Diversification of Organic Pig Feed with Vegetable and Fruit Scraps

Maxime Garcia, Florian Leiber, Mirjam Holinger
Forschungsinstitut für biologischen Landbau FiBL, 5070 Frick, Schweiz

Information: Mirjam Holinger, email: mirjam.holinger@fibl.org
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Fattening pigs marked for individual identification during behavioral observations. Photo Credit: Mirjam Holinger, FiBL

Abstract

The cultivation of animal feed significantly affects global land use and resources, creating competition for arable land between livestock feed and human food production. At the same time, by-products from food production are often used in suboptimal processes like biogas production. Concentrate feed for pigs also does not fully meet their health and behavioral needs. To explore more sustainable and species-appropriate feeding practices, in this on-farm study eight groups of organic pigs were fed either with concentrate feed only, or supplementing part of the concentrate feed with vegetable and fruit scraps. This approach aimed to diversify their diet and reduce concentrate feed intake while offering an upcycling alternative for human food by-products. Results indicated that vegetable and fruit scraps contributed little to the pigs' energy and nutrient supply. This was highlighted by lower daily weight gains and lower weights in animals exposed to the vegetable-enriched diet. Nevertheless, this diet positively influenced animal welfare and health, leading to increased playfulness and reduced diarrhea, respectively. Therefore, incorporating vegetable and fruit scraps into pigs' diet is a promising, yet to be optimized, approach towards increasing sustainability in the pork industry while enhancing animal welfare.

Key words: domestic pig, feed no food, food systems, sustainability, upcycling.

Introduction

Food production systems in our modern societies are confronted with a paradox. On the one hand, a significant part of the food we produce ends up as food waste, with approximately one-third of all food produced for human consumption being discarded or ending up as by-products (Bond *et al.*, 2013). On the other hand, we need to increase arable land availability for the cultivation of food for human consumption, as these lands are currently increasingly allocated to the production of feed for livestock (Schader *et al.*, 2015; van Zanten *et al.*, 2016). Although we cannot fully dissociate animal feed from the use of arable lands, mitigating this paradox represents one of the key challenges towards more sustainable agricultural practices.

The feeding of domestic pigs represents, for several reasons, an ideal study case to innovate solutions towards optimized feeding strategies that are both species-appropriate and more sustainable. First, pig nutrition in standard (both organic and conventional) production systems relies essentially on feed produced from the use of arable lands. Second, concentrate feed is not always fully adapted to the pigs' physiological and behavioral needs, with a chemical composition sometimes detrimental to their health and performance (Shurson *et al.*, 2021) and because concentrate feed is made of fine-sized particles eaten at a much faster pace than natural foraging behavior, which in turn might turn into digestive troubles (Kiarie & Mills, 2019) and high prevalence of gastric ulcers (Nielsen & Ingvartsen, 2000). Lastly, pigs are omnivorous animals and have a propensity for a diverse diet, extending beyond the mere concentrate feed typically provided.

A historical review of animal husbandry practices reveals that older husbandry conditions relied on food scraps (Mizelle, 2012), reducing waste and enhancing the nutritional variety available to pigs. This was a pioneer example of the concept of "upcycling", which involves utilizing by-products from food processing as animal feed. However, applying this concept in today's pork industry faces several challenges. Regulatory restrictions on feeding animal-derived waste, logistical issues related to collection and transport of by-products, and the need for specific feed formulations adjusted to these by-products, create barriers to widespread adoption (Shurson, 2020). At present, a significant portion of food by-products is diverted for biogas production (Papargyropoulou *et al.*, 2014; Keerthana Devi *et al.*, 2022), often representing a missed opportunity for sustainable animal nutrition. Vegetable and fruit wastes are of particular interest here as they do not undergo the same policy limitations as animal-derived waste, do not require any transformation process and involve moderate logistics for storage and transport.

As a result, an organic producers' organization partnered with FiBL and Bio Suisse to explore more effective uses of vegetable and fruit scraps. The objective was to target socio-economic issues related to food waste while promoting species-appropriate feeding practices for organic pigs. More specifically, we postulated that the use of food scraps could help reduce the amount of concentrate feed used during the fattening process and improve pigs' welfare by diversifying and lengthening foraging activity. We also investigated whether this change in the pigs' diet could affect body fat composition and provide health benefits. Although involving organic pigs and therefore requiring vegetables and fruits originating from organic producers, the approach investigated in this study also applies to non-organic pig husbandry.

Material and Methods

The project was carried out at the Schwand organic farm, located in Münsingen, BE, Switzerland. The experiments (approved by the veterinary authorities under the approval number BE86/2022) took place during two consecutive fattening rounds, respectively from August to October 2022, and from January to April 2023. Pigs were housed according to organic regulations with a solid outdoor run (Bio Suisse, 2025). Feed was provided in a trough in the outdoor run. For each fattening round, 24 pigs were kept in four groups receiving one of two possible feeding treatments: two groups of six animals received a diet only comprising standard concentrate feed (Demeter 7-2330 from Biomühle Lehmann – Table 1; 'CO' diet thereafter), and two groups of six animals received a diet made of the same standard concentrate feed, however part of which was replaced with vegetable

Table 1 | Nutritional information (in g/Kg feed) and composition of the concentrate feed used during all fattening rounds.

VES (MJ)	Crude Protein	Crude fat	Crude ash	Crude fiber	Ca	Phosphorus	Na	Lysine	Methionine
13.6	180	27	52	42	7.2	4.5	2.0	9.0	2.4

Composition: barley, wheat, peas, soybeans, sugar beet pulp, potato protein, vitamin mix, calcium carbonate, monocalcium phosphate, sodium chloride and fruit scraps ('VG' diet thereafter). Thus, in total, the trial comprised 48 animals split into eight groups (four per round) and two treatment conditions (CO and VG). Food scraps were obtained weekly from Terraviva, an organic producers' organization marketing vegetables and fruits. The food scraps were unprocessed and stored at 4 °C before delivery.

When possible, vegetables and fruits were sampled once a week to visually assess their raw (i.e. wet) composition (percentage of each vegetable/fruit type). Corresponding estimated nutritional values were calculated proportionally to each vegetable/fruit's respective nutritional values (retrieved from https://naehrwertdaten.ch; see Table 2 for a list of vegetables and fruits provided during the study and their respective nutritional value). In addition, dry matter and ash content were determined using a prepASH Series 340 thermogravimetric analyzer (following drying protocols of 105°C for 720 minutes and 600 °C for 300 minutes, respectively).

Throughout the fattening periods, pigs were fed twice a day with pig feed, to which vegetables and fruits were added for VG groups. In both fattening rounds, VG pigs only started receiving vegetable and fruit scraps during the trial, meaning that they had only been fed with concentrate during their weaning phase. Feed was provided restrictively, and the quantities were adjusted by the farm supervisors during the fattening period, based on whether there was still feed and/or vegetables and fruits in the troughs after feeding events (therefore the quantity of feed consumed – concentrate and vegetables/fruits alike – corresponded to the quantity of feed provided). Vegetables and fruits were aimed at replacing progressively part of the pig feed. At the start of the fattening rounds, the pig feed was therefore complemented with vegetables and fruits, and then part of the feed was gradually replaced with vegetables and fruits, resulting in a moderate restriction of concentrate feed in groups that received vegetables and fruits (see Table 3 for a detail of the weekly quantities of feed / vegetables and fruits per pig in the different groups and fattening rounds). The restriction of concentrate feed for the VG groups was overall stronger in the second fattening round than in the first, aiming to increase vegetable and fruit intake, because pigs initially favored concentrate

Table 2 | Nutritional values of food items provided during the experiments. Values are given per Kg of edible portion; data source for vegetables: https://naehrwertdaten.ch; for concentrate: Biomühle Lehmann

Food Item	Energy	Fat	Dietary Fiber	Protein	Sodium (Na)	Calcium (Ca)	Phosphorus (P)
	kJ	g	g	g	g	g	g
Concentrate (Demeter 7-2330)	13600	27	42 (Crude fiber)	180	2	7.2	4.5
Carrot	1760	4	27	6	0.28	0.29	0.23
Potato	3200	1	21	20	0.01	0.051	0.51
Cauliflower	1090	7	20	18	0.06	0.23	0.4
Chinese Cabbage	600	2	11	14	0.065	0.32	0.4
Red Cabbage	1210	2	26	11	0.058	0.34	0.28
White Cabbage	1520	6	35	14	0.048	0.52	0.29
Kale	1290	3	26	28	0.072	0.5	0.48
Cucumber	570	1	8	7	0.009	0.15	0.18
Swiss Chard	970	2	10	21	1.7	0.8	0.43
Iceberg Lettuce	650	2	18	10	0.036	0.34	0.22
Lettuce	600	2	16	13	0.023	0.31	0.17
Sugar Lettuce	670	2	16	12	0.1	0.35	0.3
Leaf Lettuce	790	3	17	16	0.17	0.49	0.34
Chicory	790	1	30	14	0.075	0.31	0.41
Apple	2220	3	14	3	0.015	0.053	0.14
Pear	2270	3	29	5	0.018	0.065	0.15
Green Pepper	850	3	20	8	0.06	0.06	0.15
Red Pepper	1330	4	20	9	0.03	0.09	0.2
Pepper (average)	1090	3.5	20	8.5	0.045	0.075	0.175
Asparagus	1150	2	17	22	0.016	0.16	0.49
Leek	1240	3	28	16	0.051	0.25	0.28

Table 3 | Food quantities provided throughout the experiments (VG: diet comprising concentrate and vegetable/fruit scraps; CO: diet comprising concentrate only).

Round	Week*	Vegetables (Kg/pig)	Concentrate (Kg/pig)	Concentrate (Kg/pig)
		VG	VG	CO
1	8/3/2022	4.67	9.33	9.33
1	8/9/2022	7.00	13.00	13.00
1	8/17/2022	7.00	11.67	11.67
1	8/23/2022	7.00	15.08	14.75
1	8/30/2022	7.00	16.33	16.67
1	9/6/2022	7.00	17.54	18.92
1	9/14/2022	7.00	19.29	20.46
1	9/20/2022	7.67	20.37	20.71
1	9/27/2022	9.33	23.00	23.17
1	10/4/2022	9.33	19.33	21.33
1	10/11/2022	10.00	16.83	20.50
1	10/19/2022	11.17	19.50	20.17
1	10/25/2022**	5.67	10.92	10.42
2	1/17/2023	4.67	7.21	8.92
2	1/24/2023	4.67	6.75	10.33
2	1/31/2023	4.83	8.83	13.50
2	2/7/2023	5.83	12.33	17.00
2	2/14/2023	8.17	13.08	17.33
2	2/21/2023	9.33	16.21	19.46
2	2/28/2023	9.67	16.67	19.67
2	3/7/2023	10.50	17.42	20.83
2	3/14/2023	10.50	17.00	20.67
2	3/21/2023	10.50	17.75	21.25
2	3/28/2023	10.17	19.83	19.94
2	4/4/2023	9.08	17.33	20.98
2	4/11/2023	9.58	19.38	20.25
2	4/18/2023	10.21	23.17***	21.00
2	4/25/2023**	7.29	15.00	15.00

* Weeks centered on Tuesday/Wednesday = sampling day for the calculation of nutritional values
** Reduced amounts are due to incomplete weeks (marking the end of the fattening rounds with the last animals being sent to slaughter).
*** This large quantity results from delayed adjustment to the departure of some individuals for slaughter

feed over vegetables and fruits in the very early stage of the experiment. In a pilot feeding trial, we had shredded the vegetables and fruits before feeding, in an attempt to increase acceptance/intake. Because no differences had been found between shredded and non-shredded, the vegetables and fruits were provided as non-shredded throughout the trial, thereby minimizing the workload. Finally, all groups also received an armful of grass silage twice a day, placed onto the ground near the feeding troughs.

Regular weighing of the pigs was performed every three to four weeks until the first pigs were sent to slaughter. Because not all pigs reached their slaughter weight at the same time, we additionally collected carcass weights whenever possible. On weighing days, health evaluations were performed by assessing diarrhea, skin lesions and tail-ear injuries (based on Leeb *et al.*, 2019). On these days, we also conducted behavioral observations for 2 hours following the morning feeding of the pigs. The observations were conducted simultaneously on all four groups by two observers. To avoid experimental biases, observers each observed one CO and one VG group at the same time, and they rotated their observation groups every 30min. Within each group, pigs were marked with spray paint with distinct pattern to allow individual identification. Behavioral data collection included two sampling methods. Using 'scan sampling', we recorded every 10 minutes the number of pigs present on the outdoor run within each group and their foraging activity – specifically, whether they were eating concentrate, grass silage, vegetables or if uncertain (NA) for each individual. Using 'continuous sampling', we recorded the number of play behaviors, fights (fights occurring at, near (< 1 m) and away from (> 1 m) the feeding trough; fights included head knocks and biting body parts other than ears and tails) and tail and ear biting within each group.

Researchers attended three different slaughter days, where a total of 23 animals could be inspected (comprising 14 individuals (6 from CO groups and 8 from VG groups) and 9 individuals (5 from CO groups and 4 from VG groups) in the first and second fattening rounds, respectively). On these occasions, the gastric mucosa of the slaughtered animals was examined, stomach damage and ulcers were documented, and shoulder fat samples and carcass weights were collected. Fat samples were analyzed for concentrations of saturated fatty acids (SFA), monounsaturated fatty acids (MUFA) and polyunsaturated fatty acids (PUFA) with near infrared spectroscopy.

Data analyses accounted for several corrections: first, the PUFA values obtained from the shoulder fat are on average 1.9% higher than the PUFA values measured in the slaughterhouse, taken from the backfat (Quander *et al.*, 2021); second, the individual carcass weight of slaughtered pigs was collected whenever possible and used to estimate the final live weight before slaughter (because not all pigs were slaughtered on the same day, and thus the final weighing event would not approximate the final live weight equally for all individuals). Conversion from slaughter weight to live weight at slaughter followed the equation 'live weight at slaughter = slaughter weight/0.72' (as per the correction of 0.72–0.73 suggested by Vitek *et al.*, 2011). Statistical analyses were performed using mixed effects models in R (R Core Team, 2023). Random factors allowed correcting for dependencies within groups and fattening rounds. For the model including the interaction between Feeding occupation and Treatment, post-hoc tests were computed for pairwise comparisons using the 'emmeans' package. Two-tailed p-values are reported, and the significance level was set at 0.05.

Results

Rearing performance

The fattening period lasted equally long for pigs in treatment and control conditions (p=0.83). Our results show that the applied treatment (provision of vegetables and fruits scraps and reduction of concentrate feed) resulted in a lower overall concentrate feed consumption (p=0.01) and lower average daily weight gain (p=0.01) per pig in the VG compared to CO groups. The average individual liveweight at slaughter, estimated from carcass weights, did not significantly differ between groups (p=0.20). However, carcass weights were only obtained from 23 individuals (11 from CO groups, 12 from VG groups) and average weight estimates do highlight a 5 Kg difference with pigs from CO groups being heavier. The concentrate feed conversion ratio showed no difference between CO and VG groups (p=0.97).

Table 4 | Overview of the rearing performances obtained in pigs fed with concentrate only (CO), or with concentrate and vegetable and fruit scraps (VG).

	CO	VG	Model significance (p-value)
Average fattening period per pig in days (± SD)	98 days (± 11)	99 days (± 11)	p = 0.83
Average daily weight gain per pig in g (± SD) (up to the last weighing)	955 g (± 118)	844 g (± 125)	p = 0.01
Average estimated liveweight at slaughter in Kg (± SD) (available from N= 23 individuals) (12 VG and 11 CO)	123.2 (± 7.54)	118.4 (± 8.39)	p = 0.20
Average concentrate feed conversion per pig in kg/kg (± SD) (up to the last weighing)	2.59 (± 0.36)	2.60 (± 0.31)	p = 0.97
Average consumption of concentrate feed per pig in Kg (± SD)	246.6 kg (± 30.4)	223.1 kg (± 13.9)	p = 0.01
Average consumption of vegetable and fruit scraps per pig in Kg (± SD)	–	114.4 kg (± 17.2)	NA

The median individual body weight for each treatment on each data collection day of the two fattening rounds is shown in Figure 1. Overall and up until their slaughter, pigs in VG groups had a significantly lower weight than pigs in CO groups (p = 0.01), and this was most noticeable in the second round. This closely aligns with the results obtained from the calculation of nutritive and energetic values of the CO and VG diets (Fig. 2). Indeed, pigs following the VG diet had on average a lower estimat-

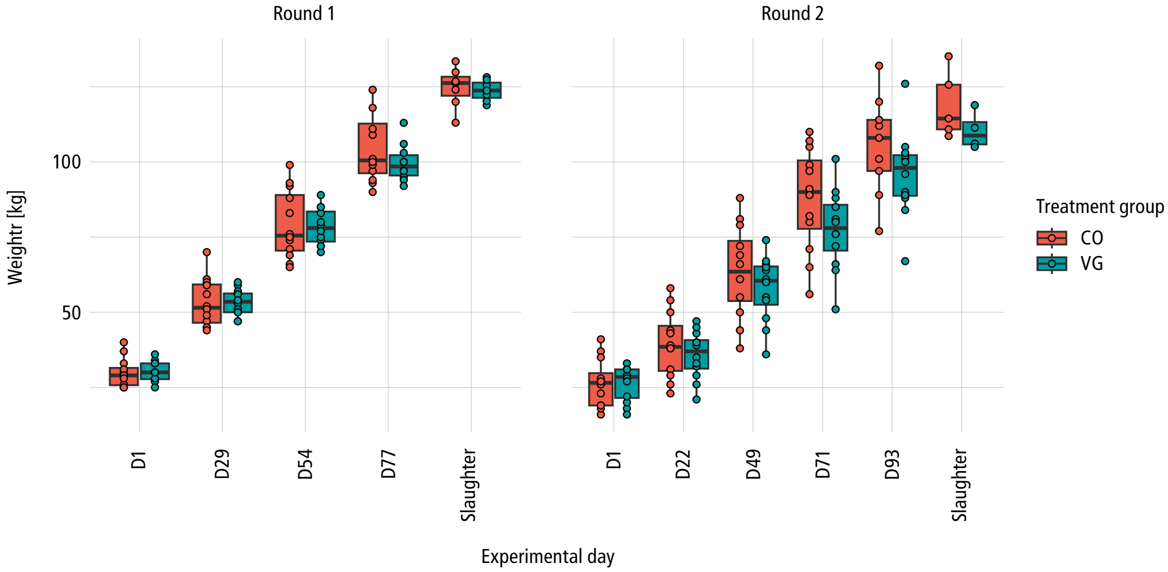

Figure 1 | Individual weight development over time (left: fattening round 1; right: fattening round 2) in the groups receiving a concentrate-only (CO, in red) or a concentrate + vegetable and fruits scraps (VG, in blue) diet. The estimated live weights at slaughter in the two fattening rounds are derived as 'carcass weight/0.72' (available from N = 23 individuals).

ed energy (p = 0.003), fat (p = 0.04), protein (p = 0.003), sodium (p < 0.001), calcium (p < 0.001) and phosphorus (p = 0.002) intake, which was again most noticeable during the second fattening round (Fig. 2, top and middle rows). Conversely, VG diet led to a higher fiber intake (p < 0.001; Fig. 2, bottom row).

Lastly, the fat quality assessments made from shoulder fat sampling (available upon slaughter from a total of 23 pigs) showed no differences in SFA and MUFA values between pigs from VG and CO groups (p = 0.09 and p = 0.80, respectively). However, pigs from VG groups had on average significantly higher PUFA values (Fig. 3; p = 0.04).

Pig Health

Regular health assessments showcased an overall excellent health status for all groups involved in the study. Across VG and CO groups, very few skin lesions could be observed, and no ear or tail biting occurred (only one animal across both fattening rounds had a shorter tail, yet this preceded the start of the trial). In addition, visual inspections of the stomachs right after slaughter revealed the absence of hyperkeratosis, erosion, or ulcers in all the individuals examined, regardless of the feeding treatment (N = 23). However, we counted significantly fewer instances of diarrhea in pigs from the VG groups compared to those in the CO groups (p = 0.007; Fig. 4).

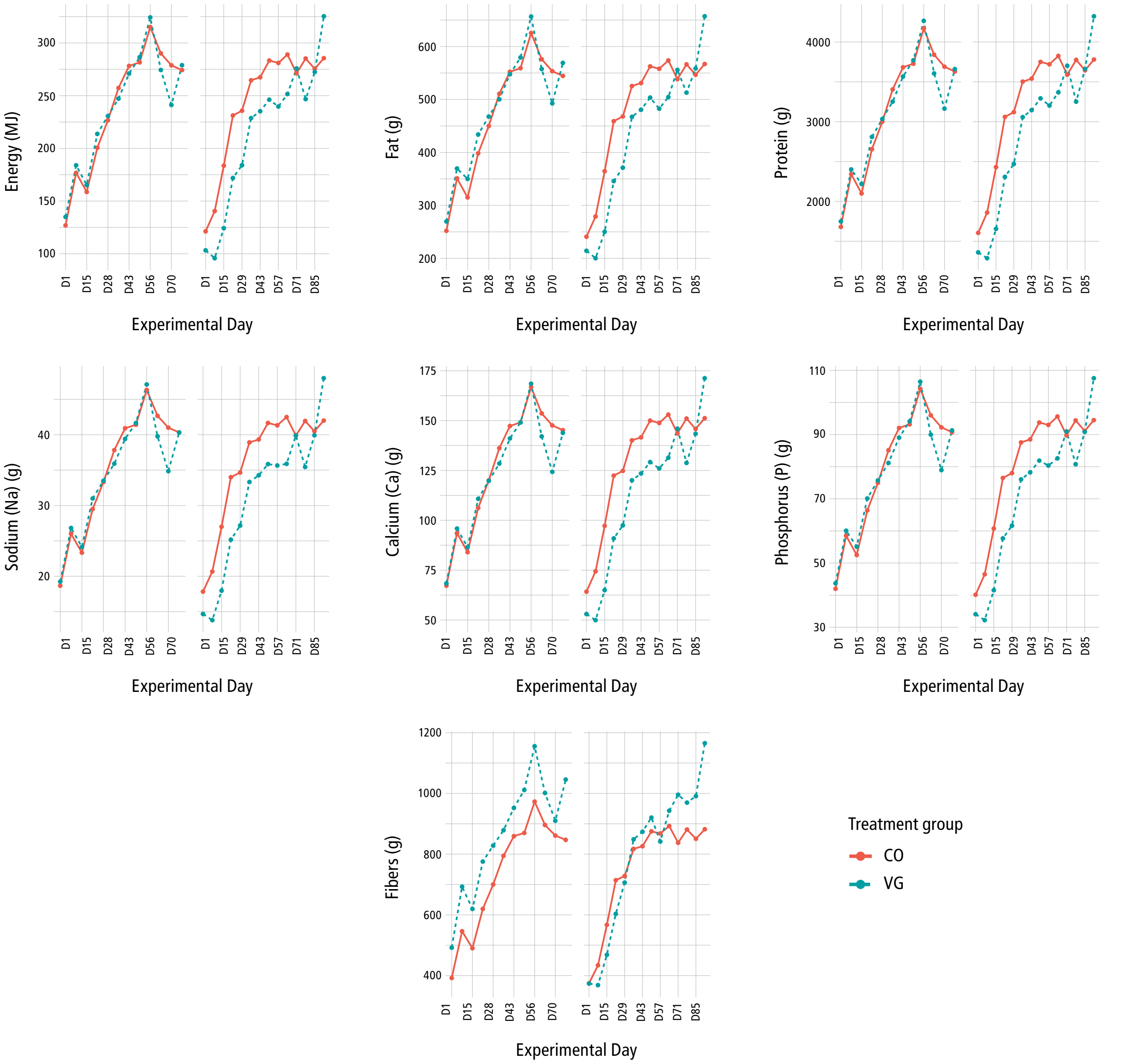

Figure 2 | Weekly average individual nutrient intake during the two fattening rounds, calculated based on the nutritional values of food items (see Table 2) and feed quantities (see Table 3) provided (and consumed) during the experiments (and adjusted to weekly vegetable and fruit composition). From left to right: energy, fat, protein (top row); sodium, calcium, phosphorus (middle row); fibers (bottom row).

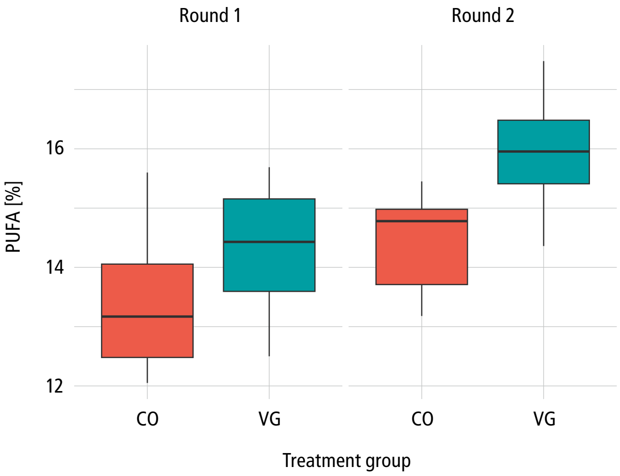

Figure 3 | Concentration of polyunsaturated fatty acids (PUFA) in the shoulder fat of pigs (N = 23 animals). The measured values were corrected by –1.9 % for meaningful comparison with values from the back fat as collected in the slaughterhouse.

Pig Behaviour

As part of the concentrate feed was progressively replaced by vegetable and fruit scraps throughout the rounds, we observed a shift in how pigs seemed to get habituated to the food scraps. While VG pigs initially ate vegetable and fruits scraps only once the concentrate was eaten, suggesting a preference for the latter, they ended up eating scraps and concentrate alike. Overall, pigs in VG groups were more often observed displaying feeding behavior than CO pigs ($p < 0.001$; see 'Overall' Fig 5a). When distinguishing between feeding occupations, CO pigs were observed significantly more often eating concentrate than VG pigs ($p < 0.001$; Fig. 5a). Yet, feeding occupation in VG pigs was also more often 'unclear' than in CO pigs ($p < 0.001$, Fig. 5a), as observers could not be perfectly certain about whether individuals were eating concentrate or vegetables/fruit pieces. In addition, VG pigs were observed eating vegetables and fruits ('Vegetables'), approximately as often as they ate concentrate(Fig. 5a). Pigs in both groups were most often observed eating grass silage, without a difference between the treatment groups ($p = 0.39$; Fig. 5a).
The total number of times that pigs were seen in the outdoor run over the two fattening rounds (as opposed to being in the indoor area) was not affected by feeding treatment ($p = 0.45$; Fig. 5b). Similarly, the amount of fights at and around the feeding troughs did not differ between CO and VG groups ($p = 0.12$; Fig. 5c). This also applied to ear and tail manipulations, which remained overall very low (less than 0.1 ear/tail manipulation per 30-minute observation block on average; data not shown). One behavioral trait that was, however, influenced by the vegetable and fruit scraps supplementation was the amount of play behavior observed, with pigs in VG groups playing significantly more often than pigs in CO groups ($p < 0.001$; Fig. 5d).

Discussion

Performance

Pigs from VG groups did not put on weight as fast as pigs from CO groups, which was particularly true in the second fattening round (Fig. 1). A likely explanation for such observation comes from the fact that concentrate feed reduction was stronger in the second fattening round, as highlighted by the lower nutritional values measured for pigs in VG groups in the second round (Fig. 2). This implies that there is a threshold below which pigs' growth becomes sub-optimal when too much concentrate feed is replaced by vegetables, in that case decreasing the production performance. To obtain similar weights at slaughter for pigs receiving CO and VG diets, given that similar concentrate feed conversions are observed in both diets, it would then be necessary to extend the fattening period for pigs receiving a VG diet (and thus close the 5 Kg-gap estimated from carcass weights at slaughter in our study). Further investigation is needed to assess whether this approach may still be economically viable, as additional costs associated with extended fattening might eventually lead to similar overall amounts of concentrate feed consumed per pig. This is even more relevant given our preliminary attempt at comparing transport costs associated with vegetable/

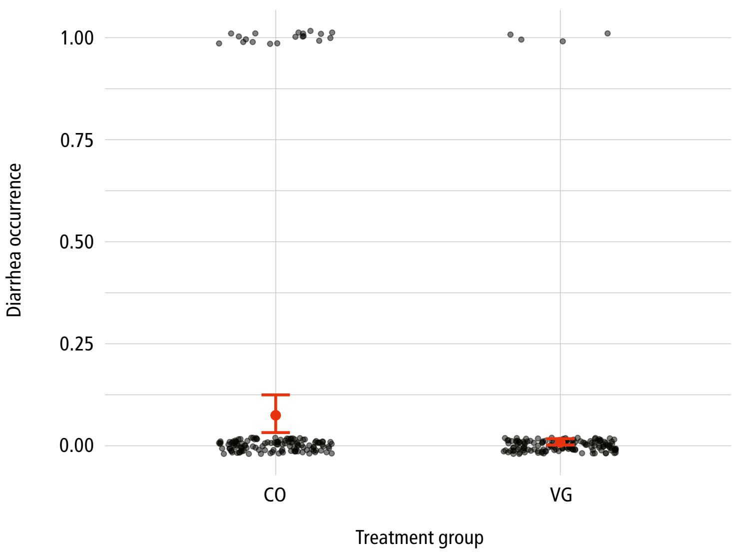

Figure 4. | Occurrence of diarrhea observations (yes or no), overlaid by model estimates (± confidence intervals) in pigs from CO and VG groups.

fruit scraps and concentrate feed, which showed higher costs per unit of dry matter (2.80 vs 1.42 CHF/Kg), energy (1.70 vs 0.11 CHF/MJ) and protein (16.10 vs 8.10 CHF/Kg) for vegetables/fruits scraps.

Besides the need for an in-depth economic assessment of feeding strategies, there is also a need for further research quantifying the nutritional values (for pigs) associated with specific vegetable and fruit types. Indeed, identifying vegetable and fruit types with high nutritional potential might improve efficiency in the use of alternative feed sources, and help balancing dietary formulations to maintain optimal growth rates (including modified concentrate feed formulation that could improve conversion ratios of vegetable and fruit scraps). For instance, the fiber intake (Fig. 2, bottom row) shows higher values for VG pigs mainly during the first fattening round, which comprised proportionally more vegetables than fruits compared to the composition in the second fattening round. Although a mere example, this highlights the need for better understanding the relationship between alternative feed sources and production performance. A certain trade-off between "keeping it simple" and "feeding precisely" will remain whenever by-products or waste-streams are incorporated into livestock nutrition.

The fat quality analyses that we carried out from shoulder fat demonstrated a higher concentration of PUFAs in pigs fed with a VG diet. This is at first surprising, in light of the lower PUFA levels generally found in vegetable and fruits, and the fact that higher dietary PUFA lead to

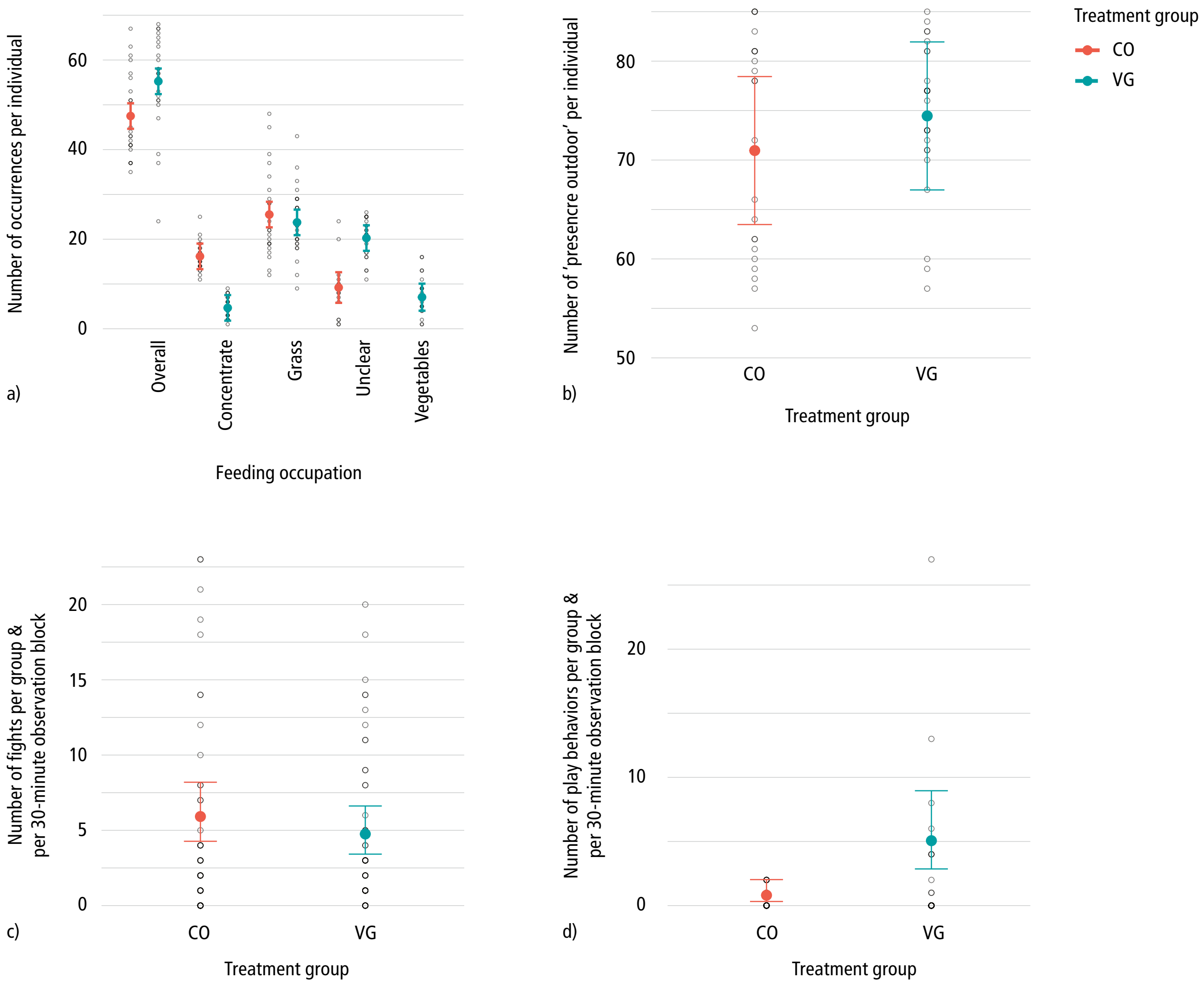

Figure 5 | Quantifications made from behavioral observations across both fattening arounds (model estimates ± confidence intervals). a) Total number of times pigs were observed as involved with feeding activity ('Overall'), and more specifically eating either concentrate, vegetables/fruits, any of concentrate/vegetables/fruits (unclear), or grass silage; b) Total number of times pigs were observed in the outdoor run; c) Sum of fights and d) sum of play behaviors observed within groups per 30-minute observation block. a) and b) were computed from scan sampling; c) and d) were computed from continuous sampling and are shown at the group level given the social nature of fight and play behaviours).

higher backfat PUFA in pigs (Quander-Stoll *et al.*, 2021). However, when considering the lower weight at slaughter for pigs receiving a VG diet, there is a high probability for a 'dilution effect'. In other words, pigs from CO groups, which are heavier, also possess a thicker fat cover for a similar PUFA content, thereby lowering the PUFA concentration. The difference observed between the first and second fattening rounds corroborates this 'dilution effect' hypothesis: individuals in the first round indeed had a higher overall weight and lower PUFA values (Fig. 3) than those in the second round. Importantly however, the slight increase in PUFA levels seen in this study for pigs under a VG diet does not have any economical implication, since these values remained below the required thresholds for commercial production, and did not lead to any penalty.

Pig Health

Research has shown that feeding grass silage leads to a reduction in severe damages to the gastric mucosa (Holinger at al., 2018). Thus, as expected given the feeding of grass silage in both treatment conditions, no ulcers or other signs of damage were found in any of the stomachs examined upon slaughter. However, a digestion-related difference did appear between treatment groups: diarrhea occurred slightly but significantly less often in pigs receiving a VG diet (Fig. 4). The higher fiber intake in the VG diet (Fig. 2 bottom row) might explain this result. More specifically, it is assumed that a (moderately) increased fiber content in the feed leads to an enhanced maturation of the gastrointestinal tract of the pigs and contributes to a positive influence on the intestinal microbiota (reviewed by Molist *et al.*, 2014). In addition, a high fiber concentration in the intestinal contents ensures that pathogenic germs are less able to adhere (Molist *et al.*, 2014).
With regards to other health issues, our evaluations showed that there were hardly any injuries to the tail and ears and very few skin lesions. This suggests that serious behavioral problems did not occur overall or only to a small extent.

Pig Behavior

Pigs from VG groups were overall more often occupied by feeding activities than pigs in CO groups (Fig. 5a), highlighting the enrichment potential of diet diversification in domestic pigs. The fact that feeding occupation involved concentrate feed and vegetables equally often (Fig. 5a), points towards using such alternative feed sources to release social tensions at and around feeding troughs (in particular because vegetables/fruit scraps were frequently observed to be carried away from the feeding troughs to be eaten alone). Fruits were consumed very readily right from the start of the experiment, which is not surprising given the strong gustatory inclination of pigs for sugar (Glaser *et al.*, 2000). On the contrary, all pigs initially showed a strong preference for the concentrate feed over vegetables scraps, which were eaten only when there was no concentrate left. Based on a pilot test, shredding vegetable scraps had no effect on this preference. Yet, the observers had the impression (no quantitative data were actually collected) that moist vegetable scraps quickly became appealing to the pigs, matching with documented preferences for moister feedstuffs in pigs (Olsen *et al.*, 2000; Studnitz *et al.*, 2007). In addition, the overall propensity for vegetable intake increased over the course of the fattening period, in both fattening rounds (leading to an overall similar amount of time spent eating concentrate and vegetables in VG pigs – see Fig. 5a). This finding indicates that pig dietary preferences evolve as they become habituated to the introduction of new feed types, in parallel to the increasing feed consumption that directly resulted from pigs growing bigger and heavier. In order to avoid this habituation effect to occur during the fattening period, starting to feed vegetable and fruit scraps earlier in life (e.g. in the weaning phase) would facilitate acceptance and allow for optimal nutritional benefits over time. This would furthermore enhance vegetables' digestibility by allowing the gut microbiota to adapt for a longer time (Molist *et al.*, 2014).
The low number of tail and ear manipulations observed confirms the low number of lesions detected during the health examinations, indicating an overall low level of abnormal behaviour in both VG and CO groups. One potential factor contributing to this observation is the presence of grass silage for all groups throughout the fattening period. The number of times pigs were observed eating grass silage was indeed higher than any other feeding-related activity (Fig. 5a), and grass silage could therefore have a dual physiological (reducing gastric ulcers likelihood) and behavioral (through enrichment) benefit. A factor explaining the low levels of aggression at and around the feeding troughs could have to do with the weekly adjustments of the feed quantities decided on the farm after visual assessment of the feeding events leftovers. While standardized feeding schedules are key to an optimal production performance, our results also underline the importance of direct on-farm daily observation to provide optimal social environments (for instance by avoiding fights over feed) for the pigs. Finally, the higher proportion of play

behavior in the VG groups indicates a potentially higher level of well-being. Play behavior is indeed often used as an indicator of animal welfare, as per the correlation between welfare and play behavior shown in various animal species (Held & Špinka, 2011; Olsen *et al.*, 2001).

Conclusions

The findings of this study highlight the potential of using vegetable and fruit scraps as an enriching feed option for organic pigs. This approach can substitute only small shares of concentrate feed, though. However, it clearly yields benefits to animal welfare. Although it appears as an innovative solution to the feed/food competition for arable lands, care must be taken regarding growth performance and nutritional quality outcomes. Early habituation to vegetable and fruit scraps is recommended to enhance their intake and potentially reduce the gap in performance when compared with pigs fed concentrate feed only. Further research is warranted to 1) identify vegetable and fruits scraps with higher nutritional values, and 2) select genetic lines or breeds that are best adapted for diets integrating human food by-products in general.

Overall, the positive health and behavioral outcomes are promising indicators for further exploring by-product feeding strategies for organic pigs, provided that logistical and economic considerations regarding the transport and storage of these by-products are fully factored into future implementations. More generally, the ethical value and potential changes in meat quality resulting from the use of food by-products also require further assessment among consumers if such use is to become more widespread. ■

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References

- Bio Suisse (2025). Cahier des charges pour la production, la transformation et le commerce des produits Bourgeon. https://www.bio-suisse.ch/dam/jcr:9be72345-f2f0-4b3a-bbd8-dd49b1e227d0/Bio_Suisse_Cahier_des_charges_2025_FR_Final.pdf
- Bond, M., Meacham, T., Bhunnoo, R., & Benton, T. (2013). Food waste within global food systems. Swindon, UK: Global Food Security.
- Glaser, D., Wanner, M., Tinti, J.M., & Nofre., C. (2000). Gustatory responses of pigs to various natural and artificial compounds known to be sweet in man. *Food Chemistry* **68**, 375–385.
- Held, S. D. E., & Špinka, M. (2011). Animal play and animal welfare. *Animal Behaviour* **81** (5), 891–899.
- Holinger, M., Früh, B., Stoll, P., Kreuzer, M. & Hillmann, E. (2018) Grass silage for growing-finishing pigs in addition to straw bedding: effects on behaviour and gastric health. Livestock Sciences. 218:50–7.
- Keerthana Devi, M., Manikandan, S., Oviyapriya, M., Selvaraj, M., Assiri, M.A., Vickram, S., Subbaiya, R., Karmegam, N., Ravindran, B., Chang, S.W., Awasthi, M.K. (2022). Recent advances in biogas production using Agro-Industrial Waste: A comprehensive review outlook of Techno-Economic analysis. *Bioresource Technology* **363**, 127871.
- Kiarie, E.G. & Mills, A. (2019) Role of Feed Processing on Gut Health and Function in Pigs and Poultry: Conundrum of Optimal Particle Size and Hydrothermal Regimens. Front. Vet. Sci. 6:19. doi: 10.3389/fvets.2019.00019
- Leeb, C., Rudolph, G., Bochicchio, D., Edwards, S., Früh, B., Holinger, M., Holmes, D., Illmann, G., Knop, D., Prunier, A. & Rousing, T. (2019). Effects of three husbandry systems on health, welfare and productivity of organic pigs. *Animal* **13** (9), 2025–2033.
- Mizelle, B. (2012). Pig. Reaktion Books.
- Molist, F., van Oostrum, M., Pérez, J. F., Mateos, G. G., Nyachoti, C. M., & van der Aar, P. J. (2014). Relevance of functional properties of dietary fiber in diets for weanling pigs. *Animal Feed Science And Technology* **189**, 1–10.
- Nguyen, T.L.T., Hermansen, J.E., Mogensen, L. (2012). Environmental costs of meat production: the case of typical EU pork production. *Journal of Cleaner Production* **28**, 168–176.
- Nielsen, E.K. & Ingvartsen, K.L. (2000). Effect of cereal type, disintegration method and pelleting on stomach content, weight and ulcers and performance in growing pigs. *Livestock Production Science* **66** (3), 271–282.
- Olsen, A. W., Dybkjær, L., & Simonsen, H. B. (2001). Behavior of growing pigs kept in pens with outdoor runs: II. Temperature regulatory behavior, comfort behavior and dunging preferences. *Livestock Production Science*, **69** (3), 265-278.
- Olsen, A. W., Vestergaard, E. M., & Dybkjær, L. (2000). Roughage as additional rooting substrates for pigs. *Animal Science* **70** (3), 451–456.
- Papargyropoulou, E., Lozano, R., Steinberger, J. K., Wright, N. & bin Ujang, Z. (2014). The food waste hierarchy as a framework for the management of food surplus and food waste. *Journal of Cleaner Production* **76**, 106–115.
- Quander-Stoll, N., *et al.* (2021). Fütterung von Bioschweinen unter Berücksichtigung der Fettqualitätsanforderungen und einer 100 % Biofütterung. Presented at Bioland Tagung 10.02.2021, Germany.
- R Core Team (2023). _R: A Language and Environment for Statistical Computing_. R Foundation for Statistical Computing, Vienna, Austria. https://www.R-project.org/
- Schader, C., Muller, A., Scialabba, N.E., Hecht, J., Isensee, A., *et al.* (2015). Impacts of feeding less food-competing feed-stuffs to livestock on global food system sustainability. Journal of the Royal Society Interface 12: 20150891.
- Shurson, G.C. (2020). "What a waste" – can we improve sustainability of food animal production systems by recycling food waste streams into animal feed in an era of health, climate, and economic crises? *Sustainability* **12**, 7071.
- Shurson, G.C., Hung, Y.-T., Jang, J.C., Urriola, P.E. (2021). Measures Matter – Determining the True Nutri-Physiological Value of Feed Ingredients for Swine. *Animals* **11**, 1259. https://doi.org/10.3390/ani11051259
- Studnitz, M., Jensen, M. B., & Pedersen, L. J. (2007). Why do pigs root and in what will they root? A review on the exploratory behavior of pigs in relation to environmental enrichment. *Applied Animal Behavior Science* **107** (3–4), 183–197.
- van Zanten, H.H.E., Mollenhorst, H., Klootwijk, C.W., van Middelaar C.E. & de Boer, I. J. M. (2016). Global food supply: land use efficiency of livestock systems. *The International Journal of Life Cycle Assessment* **21**, 747–758.
- Vítek M., Vališ L., David L., Pulkrábek J. (2011). Coefficients for the estimation of pig live weight. *Research in Pig Breeding* **5**, 51–51