less production of inflammatory signals which can modify the intestinal morphology (Pluske et al. 1997). Furthermore, even if the block ingestion data were not significant due to the impossibility of determining the waste with respect to the quota ingested for the F6, F7 and F8 groups, the data relative to the larger absorbent surface of the F8 group may have indirectly indicated the greater ingestion of blocks in this group. Moreover, the early effect of feed ingestion is reflected, in the short term, on the mucosa of the proximal portion of the small intestine which draws direct nourishment from the feed, and suffers more from post-weaning anorexia (Lallès et al. 2004), unlike the distal part which derives the major part of its nutrients from the bloodstream.

Conclusions

Composition may influence block consumption as the inclusion of some ingredients increased the disappearance of the block, suggesting that some of them (wheat middlings, molasses, coconut oil and milk whey) are more important than others. The disappearance of the block material did not mean that the feed block was actually ingested. This would explain the large variation in feed block consumption among the trials, the occasional positive effect on growth in the first 4 days post-weaning and, also, the small effect on the characteristics of the intestinal epithelium. The observations made using a camera on piglets on the experimental farm showed that the F6 formula positively influenced some of their behavioural parameters of them.

In conclusion, the formula based on milk whey, molasses, wheat middlings, coconut oil and a small quantity of salts might support the welfare of weaning pigs with potential benefit on growth in this phase, suggesting the thesis that the use of an "edible" environmental enrichment reduced the negative effects of weaning.

However, additional research is necessary in order to improve the formulation of the supplementary feed blocks so as to reduce waste without limiting their palatability.

Disclosure statement

No potential conflict of interest was reported by the authors.

Funding

The project was supported by MIPAAF-OIGA project "PIGBLOCK" (Ministry of Agricultural, Food and Forestry Policies). The authors wish to thank Azienda Agricola Alberini and the responsible Luca Alberini for guesting the in field trials.

ORCID

Maurizio Mazzoni http://orcid.org/0000-0002-7384-5990
Leonardo Nanni Costa http://orcid.org/0000-0002-5260-7248
Paolo Bosi http://orcid.org/0000-0002-0755-8002

References

Backus BL, Sutherland MA, Brooks TA. 2017. Relationship between environmental enrichment and the response to novelty in laboratory-housed pigs. J Am Assoc Lab Anim Sci. 56:735–741.

Barbari M, Conti L, Rossi G, Simonini S. 2017. Supply of wood as environmental enrichment material to post-weaning piglets. Agron Res. 15:313–321.

Bosi P, Russo V. 2004. The production of the heavy pig for high quality processed products. Ital J Anim Sci. 3: 309–321.

Boudry G, Péron V, Le H, Luron I, Lallès JP, Sève B. 2004. Weaning induces both transient and long-lasting modifications of absorptive, secretory, and barrier properties of piglet intestine. J Nutr. 134:2256–2262.

European Union. 2014a. Commission Implementing Decision of 24 January 2014 authorising methods for grading pig carcases in Italy [notified under document C (2014) 279]. Off J. L 23.

European Union 2014b. Corrigendum to Commission Implementing Decision 2014/38/EU of 24 January 2014 authorising methods for grading pig carcases in Italy (Off. J. L 23, 28.1.2014). Off J. L 54.

Jin CF, Kim JH, Han IK, Jung HJ, Kwon CH. 1998. Effects of various fat sources and lecithin on the growth performance and nutrient utilization in pigs weaned at 21 days of age. Asian-Aust J Anim Sci. 11:176–184.

Kisielinski K, Willis S, Prescher A, Klosterhalfen B, Schumpelick V. 2002. A simple new method to calculate small intestine absorptive surface in the rat. Clin Exp Med. 2:131–135.

Lallès JP, Boudry G, Favier C, Le Floc'h N, Luron I, Montagne L, Oswald IP, Pié S, Piel C, Sève B. 2004. Gut function and dysfunction in young pigs: physiology. Anim Res. 53: 301–316.

Li AK, Schattenkerk ME, Huffman RG, Ross JS, Malt RA. 1983. Hypersecretion of submandibular saliva in male mice: trophic response in small intestine. Gastroenterology. 84: 949–955.

Muller TL, Callaghan MJ, Hewitt RJE, van Barneveld RJ. 2015. Use of a nutritional lick block and higher feeding levels to reduce aggression and provide enrichment for sows in groups. Anim Prod Sci. 55:1498.

Nannoni E, Sardi L, Vitali M, Trevisi E, Ferrari A, Barone F, Bacci ML, Barbieri S, Martelli G. 2016. Effects of different enrichment devices on some welfare indicators of post-weaned undocked piglets. Appl Anim Behav Sci. 184: 25–34.

Nowicki J, Klocek C. 2012. The effect of aromatized environmental enrichment in pen on social relations and behavioural profile of newly mixed weaners. Ann Anim Sci. 12: 403–412.

Pié S, Lallès JP, Blazy F, Laffitte J, Sève B, Oswald IP, 2004. Weaning is associated with an upregulation of expression of inflammatory cytokines in the intestine of piglets. J Nutr. 134:641–647.

Pluske JR, Hampson DJ, Williams IH. 1997. Factors influencing the structure and function of the small intestine in the weaned pig: a review. Liv Prod Sci. 51:215–236.

Salem HB, Nefzaoui A. 2003. Feed blocks as alternative supplements for sheep and goats. Small Rum Res. 49:275–288.

Studnitz M, Jensen MB, Pedersen LJ. 2007. Why do pigs root and in what will they root?: a review on the exploratory behaviour of pigs in relation to environmental enrichment. Appl Anim Behav Sci. 107:183–197.

Trevisi P, Latorre R, Priori D, Luise D, Archetti I, Mazzoni M, D'Inca R, Bosi P. 2017. Effect of feed supplementation with live yeast on the intestinal transcriptome profile of weaning pigs orally challenged with *Escherichia coli* F4. Animal. 11:33–44.

Winfield JA, Macnamara GF, Macnamara BL, Hall EJ, Ralph CR, O'Shea CJ, Cronin GM. 2017. Environmental enrichment for sucker and weaner pigs: the effect of enrichment block shape on the behavioural interaction by pigs with the blocks. Animals. 7:91.

Wood-Gush DGM, Vestergaard K. 1989. Exploratory behaviour and the welfare of intensively kept animals. J Agric Ethics. 2:161–169.

Zelles T, Purushotham KR, Macauley SP, Oxford GE, Humphreys-Beher MG. 1995. Concise review: saliva and growth factors: the fountain of youth resides in us all. J Dent Res. 74:1826–1832.