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IMPACT OF NUTRIENT SELF-SUPPLY THROUGH CHOICE FEEDING ON GROWTH PERFORMANCE, FEEDING BEHAVIOUR AND PROTEIN EFFICIENCY IN GROWING FINISHING PIGS

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Invited paper

Abstract: This pilot study aimed to compare the growth performance, nutrient deposition efficiency and feeding behaviour of growing pigs fed on a standard two-phase feeding or a choice feeding regime. The experiment was performed with 12 Swiss Large White barrows between 23.2 and 108.0 kg body weight (**BW**). Six pigs assigned to the standard (**ST**) treatment were offered *ad libitum* access to a grower (**ST-G**) and finisher (**ST-F**) diet from 23.2 to 63.4 kg and from 63.4 to 108.0 kg, respectively. The ST-G and ST-F diets were formulated based on the Swiss feeding recommendation for swine for an average BW of 40 and 80 kg, respectively. The other six pigs assigned to the choice (**CH**) treatment had constant *ad libitum* access to both a grower (**CH-G**) and a finisher (**CH-F**) diet formulated for a reference BW of 20 and 100 kg. All diets were isocaloric and differed only in the crude protein and essential amino acid content according to the reference BW used for feed formulation. To determine the empty body nutrient deposition rate, pigs were scanned using dual-energy x-ray absorptiometry at 25.8 and 103.8 kg BW. Individual feed intake and feeding behaviour were monitored with automatic feeders. Changes in BW were determined weekly. Compared to ST pigs, CH pigs ingested more feed daily ($P = 0.05$) and grew faster ($P = 0.02$). Total crude protein consumption tended to be greater ($P = 0.08$) in CH than ST pigs due to a numerically greater intake of the protein-rich CH-G diet during the finisher period. A greater crude protein intake in CH than ST pigs was accompanied by a greater ($P = 0.04$) daily protein deposition rate but a similar protein efficiency. Regarding feeding behaviour, CH pigs went more often to the feeder, spent less time at the feeder, ate less feed per visit and had shorter intervals between two meals than ST pigs ($P < 0.01$ for each) in the grower but not in the finisher period. Considering the feeding behaviour traits, the CH pigs with a greater protein deposition potential preferred the protein-rich CH-G over the CH-F diet. In conclusion, these results show that, like the wild pigs, the domesticated modern pigs maintained the ability for an adequate nutrient self-supply according to their nutritional requirements.

Key words: dual-energy x-ray absorptiometry, empty body composition, nutrient deposition, pig

Introduction

Regarding the increasingly limited feed resources, there is a clear incentive to further improve the nutrient or, more specifically, the crude protein (**CP**), essential amino acids (**EAA**) and phosphorus efficiency in pig production. To achieve this objective, nutrient supply in a specific feeding scheme should cover as closely as possible the nutrient requirements of growing pigs at a given body weight (**BW**). The widely used phase-feeding strategies have precisely this goal in mind *(Han et al., 2000)*. The core element of developing phase-feeding strategies leverages the principle that pigs' ability to ingest feed surpasses its capacity to deposit protein *(NRC, 2012)*, and the latter is closely linked to the dietary supply of EAA *(van Milgen and Dourmad, 2015; Ruiz-Ascacibar et al., 2019)*. In most swine diets, lysine is the first limiting EAA, and the requirements for the other EAAs are, expressed in percentage of lysine, relatively constant *(van Milgen and Dourmad, 2015)*. As the protein and lysine requirements per kg of diet decrease from birth to slaughter *(NRC, 2012)*, the key factor of phase-feeding strategies lies in fixing the dietary CP and lysine requirements for optimal growth and lean tissue deposition. Subdividing the growth period into small BW ranges to increase the number of phase-feeding periods limits the time span when CP and lysine supplies are below or above requirements. Interestingly, *Menegat et al. (2020)* showed that increasing the number of dietary phases from 2 to 3 or 4 did not significantly improve the overall growth performance and carcass characteristics of pigs. One explanation could be that variation in BW, growth rate, and feed intake within a pen prevents, on an individual basis, the accurate delivery of an optimal CP and lysine level for growth and, ultimately, protein deposition *(Pomar and Remus, 2019)*.

To overcome or limit these variabilities in group-housed pigs, there are two possibilities: either the feed composition is adjusted daily according to their BW and thus their nutrient requirements or pigs could be offered a choice of diets differing in their CP and lysine contents, thereby allowing them to compose their diet. Hence, pigs could adjust their nutrient supply according to the requirements of their actual growth phase. This ability for adequate nutrient self-supply, which is a common trait in the wild pig *(Henry, 1985)*, seems to have also been preserved in the domestic pig despite the strong genetic selection for feed efficiency and lean tissue deposition. The older publications of *Kyriazakis et al. (1991)* and *Ettle and*

Roth (2009) and also the more recent one of *Pichler et al. (2020)* revealed that the nutrient self-supply characteristic of modern pig lines has been preserved. Specifically, the aforementioned experiments examined the impact of choice versus conventional phase-feeding strategies on growth performance, feeding behaviour, and carcass or meat quality. This pilot study aimed to extend this knowledge and determine how choice versus phase feeding impacts nutrient and energy deposition rates alongside protein and energy deposition efficiency. To address these questions, the feed intake and the body composition of choice- and phase-fed pigs were monitored using automatic feeders and dual-energy x-ray absorptiometry (DXA).

Materials and Methods

The Swiss cantonal Committee for Animal Care and Use approved all procedures involving animals (Animal welfare permit number 32382).

Animals, diets and housing conditions

For this pilot study, 12 Swiss Large White barrows originating from five litters of the Agroscope sow herd were used. From weaning to the start of the experiment, the pigs were reared in the same pen and offered *ad libitum* access to the same standard starter diet (weaning to 25 kg BW). At an average BW of 23.2 ± 1.39 kg (mean ± standard deviation), the pigs were randomly allotted to the standard (**ST**) and the choice (**CH**) treatment. Pigs in the ST group were offered *ad libitum* access to a grower (**ST-G**) and finisher (**ST-F**) diet from 23.2 to 63.4 (± 3.01) kg and from 63.4 to 108.0 (± 3.01) kg, respectively. The ST-G and ST-F diets were formulated according to the Swiss feeding recommendations for pigs *(Agroscope, 2017)* for an average BW of 40 and 80 kg, respectively. During the whole experimental period, pigs in the CH group had constant *ad libitum* access to both a grower (**CH-G**) and a finisher (**CH-F**) diet formulated for a reference BW of 20 and 100 kg according to the Swiss feeding recommendations for pigs *(Agroscope, 2017).*

To monitor individual feed intake, each pen was equipped with two automatic feeders and an individual pig recognition system (Schauer Maschinenfabrik GmbH & Co. KG, Prambachkirchen, Austria), as previously described *(Bee et al., 2008)*. The pigs were raised in two pens of equal size (17.35 m^2) connected by an alleyway and therefore accessible to the 12 pigs. Water was offered *ad libitum* through nipple drinker. Pigs were weighed weekly. When they reached a BW ≥ 98 kg, they were DXA-scanned two days later and slaughtered four days after the DXA measurements.

Feeding behaviour

Feeding behaviour data were collected by single-space automatic feeders (MLP, Agrotronic Schauer, Austria). The feeders are 0.6 m wide and 2.2 m long. The feeding system recorded all daily visits at the feeder, feed intake (**FI**) per visit and time spent at the feeder. Data evaluations considered only feeder visits that coincided with the intake of feed (but not sham visits). Between-visit intervals shorter than 5 min (which was used as the meal criterion) were regarded as within-meal feeder visits (**WMFV**), and these visits were grouped into meals *(De Haer and Merks, 1992)*. As proposed by *Carcò et al. (2018)*, the day, rather than the single meal, was considered the temporal basis for describing the feeding behaviour of the pigs in the experimental period. The total FI, total feeder visits and total feeding time per day per pig were therefore calculated. Those data were then used to calculate the average total time spent feeding per day (**TTF** expressed in min), the average frequency of feeder visits (**FFV**), the average time per visit (**TV** = TTF/FFV, expressed in min), the average daily feed intake (**ADFI**), the mean feed intake per visit (**FIV** = ADFI/FFV, expressed in g), the mean rate of feed intake (**RFI** = ADFI/TTF expressed in g/min) and the interval between two meals (**FI** expressed in min).

Dual-energy x-ray absorptiometry (DXA) measurements

The DXA scans of the live animals were performed at an average BW of 25.8 (± 2.1) and 103.8 (± 3.4) kg BW using a GE Lunar DXA (i-DXA, GE Healthcare Switzerland, Glattbrugg, Switzerland) with a narrow-angle fan beam (Collimator Model 42129), applying the protocol described by *Kasper et al. (2020)*. Briefly, the day prior to the DXA scan, the pigs were fasted for at least 16 h and then sedated using isoflurane (Attane, Piramal Critical Care, Inc., Bethlehem, PA, USA). The scans were conducted using the 'total body thick' mode with the enCORE software (version 16). Subsequently, the scan images were pre-processed to remove artefacts and to position the regions of interest. The variables 'total mass', 'BMC' (bone mineral content), 'lean' and 'fat' of the live empty body were obtained from the software. The water, ash, protein, fat and energy contents of the empty body of the animals were calculated using the DXA values and the regression equations published by *Kasper et al. (2020)*. Pigs were weighed after the DXA exam.

Chemical analysis of the feed

The diet analyses were conducted in duplicate except when the results differed by more than 5%, then up to four replicates were obtained. The dry matter and ash content were determined by gravimetry after drying at 105°C for 3 h and after 3 h at 550°C, respectively. In the same samples, the CP (CP = total nitrogen ×

6.25) content was analysed with a LECO FP-2000 analyser (Leco, Mönchengladbach, Germany) (International Organization for Standardization (ISO), 2008). The amino acid composition of the diets was determined after 24 h of acid hydrolysis (48 h for leucine, isoleucine and valine). Methionine and cystine were hydrolysed after peroxidation with formic acid. The amino acid profile was determined by HPLC coupled with a fluorescence detector (Alliance 2695; Waters, Milford, MA, USA), as described in the manual (Waters AccQ Tag Chemistry Package 052874 TP, rev. 1). To determine the crude fat content, samples were hydrolysed in 10% HCl (v/v) for 1 h. The hydrolysate was dried and subsequently extracted with petrol ether using the Büchi SpeedExtractor E 916 (Büchi Labortechnik AG, Flawil, Switzerland). The dry residual of fat was determined by gravimetry. The fat content in the freeze-dried samples was determined using the Avanti Soxtec System (2050 Extraction Unit; Foss Tecator, Hillerød, Denmark).

Calculations and statistical analysis

Using the calculated nutrient and energy content of the empty body at the start and the end of the experiment, the daily nutrient and gross energy deposition rates were calculated as the amount of deposited nutrients and energy from the start to the end of the experiment divided by the days on feed. The CP and energy deposition efficiency were calculated as the total CP and gross energy deposition divided by the amount of ingested CP and digestible energy.

The data were analysed with the MIXED procedure of SAS (SAS Inst. Inc., Cary, NC) with the individual pig as the experimental unit. The model used for the data analyses included the feeding regime as the fixed effect and the litter of origin as the random effect. Least square means and the pooled standard error of the mean were calculated and reported in tables. Treatment differences were considered to be significant at $P \leq 0.05$ and tendency at $P > 0.05$ and $P \leq 0.10$.

Results

Diets

The CH-G diet contained 12 g/kg more CP content than the ST-G diet, and the CH-F diet contained 13 g/kg less CP content than the ST-G diet (Table 1). The differences in the CP contents can be explained by the different reference BWs that were used to formulate the two grower and two finisher diets *(Agroscope, 2017)*. In accordance with the CP levels, the digestible EAA content was, on average, 14% greater [range: +6% (histidine) to +21% (lysine, methionine, threonine)] in the CH-G than the ST-G diet and 17% lower [range −7% (lysine, cystine, threonine) to −17% (tyrosine, isoleucine)] in the CH-F than the ST-F diet. The digestible methionine content was twice greater in the CH-F than in the ST-F diet. The crude fibre and crude fat content were similar between the CH-G and ST-G diets and between the CH-F and ST-F diets.

Table 1. Feed ingredients (%), nutrient composition and energy content of the experimental diets[1]

Item[2]	CH-G	CH-F	ST-G	ST-F
Barley	30.00	30.00	30.00	30.00
Oat	3.50	3.50	3.50	3.50
Corn	0.60	10.49	3.62	7.53
Wheat	40.00	40.00	40.00	40.00
Blended fat	1.10	0.22	0.71	0.43
Potato protein	5.84	1.80	3.85	2.83
Soy bean meal extract	3.39		3.90	2.04
Rapeseed press cake	3.50	3.50	3.50	3.50
Dried sugar bett pulp	5.00	5.00	5.00	5.00
Apple pommace	0.53	0.46	0.40	0.29
L-Lysin-HCl	0.441	0.255	0.323	0.181
DL-Methionin	0.039	0.246	0.012	
L-Threonin	0.088	0.036	0.044	
L-Tryptophan	0.008			
Monocalcium phosphate	1.007	0.111	0.476	0.209
Limestone	1.199	0.845	1.003	0.896
NaCl	0.423	0.198	0.311	0.256
Pellan	0.30	0.30	0.30	0.30
Celite 545	2.00	2.00	2.00	2.00
Vitamin-mineral mix	0.40	0.40	0.40	0.40
Sweetener Sucram	0.02	0.02	0.02	0.02
Flavour Pigortek	0.02	0.02	0.02	0.02
Natuphos 5000 G	0.01	0.01	0.01	0.01
Mikrogrit	0.60	0.60	0.60	0.60
Nutrient content, g or MJ/kg				
Crude ash	75	58	67	61

[1] The CH-G and CH-F diets were formulated based on the Swiss feeding recommendations for swine (Agroscope, 2017) and optimised for a BW of 20 and 100 kg, respectively. The ST-G and ST-F diets were formulated based on the same feeding recommendations but optimised for a BW of 40 and 80 kg, respectively.

[2] The digestible and net energy coefficients from each feed ingredient were obtained from the Swiss (Agroscope, 2017) and French (Noblet et al., 2003) databases, respectively. Considering the relative amount of each feed ingredient in the diet, digestible and net energy content were calculated.

Crude protein	176	135	164	148
Crude fat	37	30	34	32
Crude fibre	40	40	40	40
Sugar	30	29	31	30
Starch	484	554	506×	534
Digestible energy	13.70	13.70	13.70	13.70
Net energy	10.10	10.26	10.15	10.21
Digestible amino acids[3]				
Lysine	10.03	5.82	8.30	6.25
Methionine	2.92	4.22	2.41	2.07
Cystine	2.72	2.29	2.62	2.47
Threonine	5.76	3.47	4.77	3.74
Tryptophan	1.64	1.10	1.44	1.28
Phenylalanine	7.11	4.85	6.42	5.66
Tyrosine	5.06	3.19	4.44	3.84
Valine	6.79	4.64	6.11	5.4
Leucine	10.79	7.62	9.81	8.77
Isoleucine	5.52	3.57	4.93	4.28
Histidine	3.08	2.31	2.91	2.63

Growth performance

Pigs were weighed weekly and slaughtered six days after weighing ≥ 98 kg according to protocol. Despite this defined time table, pigs in the CH group were heavier ($P < 0.01$) the day of slaughter than the ST pigs (Tabela 2). The difference in slaughter weight can be explained by the greater ADG and greater ADFI in the finisher ($P = 0.03$) and overall period ($P \leq 0.05$) in the CH group. Pigs in the CH group tended ($P = 0.08$) to ingest more CP over the whole grower-finisher period than the ST pigs. The CP efficiency, expressed as kg daily ingested CP/kg ADG, was greater ($P < 0.01$) in the grower but not in the finisher and overall period.

[3] The content of digestible essential amino acids was based on nutritional characteristics of ingredients estimated from their chemical analyses with Allix.

Table 2. Growth performance of pigs either offered constant free access to the CH-G and CH-F diets (Choice) or offered ad libitum access to the ST-G from 20 to 60 kg BW and to the ST-F diet from 60 kg BW to slaughter (Standard) [4]

	Treatment			
Item[5]	Choice	Standard	SEM	P-value[6]
BW, kg at				
Start	23.20	23.15	0.633	0.95
Start of finisher period	65.53	63.38	1.015	0.17
Slaughter	110.89	107.39	1.534	< 0.01
ADG, kg/d				
Grower	0.908	0.862	0.0272	0.23
Finisher	1.217	1.108	0.0512	0.03
Overall	1.040	0.971	0.0354	0.02
ADFI, kg/d				
Grower	1.886	1.783	0.0382	0.07
Finisher	3.271	3.042	0.0615	0.03
Overall	2.492	2.357	0.0455	0.05
Total feed intake, kg				
Grower	89.538	84.678	3.4011	0.08
Finisher	121.234	120.088	3.7638	0.83
Overall	210.573	204.566	4.0769	0.14
Total CP intake, kg				
Grower	13.923	13.858	0.3414	0.85
Finisher	19.175	17.753	0.6132	0.14
Overall	32.871	31.384	0.5270	0.08
Gain-to-feed, kg/kg				
Grower	0.479	0.481	0.0118	0.79
Finisher	0.373	0.365	0.0134	0.47
Overall	0.417	0.413	0.0111	0.58
CP intake/ADG, kg/kg				
Grower	0.326	0.340	0.0060	< 0.01
Finisher	0.422	0.404	0.0126	0.26

[4] The CH-G and CH-F diets were formulated based on the Swiss feeding recommendations for swine (Agroscope, 2017) and optimised for a body weight (BW) of 20 and 100 kg, respectively. The ST-G and ST-F diets were formulated based on the same feeding recommendations but optimised for a BW of 40 and 80 kg, respectively.

[5] ADG = average daily gain; ADFI = average daily feed intake; CP = crude protein

[6] P-values of the main factor experimental treatment.

Overall	0.375	0.373	0.0080	0.78
Days on feed, d				
Grower	47.5	47.5	2.02	1.00
Finisher	37.2	39.5	1.38	0.26
Overall	84.6	86.9	2.20	0.33
Age at slaughter, d	145.8	149.5	2.65	0.22

Feeding behaviour

The CH pigs went more often to the feeder (FFV), spent less time at the feeder (TV), ate less feed per visit (FIV) and had shorter intervals between two meals (FI) than ST pigs ($P < 0.01$ for each; (Tabela 2.). Overall, the CH pigs spent more time per day in total ($P = 0.04$) at the feeder (TTF) because the 2.8 min shorter feeder visits were compensated for by up to 11.4 greater number of feeder visits. The CH pigs appeared to be nibbler, as they had a larger ($P < 0.01$) number of feeder visits (WMFV) within a meal than the ST pigs. The feeding behaviour of the two control groups did not differ significantly during the finisher period, even though similar tendencies were noted. Interestingly, the CH pigs changed their feeding behaviour more drastically from the grower to the finisher period. Compared to ST pigs, pigs in the CH group reduced the frequency of feeder visits (dFFV, $P < 0.01$), stayed for a longer time at the feeder (dTV, $P = 0.03$) and increased the between meal interval (dFI, $P < 0.01$).

As per design, the CH pigs had constant access to the CH-G and CH-F diets that differed mainly in the CP and digestible EAA level. The current data suggest that neither in the grower nor the finisher period did the CH pigs prefer one diet over the other, as none of the feeding behaviour traits differed (Tabela 4).

Table 3. Feeding behaviour in the grower and finisher period f pigs offered constant free access to the CH-G and CH-F diets (Choice) or offered ad libitum access to the ST-G from 20 to 60 kg BW and to the ST-F diet from 60 kg BW to slaughter (Standard)[7]

	Treatment			
Item[8]	Choice	Standard	SEM	P-value[9]
Grower period				
TTF, min	*78.5*	63.7	4.41	*0.04*
FFV, n	*20.8*	9.4	1.73	*< 0.01*
WMFV, n	*24.1*	11.1	2.04	*< 0.01*
TV, min	4.0	*6.8*	0.33	*< 0.01*
FIV, g	99	*193*	12.2	*< 0.01*
RFI, g/min	25	28	1.6	0.12
FI, min	33.5	*78.8*	48.2	*< 0.01*
Finisher period				
TTF, min	76.1	65.6	5.61	0.21
FFV, n	15.1	9.8	2.07	0.11
WMFV, n	17.0	12.3	2.52	0.24
TV, min	5.6	6.8	0.65	0.15
FIV, g	254	329	37.9	0.19
RFI, g/min	44	48	2.8	0.35
FI, min	*45.6*	63.7	5.65	0.08
Difference between the grower and finisher period[10]				
dTTF, min	2.9	−1.4	4.08	0.42
dFFV, n	*5.9*	−0.2	*0.81*	*< 0.01*
dWMFV, n	*7.3*	−1.0	1.17	*< 0.01*
dTV, min	*−1.7*	0	0.46	*0.03*

[7] The CH-G and CH-F diets were formulated based on the Swiss feeding recommendations for swine (Agroscope, 2017) and optimised for a body weight (BW) of 20 and 100 kg, respectively. The ST-G and ST-F diets were formulated based on the same feeding recommendations but optimised for a BW of 40 and 80 kg, respectively.

[8] TTF = total time feeding per day; FFV = frequency of feeder visits; WMFV = within meal feeder visits; TV = time per visit; FIV = feed intake per visit; RFI = rate of feed intake; FI = interval between two meals.

[9] P-values of the main factor experimental treatment.

[10] dTTF = difference between TTF in the grower and finisher period; dFFV = difference between FFV in the grower and finisher period; dWMFV = difference between WMFV in the grower and finisher period; dTV = difference between TV in the grower and finisher period; dFIV = difference between FIV in the grower and finisher period; dRFI = difference between RFI in the grower and finisher period; dFI = difference between FI in the grower and finisher period.

dFIV, g	−157	−136	27.4	0.61
dRFI, g/min	−19	−19	2.0	0.99
dFI, min	−11.5	15.8	4.88	*< 0.01*

Table 4. Feeding behaviour in the grower (20 – 60 kg BW) and finisher period (60 – to slaughter) of pigs in the choice-feeding group with constant access to the CH-G and CH-F diets[11]

	Diets			
Item[12]	CH-G	CH-F	SEM	P-value[13]
Grower period				
DFI, g/d	949	934	121.9	0.93
TTF, min	36.5	42.0	5.7	0.51
FFV, n	10.0	11.6	1.63	0.43
WMFV, n	11.3	13.5	1.92	0.35
TV, min	3.9	3.7	0.42	0.53
FIV, g	101	81	12.9	0.12
RFI, g/min	15.6	22.7	1.60	0.12
FI, min	33.5	31.8	4.45	0.75
Finisher period				
DFI, g/d	1878	1394	291.9	0.27
TTF, min	41.3	34.9	6.85	0.52
FFV, n	8.2	7.8	1.64	0.75
WMFV, n	9.2	8.9	1.91	0.84
TV, min	4.6	4.8	0.81	0.40
FIV, g	259	196	43.35	0.22
RFI, g/min	44.8	41.4	2.80	0.07
FI, min	49.7	39.6	8.57	0.40

[11] The CH-G and CH-F diets were formulated based on the Swiss feeding recommendations for swine (Agroscope, 2017) and optimised for a body weight of 20 and 100 kg, respectively.

[12] TTF = total time feeding per day; FFV = frequency of feeder visits; WMFV = within meal feeder visits; TV = time per visit; FIV = feed intake per visit; RFI = rate of feed intake; FI = interval between two meals.

[13] P-values of the main factor experimental treatment

Nutrient and energy content of the empty body

At the start of the experiment, the water, nutrient and gross energy content of the empty body of CH and ST pigs did not differ (Table 5). Four days before slaughter, the ash content was greater (P = 0.02) and the water and protein contents tended (P = 0.09) to be greater in the CH than the ST pigs, whereas fat and energy contents of the empty body did not differ. The differences in ash, water and protein contents can be explained by the greater (P = 0.04) empty body weight of the CH pigs because when ash, water, protein and fat contents were expressed as a percentage of the empty body weight, no treatment differences were observed.

Table 5. Nutrient and energy content of the empty body determined by dual-energy x-ray absorptiometry (DXA) at the start of the experiment and prior to slaughter of pigs offered constant free access to the CH-G and CH-F diets (Choice) or offered ad libitum access to the ST-G from 20 to 60 kg BW and to the ST-F diet from 60 – to slaughter (Standard) [14]

	Treatment			
Item[15]	Choice	Standard	SEM	P-value[16]
Empty body nutrient composition				
At the start of the experiment				
Empty body, g	25865	25316	1015.9	0.55
Water, g	17867	17510	689.8	0.57
Ash, g	693	687	19.8	0.82
Protein, g	4087	3982	202.3	0.57
Fat, g	2754	2679	119.3	0.52
Gross energy, MJ	214	208	9.5	0.49
At the end of the experiment				
Empty body, g	105533	101652	1294.2	0.04
Water, g	63478	60506	1283.4	0.09
%	60.09	59.49	0.740	0.48
Ash, g	3011	2834	66.7	0.02
%	2.86	2.79	0.007	0.19
Protein, g	17463	16591	376.4	0.09
%	16.53	16.31	2.222	0.40

[14] The CH-G and CH-F diets were formulated based on the Swiss feeding recommendations for swine (Agroscope, 2017) and optimised for a body weight (BW) of 20 and 100 kg, respectively. The ST-G and ST-F diets were formulated based on the same feeding recommendations but optimised for a BW of 40 and 80 kg, respectively.

[15] The water, ash, protein, fat and energy contents of the live animals were calculated using the DXA values and the regressions published by Kasper et al. (2020). The %-values were calculated as the ratio between the water, ash, protein, and fat content and the empty body weight.

[16] P-values of the main factor experimental treatment.

Fat, g	20212	20399	977.4	0.85
%	19.19	20.06	0.992	0.43
Gross energy, MJ	1246	1230	32.4	0.60

Water, nutrient and energy deposition rate and protein and energy deposition efficiency

The greater (P = 0.02) daily empty body weight gain was due to the greater (P ≤ 0.04) protein, ash and water deposition rate in the CH pigs than in the ST pigs (Table 6). In contrast, fat and energy deposition rates were similar among treatments. Protein and energy deposition efficiencies were similar in the CH and ST pigs.

Table 6. Daily empty body, nutrient and energy deposition rate and protein and energy deposition efficiency of pigs offered constant free access to the CH-G and CH-F diets (Choice) or offered ad libitum access to the ST-G from 20 to 60 kg BW and to the ST-F diet from 60 – to slaughter (Standard) [17]

	Treatment			
Item	Choice	Standard	SEM	P-value[18]
Daily weight gain[19]				
Empty body, g/d	1051	963	30.9	0.02
Water, g/d	602	541	24.6	0.04
Ash, g/d	31	27	1.0	< 0.01
Protein, g/d	177	159	7.2	0.04
Fat, g/d	229	225	12.2	0.74
Gross energy, MJ	13.6	13.0	0.45	0.13
Nutrient deposition efficiency[20], %				
Protein	44.55	43.73	1.603	0.69
Digestible energy	39.29	39.73	0.798	0.52

[17] The CH-G and CH-F diets were formulated based on the Swiss feeding recommendations for swine (Agroscope, 2017) and optimised for a body weight (BW) of 20 and 100 kg, respectively. The ST-G and ST-F diets were formulated based on the same feeding recommendations but optimised for a BW of 40 and 80 kg, respectively.

[18] P-values of the main factor experimental treatment.

[19] Daily weight gain = gain of weight determined between the two dual-energy x-ray absorptiometry (DXA) measurements/number of days between the two DXA measurements.

[20] Protein deposition efficiency = empty body protein content at slaughter – empty body protein content at 20 kg body weight/total protein intake between the two DXA measurements; Digestible energy deposition efficiency = gross energy content of the empty body at slaughter – gross energy content of the empty body at 20 kg body weight/total digestible energy intake between the two DXA measurements

Discussion

It is expected that at the beginning of the growing period, the amount of CP and lysine per kg of diet required by the growing pig is high and then gradually declines with increasing BW and age *(NRC, 2012; Agroscope, 2017)*. If the feed intake was driven by the CP and lysine requirements, pigs given the choice between the high (CH-G) and the low CP diet (CH-F) would select a greater amount of the protein-rich CH-G diet at the beginning. With increasing BW and age, pigs would then gradually increase the CH-F diet intake at the expense of the CH-G diet. This seems not to be the case in this experiment. Out of the six pigs, four pigs (animal ID: 7583, 7549, 7586, 7594) seemed to prefer the CH-G over the CH-F diet (Figure 1), as the cumulative differences between the CH-G and CH-F diets favoured the CH-G diet. In contrast, two pigs (animal ID: 7518 and 7613) consumed slightly more of the CH-F diet. The overall greater preference for the protein-rich diet ultimately resulted in a greater overall CP intake of pigs in the CH group compared to the ST group (Figure 2). One could hypothesise that this preference was due to differences in the appetence between the CH-G and the CH-F diets. There are three reasons that suggest that this might have not been the case. First, during feed formulation, strict care was taken to ensure that, if avoidable, the same amounts of the same feed ingredients were used in both diets. Second, a flavour and high intensity sweetener was included in the diet to limit possible differences in palatability between the diets *(Sterk et al., 2008)*. Third, the lack of significant difference in feeding behaviour parameters did not suggest that the CH-G diet was preferred to the CH-F diet. These findings partly contradict the results of earlier studies *(Kyriazakis et al., 1990; Bradford and Gous, 1991b, a)* that showed that the ability for an adequate nutrient self-supply is preserved in domesticated pigs. However, *Bradford and Gous (1991b)* found that when the CP levels of the two diets from which the pig can choose are close together, the physiological effect of each of the diets on the pig is similar. Ultimately, this makes it difficult for the pig to differentiate the diets.

The aforementioned greater CP intake of CH compared to ST pigs was converted into a greater daily protein deposition rate. However, substantial differences were observed between the six CH pigs in the deposition rate of protein (varying from 152 g/d to 208 g/d) and of fat (varying from 216 g/d to 270 g/d) (Figure 3). The variance between the six ST pigs was much smaller, at least for the protein deposition rate. The differences in protein and fat deposition rates in CH pigs appeared to be linked to the preferential selection of the CH-G or CH-F diet. For instance, the pigs that primarily selected the protein-rich CH-G diet (Figure 1; animal ID: 7518 and 7586) displayed the greatest protein deposition rate. In contrast, the pig with the lowest protein deposition rate selected primarily the low-protein CH-F diet. In a study comparing an improved (Large White × Landrace) to an unimproved (Meishan) line, *Kyriazakis et al. (1993)* established that based on their greater protein deposition potential, pigs of the improved line preferred the diet with the greater CP level than the pigs of the unimproved line. Similarly, *Meers et al. (2010)* found in pigs of similar genetic backgrounds that their nutrient intake was influenced by their body composition or composition of BW gain. In their study, they observed that female pigs with a greater amount of lean mass preferentially selected the diet with a greater CP content, while those with a greater fat mass preferentially selected the low CP diet. However, the diet selection effect was less evident in castrated male pigs. They explained this sex difference with the fact that body composition was more variable in female pigs than castrates. In addition, they hypothesised that the difference in the dietary CP level of the two diets was not sufficiently different for barrows to sense the physiological effect of each of the two diets. When considering the present findings, the ST pigs deposited a similar amount of protein, whereas when given the choice to nutrient self-supply, there seems to be a different potential in protein deposition within pigs of the same genetic background. As reviewed by *Roura and Fu (2017)* dietary EAAs such as lysine, methionine, threonine and tryptophan are important drivers of feed selection and intake in pigs. However, the exact mechanism(s) by which the body composition and the composition of BW gain drive the feeding behaviour remain partially not understood.

Feeding behaviour patterns of the ST pigs in the grower period were very similar to the feeding patterns observed in a recent study from our research group *(Bee et al., 2021)*. In contrast, in the finisher period, the ST pigs went more often to the feeder, stayed for a shorter time at the feeder and ingested less feed, and the between-meal interval was shorter compared to the pigs in the standard group of the aforementioned study. One can only speculate about the reasons for these differences. Environmental factors or genetics can be excluded as both studies were conducted in the same experimental facilities, and the pigs were of the same genetic background. However, there were large differences in stocking density, with six pigs assigned to one single-space automatic feeder in this study, whereas in the study of *Bee et al. (2021)*, there were 12 pigs per feeder. In addition, differences existed in the nutrient density of the diets, which might have contributed also to these different eating patterns. Unclear is why these differences between studies were limited to the finisher period.

When comparing the feeding behaviour traits of CH and ST pigs, they differed only in the grower period but not in the finisher period. One could speculate that the shorter but more frequent visits of the two feeders in the grower period occurred because the CH pigs needed to get accustomed to accessing two feeders, and perhaps, this spurred on the spirit of exploration. The exploratory activity faded in the finisher period as they markedly visited less the feeder and stayed for a longer period at the feeder and eating more feed per visit. In contrast, *Pichler et al. (2020)* did not find marked differences in feeding behaviour traits between the grower and finisher period of pigs given the choice to eat from two different diets. When comparing the present study with that of *Pichler et al. (2020),* it was noticeable that the pigs went on average less to the feeder and spent less time eating daily in both the grower and finisher periods in the present study.

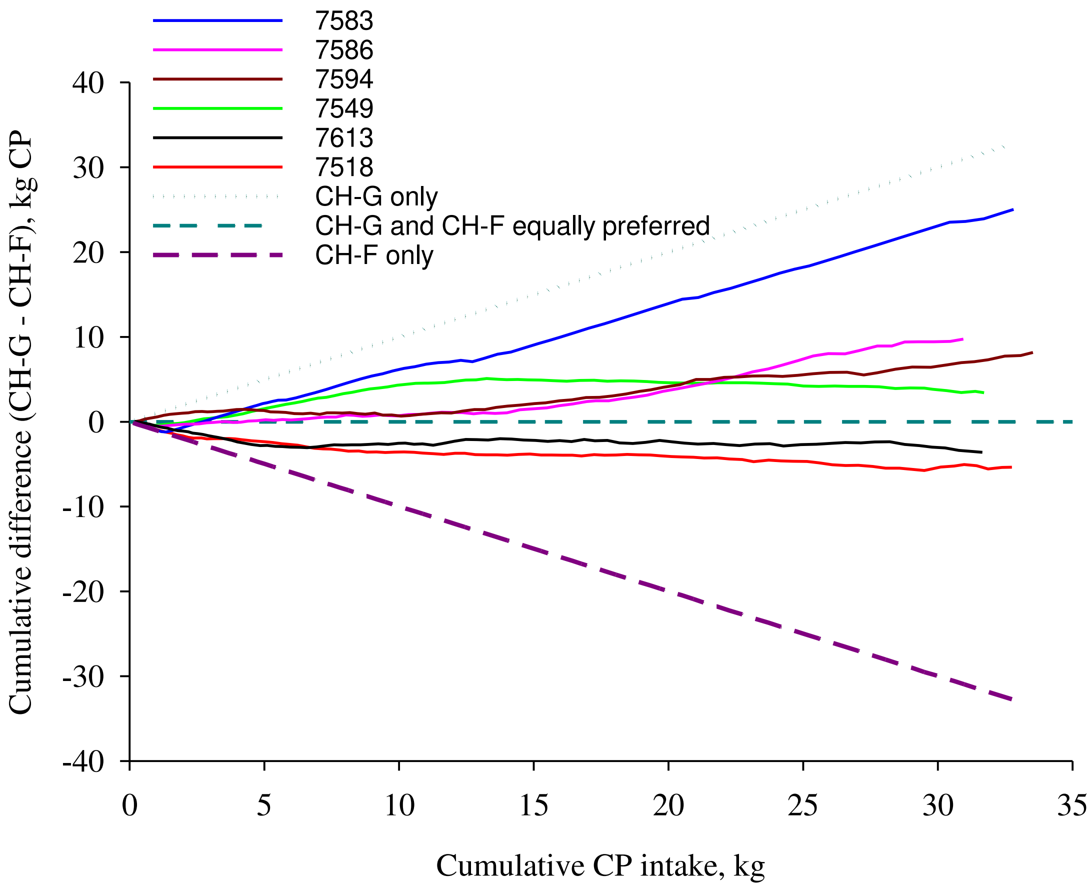


Figure 1. The paths of diet selection of the six pigs given a choice between the CH-G and CH-F diet. Each line refers to an individual pig. The dotted lines refer to a pig choosing only diet CH-G or CH-F diet. The CH-G and CH-F diets were formulated based on the Swiss feeding recommendations for swine (Agroscope, 2017) and optimised for a BW of 20 and 100 kg, respectively.

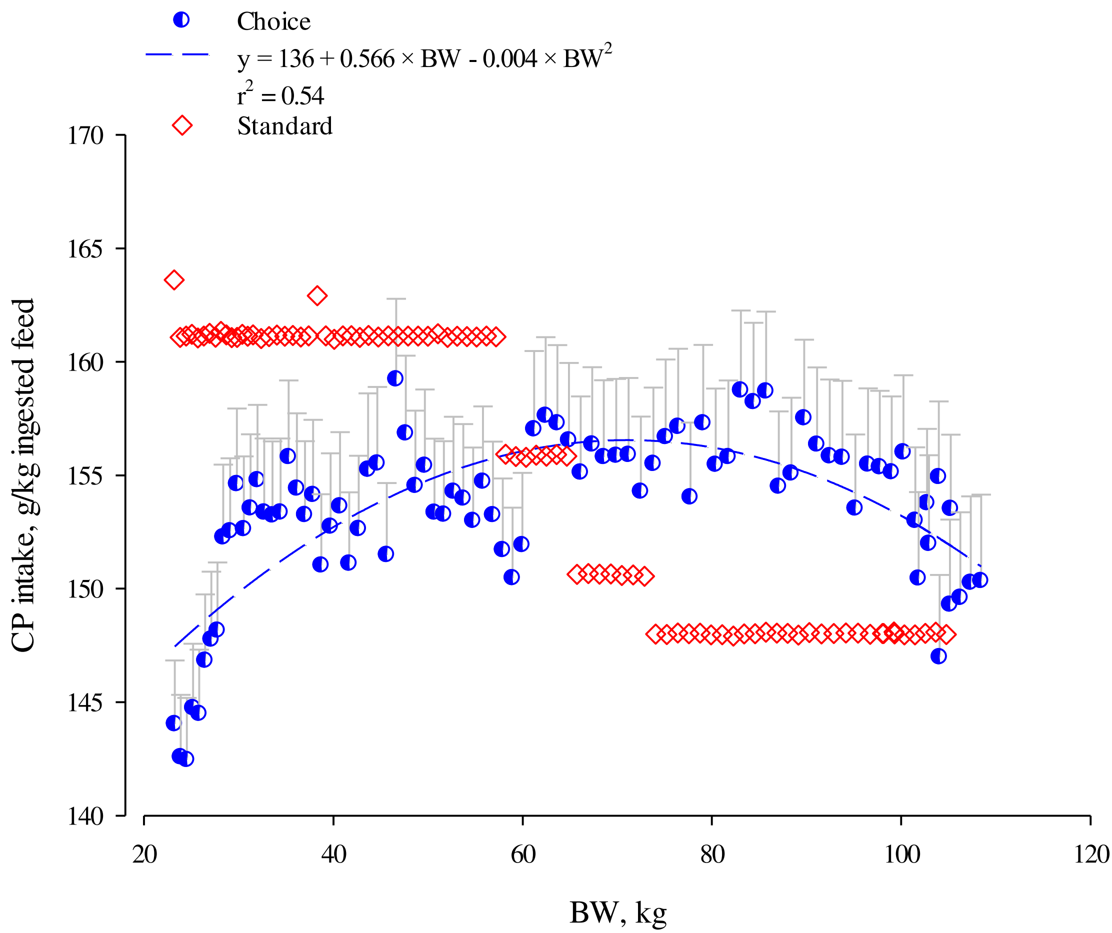
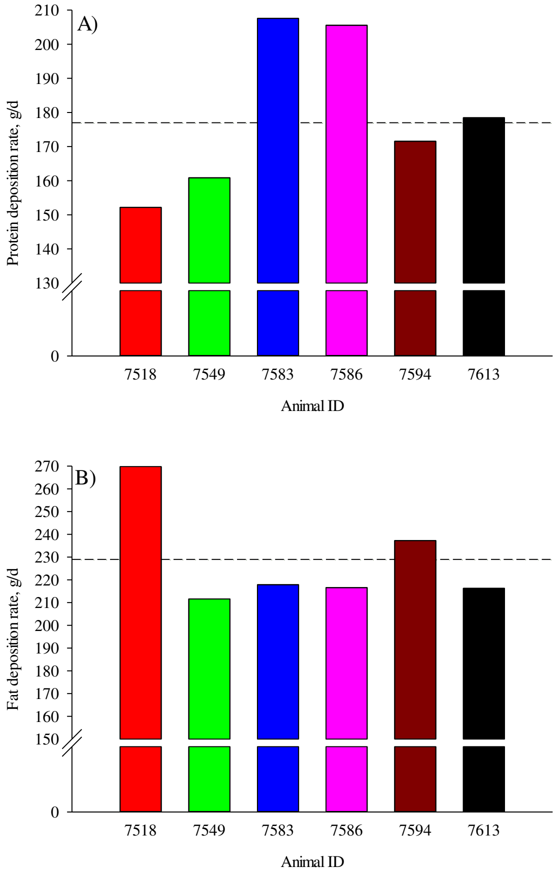


Figure 2. The average daily crude protein intake (CP, expressed as g CP/kg ingested food) over the grower and finisher period of pigs given a choice between the CH-G and CH-F diets (Choice, blue circle) and pigs having access to the ST-G and ST-F diets (Standard, red diamond). The CH-G and CH-F diets were formulated based on the Swiss feeding recommendations for swine (Agroscope, 2017) and optimised for a body weight (BW) of 20 and 100 kg, respectively. The ST-G and ST-F diets were formulated based on the same feeding recommendations but optimised for a BW of 40 and 80 kg, respectively. The regression line fits the data points of the CP intake of the Choice group.


A)
Protein deposition rate, g/d
210
200
190
180
170
160
150
140
130
0
7518
7549
7583
7586
7594
7613
Animal ID
B)
Fat deposition rate, g/d
270
260
250
240
230
220
210
200
190
180
170
160
150
0
7518
7549
7583
7586
7594
7613
Animal ID

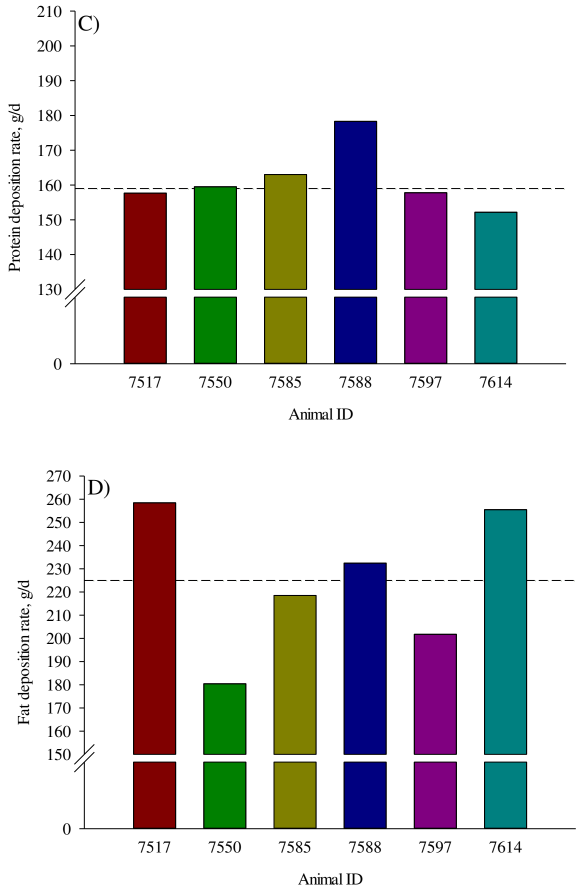


Figure 3. Individual protein and fat deposition rate (expressed as g deposition/d) of the six pigs given a choice between the CH-G and CH-F diets (panels A and B, respectively) and the six pigs fed the standard grower-finisher diet (panels C and D, respectively). The CH-G and CH-F diets were formulated based on the Swiss feeding recommendations for swine (Agroscope, 2017) and optimised for a body weight (BW) of 20 and 100 kg, respectively. The standard grower and finisher diets were formulated based on the same feeding recommendations but optimised for a BW of 40 and 80 kg, respectively. The dotted lines designate the average value for each group, as presented in Table 6.

Conclusion

The current results agree with previous studies *(Kyriazakis et al., 1990; Bradford and Gous, 1991b),* revealing that modern pig breeds can compose their diet according to their requirements and convert it efficiently into greater performance. This implies that, regarding protein supply, it is not necessary to offer a diet formulated for a given BW range to group penned pigs like it is proposed in the feeding recommendations *(NRC, 2012; Agroscope, 2017)* and implemented in phase-feeding regimes. Nevertheless, a better understanding of the mechanism(s) regulating the interaction between the growth of periphery tissues and the central feeding centres is needed, which then might help in designing the required choice of feeds.

Uticaj samostojeće ishrane kroz izbor na performanse rasta, ponašanje tokom hranjenja i efikasnosti proteina u uzgoju tovnih svinja

Giuseppe Bee, Catherine Ollagnier

Rezime

Ova pilot studija je imala za cilj da uporedi performanse rasta, efikasnost deponovanja hranljivih materija i ponašanje pri hranjenju svinja hranjenih standardnim dvofaznim hranjenjem ili režimom hranjenja po izboru. Eksperiment je izveden sa 12 švajcarskih svinja rase jorkšir između 23,2 i 108,0 kg telesne težine (BW). Šest svinja dodeljenih standardnom (ST) tretmanu su imale ad libitum pristup grover (ST-G) i finišer (ST-F) obroku od 23,2 do 63,4 kg i od 63,4 do 108,0 kg, respektivno. Obroci ST-G i ST-F formulisani su na osnovu švajcarskih preporuke za ishranu svinja prosečne težine od 40, odnosno 80 kg. Ostalih šest svinja dodeljenih tretmanu (CH) imalo je stalan *ad libitum* pristup i grover (CH-G) i finišer obroku (CH-F) formulisanom za referentnu težinu od 20 i 100 kg. Svi obroci su bili izokalorični i razlikovali su se samo po sadržaju sirovog proteina i esencijalnih aminokiselina prema referentnoj BW koja se koristi za formulaciju hrane. Da bi se odredila brzina deponovanja hranljivih materija, svinje su skenirane korišćenjem rendgenske apsorpciometrije sa dvostrukom energijom pri 25,8 i 103,8 kg BW. Pojedinačni unos hrane i ponašanje pri hranjenju praćeni su automatskim hranilicama. Promene u BW utvrđivane su nedeljno. U poređenju sa ST svinjama, CH svinje su unosile više hrane dnevno (P = 0,05) i brže rasle (P = 0,02). Ukupna potrošnja sirovih proteina imala je tendenciju da bude veća (P = 0,08) u CH u odnosu na svinje ST zbog brojčano većeg unosa CH-G ishrane bogate proteinima tokom završnog perioda. Veći unos sirovih proteina u CH nego kod ST svinja praćen je većom (P = 0,04) dnevnom stopom deponovanja proteina, ali sličnom efikasnošću proteina. Što se tiče ponašanja pri hranjenju, CH svinje su češće odlazile do hranilice, provodile manje vremena kod hranilice, jele manje hrane po poseti i imale kraće intervale između dva obroka u odnosu na ST svinje (P <0,01 za svakoga) u period rasta, ali ne i u finalnom periodu. S obzirom na osobine ponašanja pri hranjenju, CH svinje sa većim potencijalom deponovanja proteina preferirale su CH-G obrok bogat proteinima u odnosu na CH-F obrok. Zaključno, ovi rezultati pokazuju da su, poput divljih svinja, pripitomljene savremene svinje zadržale sposobnost za odgovarajuće snabdevanje hranljivim materijama u skladu sa svojim nutritivnim potrebama

Ključne reči: rendgenska apsorpciometrija sa dvostrukom energijom, sastav praznog tela, deponovanje nutrijenata, svinja

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