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Provision of lucerne in the diet or as a manipulable enrichment material enhances feed efficiency and welfare status for growing-finishing pigs

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HIGHLIGHTS

- Lucerne diet reduced feed intake, feeding rate and weigh gain.
- Lucerne diet increased feed efficiency.
- Lucerne manipulable material did not affect pig growth performance but behaviour.
- Lucerne manipulable material reduced pig resting time, increased exploration.
- No interactions between lucerne diet and manipulation on the studied traits.

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ABSTRACT

This research investigated the effects of including lucerne in a diet and as manipulable enrichment material on growing-finishing pig growth performance and behaviour. Forty-eight intact male Duroc × (Large White × Landrace) pigs with an initial live weight (LW) of 26.4 ± 2.32 kg (mean ± SD) were blocked by LW and randomly assigned to two dietary treatments (control vs lucerne), and two manipulable material treatments (without and with lucerne chaff for manipulable material). The barley and soybean meal-based control diet was formulated according to a commercial standard, while the lucerne diet replaced 100 g/kg of the barley and soybean oil in the control diet with lucerne chaff. The diets were formulated to have the same amount of digestible energy and apparent ileal digestible lysine. Manipulable material (lucerne chaff) was provided daily at 100 g/pig. Pigs had *ad libitum* access to diets via electronic feeders until they reached approximately 90 kg LW, at which time they were slaughtered. There were no interactions between dietary treatment and provision of manipulable material on pig production and behaviour. Feeding the lucerne diet reduced average daily feed intake, LW gain, feed intake per feeder visit, and feeding rate, but increased feed efficiency ($P < 0.05$). Access to manipulable material did not affect any growth traits, but the number of feeder visits per day was greater and the duration of visits to the feeder was lower in pigs that had access to lucerne chaff ($P < 0.001$). Compared to the other groups, pigs that consumed the lucerne diet or had access to manipulable material rested for a shorter duration but engaged in more social interactions and exploration behaviour. In conclusion, including 10% lucerne in growing-finishing diets improved feed efficiency and lucerne chaff appears to be an attractive enrichment source to pigs.

1. Introduction

Pig meat is the second most popular meat consumed worldwide. Its production is projected to increase over the next few decades, mainly driven by global population growth and improved standards of living (Henchion et al., 2014; OECD/FAO, 2021). Whilst pig meat consumption is expected to increase, there is increasing concern for food security, the enviroment and animal welfare. Pig diets mainly rely on grains and soybean meal, therefore pigs are competing with human food sources, and the production of these feed ingredients raise concerns in terms of environmental emissions, deforestation and biodiversity loss (Mottet et al., 2017; Nguyen et al., 2012). Indoor pig production has

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benefits for providing for the environmental and health needs of pigs, but often indoor housing is not compatible with providing a substrate or exploratory material due to slatted flooring. Unsuitable slurry systems, and the risk of blocked slats limits opportunities to provide some types of enrichment material, therefore limiting the expression of natural behaviour such as exploration and foraging (Studnitz et al., 2007).

Incorporating forage plants into pigs' diets and enriching pig houses with forage roughage may address both of the above concerns. The fibre content in forages has discouraged the feeding of herbage-based diets due to concerns that it will restrict pig growth, although there is evidence of other benefits, such as for pig gut health (Montagne et al., 2003; Kambashi et al., 2014; Jha and Berrocoso, 2015; Jarrett and Ashworth, 2018). In addition, recent studies showed no impact on the digestibility and growth rate of pigs when diets partly replaced conventional feedstuffs with forages (Liu et al., 2012; Rattanasomboon et al., 2019; Figueroa et al., 2020). Forages are recommended as manipulable material to reduce injurious and potentially harmful behaviours in pigs (European Food Safety, 2007). Pigs with acess to roughage as enrichment have opportunities to express positive, highly-motivated, species-specific behaviours by imitating their natural environment, therefore, improving their welfare indoors.

Lucerne (Medicago sativa) is a potential feed ingredient and/or manipulable material option for growing pigs. Protein content and apparent ileal digestibilities of essential amino acids in lucerne are close to growing pig requirements (Reverter et al., 1999; Tsikira et al., 2021). Lucerne meal can be included in growing-finishing pig diets at up to 75 g/kg diet during the growing period, and at up to 150 g/kg diet during the finishing period, without adverse effects on growth performance (Thacker & Haq, 2008). However, research on using lucerne as an ingredient in pig diets is scarce or old. Furthermore, studies on using lucerne chaff as a source of manipulable material for growing pigs reared indoors was only once mentioned in a review of Studnitz et al. (2007). The present study aimed to investigate the effect of feeding lucerne together with providing lucerne as manipulable material on growth performance and behaviour of growing pigs.

2. Materials and methods

The experiment was carried out at the Massey University Pig Biology Unit, Palmerston North, New Zealand and was approved by the Massey University Animal Ethics Committee (MUAEC 19/131).

2.1. Experimental design, animals and housing

2.1.1. Animals

Forty-eight intact, male Duroc × (Large White × Landrace) pigs with an initial live weight (LW) of 26.4 ± 2.32 kg (mean ± SD) were purchased from a commercial pig farm. Pigs were weighed and fitted with a numbered ear tag in the left ear and a radio frequency identification (RFID) tag in the right ear. The pigs were blocked by LW and allocated to eight pens, with 6 pigs per pen. Pigs were acclimated for 5 d before the experiment began. When pigs reached approximately 90 kg LW, they were transported approximately 2 h to a commercial abattoir (Land Meat Ltd, Wanganui, NZ), rested overnight, then slaughtered the following day.

2.1.2. Experimental design

The experiment followed a 2 × 2 factorial design, comprising diet (control vs. lucerne) and provision of manipulable enrichment material (chaff vs. no chaff). Two pens of 6 pigs were allocated randomly to each of the four treatment groups:

1) Control diet without enrichment material available
2) Control diet with enrichment material available
3) Lucerne diet without enrichment material available
4) Lucerne diet with enrichment material available

The control diet was based on barley, soybean meal, and soybean oil, while the lucerne diet was made by replacing 100 g/kg (as-is basis) of the barley and soybean oil in the control diet with lucerne chaff (Table 1). Diets were pelleted and formulated to have the same amount of digestible energy and apparent ileal digestible lysine.

In pens with material offered for enrichment, lucerne chaff was provided in a tray fastened to the floor adjacent to the feeding station. Trays were topped up with 100 g/pig of lucerne chaff each morning at approximately 0900.

2.1.3. Housing

Pigs were housed in pens measuring 20 m^2 with a solid concrete floor, enabling a space allowance of more than 3 m^2/pig. Pigs had *ad libitum* access to water and feed throughout the experiment. Pen design was described in Fig. 1.

Each pen had an unlit sleeping area separated by a wall from where the feeder and drinker were located. The sleeping area was accessed by a

Table 1
Ingredient and chemical composition of experimental diets.

Ingredient (g/kg, as-fed)	Control	Lucerne
Barley	748.3	618.2
Soybean meal	200	200
Soybean oil	10	40
Lucerne chaff	0	100
Lysine	2.5	2.5
Methionine	2	2
Threonine	2	2
Tryptophan	0.2	0.3
Vitamin + mineral premix[1]	2	2
Dicalcium phosphate	30	30
Sodium phosphate dibasic	2	2
Sodium chloride	1	1
Calculated values[2]		
Digestible energy (MJ/kg)	13.57	13.57
Apparent ileal digestible lysine (g/kg)	9.80	9.83
Chemical composition (g/kg DM, unless noted)		
Crude protein	193	177
Fat	43	97
Starch	407	343
Ash	71	69
NDF	146	164
ADF	51	72
Lignin	11	16
GE (MJ/kg DM)	18	19
Amino acids (g/kg DM)		
Aspartic acid	17.1	17.82
Threonine	7.98	7.80
Serine	7.98	7.80
Glutamic acid	37.63	32.29
Proline	13.68	12.25
Glycine	6.84	6.68
Alanine	7.98	7.80
Valine	9.64	8.93
Isoleucine	7.65	7.12
Leucine	13.45	12.47
Tyrosine	6.96	6.12
Phenylalanine	10.15	9.13
Histidine	4.56	4.34
Lysine	10.49	9.58
Arginine	12.09	11.02
Cysteine	3.31	2.9
Methionine	5.13	4.79
Tryptophan	2.51	2.45

NDF: Neutral detergent fibre; ADF: Acid detergent fibre; GE: Gross energy
[1] Provided per kilogram of diet: 7000 IU of vitamin A, 1500 IU of vitamin D3, 35 IU vitamin E, 2 mg of vitamin K, 1.5 mg of vitamin B1, 3 mg of vitamin B2, 2 mg of vitamin B6, 15 μg of vitamin B12, 11 mg of pantothenic acid, 15 mg of niacin, 20 μg of biotin, 0.25 mg of folic acid, 90 mg of choline, 80 mg of iron (sulfate), 30 mg of manganese (sulfate), 1 mg of cobalt (chloride), 0.3 mg of selenium (sodium selenite), 115 mg of zinc (oxide), 20 mg of copper (carbonate), and 1 mg of iodine (potassium iodate).
[2] Morel et al. (1999)

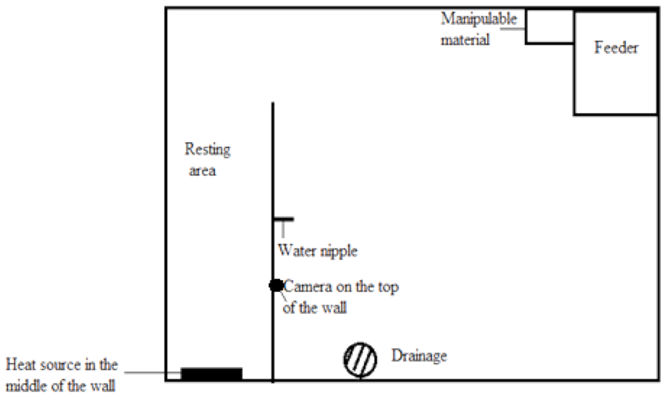

Fig. 1. Diagram of the pen design

doorway. Pigs had free access to all areas of the pen at all times. A thermostatically-controlled heat lamp maintained air temperature inside the lying area at 20 to 25°C when the pigs were under 50 kg LW, and 18 to 22°C when the pigs were over 50 kg LW. Artificial lighting in the feeding area was provided daily from approximately 0700 to 1700.

Automatic electronic feeders (Osborne FIRE System, Osborne Industries, Inc., Osborne, KS) were used in the experiment. The feeders were calibrated at the start of the study and once each week thereafter, using a 500-g calibration weight. The feeder entrance was covered by an adjustable full-body race that enabled only one pig at a time to eat unmolested. An RIFD ear tag identified each pig to the feeder, which in turn recorded the pig's tag number automatically, the amount of feed consumed per visit, the entry and exit time per visit, and visit duration. If a visit takes place but no tag was identified, then the visit was classified as a "Tag 0" event. The data were checked daily for errors and downloaded onto a hard drive until analysis. During the experiment, three of the feeders could not read some of the ear tags properly for two days. In this case, feed consumed from "Tag 0" was allocated to the pigs with an abnormally low feed intake. Moreover, the criteria detailed in Casey et al. (2005) were applied to eliminate possible erroneous data.

2.2. Data collection

2.2.1. Production trait data

Feed intake per week was calculated for each pig from the downloaded data generated by the automatic feeders. Individual pig LW was recorded weekly by weighing pigs between 0700 and 0800 on the same day each week. Pigs were limited to their lying areas from 0700 on weighing days to prevent unequal feed consumption before weighing.

Hot carcass weight (without kidney and leaf fat) and backfat depth were recorded within 30 minutes post-slaughter. Backfat depth was measured in the right side of the carcass at the P2 position, about 65 mm from the dorsal midline at the level of the last rib, using a Hennessy grading probe (Hennessy Technology, Auckland, New Zealand).

2.2.2. Pig behaviour observations

2.2.2.1. Pig feeding behavior. A total of 468,644 observations were used for analysis of feeding behaviour. Mean values for each pig for the number of feeder visits per day, feed intake per visit, feeder occupation duration per visit, feed consumption rate (feed consumption/occupation duration), and total time spent in the feeder per day were calculated.

2.2.2.2. Pig daily behaviour. To record pig daily behaviour, a video camera (CONCORD AHD CCTV 1080p PIR Bullet Cameras) was placed above each pen to produce a top view image so that all actions of the pigs were observed whilst they were in the feeding and activity area. The only area of the pen that was not visible was the resting area (Fig. 2).

Pig behaviours were recorded on the 3rd, 6th and 9th week of the experiment. In each of these weeks, behaviour was recorded over three successive days from 0900 to 1700. An instantaneous scan sampling method was used to record pig behaviour. The interval between scans was 5 minutes, resulting in 12 scans per hour and a total of 96 behavioural observations recorded per pen for each sampling day. All the videos were scanned by the same trained person. Pig activity and behaviour are described on the defined ethogram (Table 2), adapted from Smulders et al. (2006) and Argemí-Armengol et al. (2020).

Table 2
Ethogram used in scan sampling recordings.

Category	Definition
In lying area	Pigs are in the lying area (assumed to be resting).
In the feeding area	
Resting	Pigs are lying in sternal or lateral recumbency or sitting upright. (N.B. Pigs in the lying area and not visible on the video recording were assumed to be resting.)
Occupying feeder	Pigs are standing with their head in the feeder, assumed to be eating.
Exploring enrichment material	Pigs are chewing, rooting, nosing, digging, or otherwise engaged with material provided for enrichment.
Exploring pen	Pigs are licking, biting, nosing or sniffing pen fixtures, e.g., the floor, wall, tray holding enrichment material and feeder.
Total exploration	Including pig exploring enrichment material and exploring pen.
Positive social interactions	Pig's head or snout in contact with another pig (non-aggressive), e.g., nose-to-nose contact.
Negative social interactions	Pigs are chasing, biting or having aggressive contact with other pigs (including those in a feeder).
Other behaviours	Pigs are engaging in other activities, e.g., sexual behaviour, standing or walking.

Fig. 2. Camera view of the feeding and activity area of the pens.
Note: P value for effect of diet on exploring enrichment material = 0.082

2.2.3. Feed sample storage and chemical analyses

A feed sample was collected every two weeks from the feeders, pooled and stored at 4°C until chemical analysis at the Massey University Nutrition Laboratory, Palmerston North, New Zealand.

Gross energy (GE) of the trial diets was determined by combusting the sample completely in a bomb calorimeter (AC-350, LECO Corporation, St. Joseph, MI, USA). Other chemicals were analysed according to the method of AOAC (2005): dry matter (AOAC 925.10 and 930.16); crude protein (AOAC 968.06, Dumas method); fat (AOAC 922.06, Mojonnier method,); neutral detergent fibre (NDF, AOAC 2002.04); acid detergent fibre (ADF, AOAC 973.18); lignin (Lignin(sa)AOAC 973.18); starch (α-amylase Megazyme kit, AOAC 996.11); ash (Furnace 550°C, AOAC 942.05); amino acid profile (acid stable: HCl hydrolysis followed by RP HPLC separation using AccQ Tag derivatization, AOAC 994.12); cysteine/methionine (performic acid oxidation, AOAC 994.12); tryptophan (AOAC 2017.03, sub-contracted, non-accredited); and acid insoluble ash (acid reflux ash, non-accredited method).

3. Statistical analysis

Growth performance and feeding behaviour data were analysed as a two-factorial design with Proc GLM (SAS® software, version 9.4, 2016, SAS Institute Inc., Cary, NC, USA). Dietary treatment, roughage enrichment and their interaction as fixed effects were fitted in the linear model. Individual pigs were considered to be the experimental unit of the growth performance and feed intake analysis.

Behavioural data were analysed as repeated measures with Proc Mixed. The experimental unit of the daily behavioural observations was the pen. The effect of dietary treatment, enrichment, day of scanning, and interactions between factors was fitted in the model. Diet and enrichment provision was nested in pen and considered a random effect. For engagement with the manipulable material, only the groups having received lucerne chaff were used to analyse the effect of dietary treatment.

Values are presented as least square means and standard error of the mean (SE). The level of significance was set at 0.05. Differences between least square means were adjusted with the Tukey test.

4. Results

4.1. Growth performance

As there were no interactions between diet and enrichment provision, only the results for the main effects are presented in Table 3.

The dietary treatment significantly impacted pig growth traits. However, there was no effect of manipulable material provision on pig growth performance. In addition, neither dietary treatment nor manipulable material provision affected carcass weight, dressing out percentage, or backfat thickness.

Pigs fed the control diet ate almost 250 g/d more ($P < 0.001$) and gained nearly 100 g/d more ($P = 0.005$) than those fed the lucerne diet. Nonetheless, pigs fed the lucerne diet had better feed conversion than those fed the control diet. Feed conversion ratio (FCR) of the lucerne diet group and control diet group were 1.93 and 1.99, respectively ($P = 0.014$). Growth performance was the same whether pigs were provided with enrichment material or not.

Although no effect of the experimental factors was found for the carcass traits ($P > 0.05$), there was a tendency for the animals with the enrichment system to have a lower dressing percentage ($P = 0.079$) than their counterparts.

4.2. Feed intake characteristics

As there were no interactions between diet and enrichment provision, only the main effects are presented in Table 4.

The proportion of each day pigs spent in the feeders was the same (around 4.5% of each 24 h period) regardless of which diet the pigs consumed, or whether they were provided with manipulable material. Feed intake characteristics were significantly influenced by diet and manipulable material, whereas there were no interactions between those factors.

Pigs fed the control diet ate 25 g more feed in each visit ($P = 0.043$) and consumed 10 g more feed per min ($P < 0.001$) than pigs fed the lucerne diet. Compared with pigs without manipulable material, those with access to chaff spent less time in the feeders per visit (5.1 vs 3.7 min/visit) and ate less each visit (160 vs 115 g/visit) but made more frequent visits each day (13.7 vs 18.3 visits) ($P < 0.001$).

4.3. Daily behaviour

As there were no interactions between day of observation, diet and enrichment provision, only the main effects results are presented in Table 5.

Video analysis revealed daily pig behaviour was different in terms of their time budget for certain activities, which was influenced by either the dietary treatment or the provision of manipulable material (Table 5 and Fig. 3). The only behaviour not influenced by these factors was the time spent occupying a feeder.

Pigs spent most of their time resting (around 70% of the observation time). The resting time includes the time they were in the lying area. As there was no camera in the lying area, it is assumed, but not certain that they were really resting. The remainder of their day was mostly spent eating or exploring their environment, which was more than 20% for both activities. Across all groups, positive and negative social interactions occurred approximately 2 and 4% of the time, respectively, while other activities occupied about 2% of the time budget.

Dietary treatment minimally affected pig behaviour. The total time budget for resting was about 3% lower for pigs fed the lucerne diet than those fed the control diet ($P < 0.001$). However, pigs fed the control diet only tended ($P = 0.082$) to explore enrichment material more than counterparts fed the lucerne diet (Fig. 3).

However, providing manipulable material obviously caused pig

Table 3
Growth performance and carcass traits in pigs fed a barley-soybean meal-based control diet vs. one containing lucerne, with or without access to enrichment material.

Variable	Diet (D) Control	Lucerne	Enrichment provision (E) No	Yes	SE	*P*-value D	E	D × E
Time on experimental diets until slaughter (d)	60.1	61.9	61.3	60.7	0.83	0.143	0.622	0.326
LW (kg)	26.13	26.65	26.67	26.10	0.476	0.443	0.408	0.313
LW finish (kg)	93.00	90.06	92.94	90.13	1.352	0.132	0.148	0.905
ADG (kg/d)	1.12	1.03	1.08	1.06	0.022	0.005	0.440	0.929
ADFI (kg/d)	2.23	1.98	2.12	2.08	0.047	< 0.001	0.519	0.995
FCR	1.99	1.93	1.96	1.96	0.019	0.014	0.769	0.676
Carcass weight (kg)	70.99	68.27	71.00	68.25	1.164	0.105	0.101	0.970
Dressing out percentage (%)	76.3	75.8	76.3	75.7	0.24	0.156	0.079	0.638
Backfat depth (mm)	10.0	9.7	9.9	9.8	0.30	0.364	0.925	1.000

LW Live weight; ADG: Average daily gain; ADFI: Average daily feed intake; FCR: Feed conversion ratio. SE: standard error

Table 4
Intake characteristics in pigs fed a barley-soybean meal-based control diet vs. one containing lucerne, with or without access to enrichment material.

Variable	Diet (D) Control	Lucerne	Enrichment provision (E) No	Yes	SE	*P*-value D	E	D × E
Number of visits per d	15.4	16.5	13. 7	18.3	0.71	0.269	< 0.001	0.796
Feed intake per visit (g)	151	124	160	115	9.0	0.043	0.001	0.577
Occupation duration per visit (min)	4.4	4.4	5.1	3.7	0.22	0.942	< 0.001	0.709
Feeding rate (g/min)	36	26	32	31	0.8	< 0.001	0.305	0.450
Percentage time spent in feeder per d	4.4	4.7	4.6	4.5	0.12	0.114	0.615	0.357

SE: standard error

Table 5
Behavioural activity in pigs fed a barley-soybean meal-based control diet vs. one containing lucerne, with or without access to enrichment material.

Variable (%/d)	Diet (D) Control	Lucerne	Enrichment provision (E) No	Yes	SE	*P*-value D	E	D × E
Resting[1]	72.4	69.1	74.2	67.4	0.44	< 0.001	< 0.001	0.711
Occupying feeder[1]	9.2	9.4	9.1	9.6	0.20	0.445	0.107	0.530
Total exploration[1]	11.5	12.6	9.5	14.7	0.46	0.085	< 0.001	0.434
Positive social interactions	1.5	1.9	1.6	1.8	0.14	0.033	0.223	0.997
Negative social interactions[1]	3.2	4.6	3.6	4.3	0.24	< 0.001	0.038	0.784
Other behaviours	2.1	2.3	2.1	2.3	0.17	0.424	0.621	0.766

SE: standard error
[1] P-value of the day scanning < 0.05

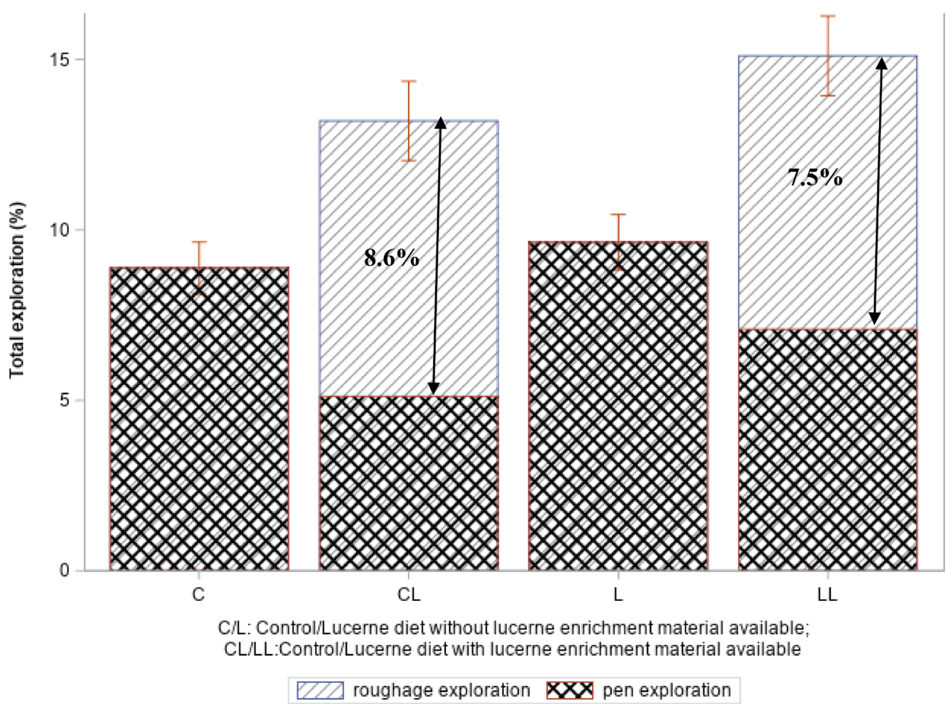

Fig. 3. Exploratory activity in pigs fed a barley-soybean meal-based control diet vs. one containing lucerne, with or without access to enrichment material.

behaviour change through significantly reducing resting time (*P < 0.001*) and increasing exploratory behaviour (*P < 0.001*; Table 5 and Fig. 3). Pigs without manipulable material spent on average 74% of the time resting while the pigs with access to lucerne chaff spent 67% of the time resting on average. Pigs with access to lucerne chaff spent less time exploring their pens, but the total exploration time was 5% greater than pigs without chaff, as they interacted with the manipulable material (Fig. 3).

5. Discussion

Growth performance reduced when lucerne was included in a pelleted diet for growing-finishing pigs, but not when provided as a source of manipulable material. Previous research likewise reported adverse effects on pig growth performance when lucerne was included in growing-finishing pig diets (Lindberg and Andersson, 1998; Thacker and Haq, 2008; Bakare et al., 2013). As expected, supplying lucerne chaff as manipulable material had a significant effect on pig behaviour.

5.1. The effect of lucerne on pig production

Decreased growth rate and feed intake of pigs fed the lucerne diet in the current study agrees with previous research. Thacker and Haq (2008) reported a linear decrease in daily weight gain and feed intake of pigs between 36 and 70 kg when fed increasing levels of dehydrated lucerne meal from 75, 150, 225 to 300 g/kg diet. A similar trend was also reported where pig average daily weight gain and digestible energy intake declined with increasing lucerne inclusion from 20, 40, to 60% in 50 to 100 kg LW pigs (Powley et al., 1981). Dietary fibre inclusion, especially from forages, increases bulkiness and decreases nutrient density of total mixed rations. Bulkiness can cause an early satiety response in pigs, which likely reduces feed consumption (Wenk, 2001). Additionally, bitter-flavoured saponins present in lucerne may influence diet palatability and reduce feed intake (Cheeke et al., 1977; Szumacher-Strabel et al., 2019). Since feed intake is lower, pig growth performance is affected.

However, the most striking observation in the present study is that pigs fed the lucerne diet had a more efficient feed conversion ratio than those fed the control diet. This finding suggests that 10% lucerne inclusion can improve feed digestibility or nutrient utilization of growing-finishing pigs. Thacker and Haq (2008) reported that adding 75 g of lucerne meal/kg feed did not affect apparent faecal digestibility of dry matter, crude protein, and energy of the overall diet when fed to pigs. According to Lindberg and Andersson (1998), inclusion of 10% lucerne in growing pig diets did not impact total tract apparent digestibility of nutrients, energy digestibility, or energy excretion in urine. Instead, digestibility of total fibre, ADF and crude fibre improved when lucerne was included. Nonetheless, a 20% or higher inclusion of lucerne in growing-finishing pig diets reduced nutrient digestibility (Kass et al., 1980b; Lindberg and Andersson, 1998; Thacker and Haq, 2008).

Lucerne may provide a valuable source of dietary fibre to benefit hindgut digestion and health. Although few studies have been performed with lucerne itself, other studies with forage or dietary fibre inclusion reported benefits in young pigs. Ivarsson et al. (2012) found that fibre from chicory forage stimulated hindgut development of weaned piglets. Hindgut fermentation accounts for 7 to 18% of the total available energy absorbed by growing pigs (Anguita et al., 2006). In general, concentration of volatile fatty acids increases with an increase in dietary fibre, however, digestibility also depends on fermentable characteristics of fibre components (Zhao et al., 2020) and pigs' age (Kass et al., 1980a). Production of volatile fatty acids in the hindgut from diets with 0, 20, 40 and 60% alfalfa meal inclusion provided up to 6.9, 11.3, 12.5 and 12.0% of the maintenance energy required for a 48 kg pig, and 4.8, 11.4, 14.0 and 12.0% for an 89 kg pig (Kass et al., 1980a). This suggests incorporating lucerne in pig diets can supply considerable energy from hindgut fermentation for growing-finishing pigs.

Feed efficiency and carcass yield are crucial economic determinants in the pig industry. While carcass yield defines gross income in pig production, feed efficiency governs total cost of production and is key to sustainability. Previous research showed that pigs adapt to fibrous diets by enlarging their digestive organs, therefore, reducing dressing out percentage. Kass et al. (1980b) found that empty gastrointestinal tract weight increased with increasing level of lucerne meal (from 20 to 40 and 60%) in pig diets. Nonetheless, the present results indicate that inclusion of 10% lucerne does not impair carcass quality or yield, hence, carcass value. Therefore, 10% lucerne chaff in growing-finishing pig diets seems a feasible inclusion level for pig producers to reduce their reliance on conventional diet ingredients based on cereal grains, while improving feed efficiency. However, the bulkiness of lucerne chaff provided as enrichment material could be the reason of the tendency of the lower dressing percentage. The animal might ingest some chaff while they were rooting. This finding is in agreement with Presto Åkerfeldt et al. (2019), who found that feeding chicory and red clover silage reduced pig dressing percentage

5.2. Feeding intake characteristics

Feeding behaviour of pigs in the current study clearly differed in response to diet composition and provision of manipulable material. The lower feed intake per visit and slower feeding rate of pigs eating the lucerne diet was possibly driven by a lower palatability and greater bulkiness of that diet, which affected feeding motivation of pigs. As mentioned earlier, pigs can detect and avoid bitter flavours (Nelson and Sanregret, 1997), such as saponins present in alfalfa (Cheeke et al., 1977; Szumacher-Strabel et al., 2019). Furthermore, meal patterns are controlled by hunger and satiety. Bulky diets can cause early satiety during a meal and prolonged satiety post-meal due to vagal stimulation of fullness signals from stomach distention (Howarth et al., 2001). Pigs in the current study fed the lucerne diet ate slower and a smaller amount of feed each visit, and even though feeding frequency and meal duration were similar to those fed the control diet, resulting total daily feed intake was lower. Our findings are in accordance with the reports of Ramonet et al. (1999) and Kallabis and Kaufmann (2012) who found that that feeding rates significantly reduced in restricted-fed sows or finishing pigs that were fed fibrous diets.

5.3. Pig behavioural observations

The advantages of providing manipulable material to pigs housed indoors have been investigated thoroughly (Robert et al., 1993; Brouns et al., 1994; Bergeron et al., 2000; Stewart et al., 2008; Bench et al., 2013). Conversely, few studies exploring the effects of high fibre diets on growing-finishing pig behaviour have been reported.

Providing lucerne for pigs to manipulate improves pig welfare through encouraging exploratory behaviour. Pigs seek out mental and physical stimulation (i.e., enrichment) by interacting with objects in their environment and provided the opportunity, pigs will express behaviours, such as rooting, nosing, digging and playing (Studnitz et al., 2007). Pigs with access to manipulable material spend less time resting and more time involved in exploration and social interaction than those without enrichment (Beattie et al., 2000; van de Weerd and Day, 2009; Cornale et al., 2015).

The higher percentage of negative social interactions among pigs provided lucerne chaff for enrichment compared to those without enrichment seems contradictory, as it would be expected that pigs housed in enriched pens would display fewer incidences of aggressive behaviour than pigs that did not have access to enrichment. A similar observation was reported previously with the possible explanation being that the material provided could cause competition among pen mates and, therefore, heightened aggression (Bracke and Koene, 2019). Research has shown that increasing the amount of straw provided to pigs each day decreases abnormal behaviour towards pen mates (Fraser et al., 1991; Day et al., 2002; Pedersen et al., 2014), however, an insufficient quantity, or lack of access by all group members, might result in social competition or aggression (Fraser et al., 1991; Studnitz et al., 2007; Zwicker et al., 2015). This illustrates the importance of adequate access to enrichment materials for them to be effective. In the present study we supplied 100 g/pig/day to groups of six pigs in pens with solid flooring, with one access point (a tray) per group. There should be further research to quantify lucerne levels and delivery methods, especially in pens with fully or partially slatted flooring, to satisfy exploratory behaviour in growing pigs.

Our results suggest that a diet containing 10% lucerne might affect pig behaviour as these pigs were apparently resting less and socialising more than those consuming the control diet. However, the actual numerical difference in these behaviours between treatments was very small (1 to 3%), so the significance of these observations must be interpreted cautiously. Bakare et al. (2014) found that growing pigs consuming a fibrous diet spent more time active (standing, walking and fighting) and more time eating and lying down than pigs fed a control diet, but once again the actual differences in the time budget (measured as seconds per hour) were very small. The interaction between a pig's diet and their behaviour is not well understood and is likely to be confounded by factors such as sex, breed, age, group composition, housing environment, feeder type, and others. Dietary fibre from lucerne might also influence microbiota-gut-brain axis, with the potential to influence pig social behaviour (Parashar and Udayabanu, 2016; Kobek-Kjeldager et al., 2022). Nonetheless, this complex interaction is still largely unstudied, and differences in pig behaviour caused by dietary treatment in the present study were minimal and unlikely to be behaviourally significant. Further studies on the effects of diet composition on growing pig behaviour are needed.

6. Conclusion

Despite lower daily gain and feed intake, the performance of pigs fed a diet containing 10% lucerne was not significantly different to pigs fed a control diet when considering feed conversion ratio, final slaughter weight, dressing out percentage and backfat thickness. Pigs with access to lucerne roughage used it as an opportunity to engage in more exploratory behaviour. In conclusion, lucerne can be a promising feed ingredient to include in growing-finishing diets and it appears to be an attractive enrichment source to pigs.

CRediT authorship contribution statement

Thanh T. Nguyen: Conceptualization, Methodology, Data curation, Formal analysis, Writing – original draft. **K.L. Chidgey:** Conceptualization, Methodology, Writing – review & editing, Supervision. **T.J. Wester:** Writing – review & editing, Supervision. **P.C.H. Morel:** Conceptualization, Methodology, Data curation, Project administration, Writing – review & editing, Supervision.

Declarations of Competing Interest

None.

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Provision of lucerne in the diet or as a manipulable enrichment material enhances feed efficiency and welfare status for growing-finishing pigs

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