Grower/Finisher Feeders: Design, Behaviour and Performance

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■ Executive Summary

A series of studies were conducted to determine the effects of feeder design on the behaviour and productivity of grow/finish pigs. Twelve commercial models of feeders were classified into 4 groups: single-space dry (2 models), multiple-space dry (4), single-space wet/dry (3), and multiple-space wet/dry (3) and used as the basis for most of the studies. An initial description of the physical properties of the feeders was combined with preliminary behaviour observations to identify design features that influenced eating style. Feeders that provided less than 34 cm of feeding width resulted in crowding with market weight pigs. However, feeding spaces wider than 39 cm increased the frequency of two small pigs eating simultaneously. Side panels more than 34 cm long provided better protection to pigs while eating, reducing the frequency of displacements from the side. Pigs often twisted their heads while eating from the shelf of wet/dry feeders, and both their heads and bodies when eating from unprotected multiple-space dry feeders. Small pigs frequently stepped into feeders which were more than 27 cm deep (lip to feed), and those from which pigs ate from an angled body position.

The feeders were evaluated for their effects on production traits - average daily feed intake (ADFI), average daily gain (ADG), feed efficiency and carcass quality - of grower/finisher pigs. Each model was used by 4 pens of 12 pigs in 12-wk trials under an incomplete block balanced design. ADG and ADFI were 5% greater with wet/dry feeders than with dry ($P<0.05$). The effect of wet/dry feeders on growth was only evident during the final 8 wk of the trial ($P<0.05$). ADFI tended to be higher with wet/dry feeders throughout the trial ($P<0.05$). Pigs using single and multiple space feeders did not differ in either gain or intake during any of the trial periods ($P>0.05$). Feed efficiency did not differ among feeder classes. Dry feeders yielded a slightly higher (1%) lean percentage of carcass than did wet/dry feeders ($P<0.05$).

During the production study, the pigs were videotaped and their eating behaviour analyzed. The total duration of eating varied from less than 75 to over 115 min/day per pig, and the number of displacements (entrances) from less than 30 to over 80 per pig per day, on the different feeders. Large pigs spent less time eating than did small pigs, but spent longer in the feeder per entrance. Wet/dry feeders also resulted in reduced eating time, with an increase in eating speed of approximately 25% compared to dry feeders. Pigs spent less time eating from single space feeders than from multiple space feeders, but this was associated with shorter durations per entrance into the feeder. The combined effects of single space and dry features in a feeder resulted in an average feeder occupancy rate in excess of 80%, which would be higher still for small pigs.

The majority of displacements did not involve force, and this was most evident for feeders with a low occupancy rate. Providing protection to the pig while eating tended to reduce the number of displacements but increased the proportion involving pushing or other force.

Each model was evaluated for feed wastage which was separated into feed spillage on the floor, feed leavage on and in the feeder, and feed adherence to the pig as it left the feeder. The floor spillage patterns

and leavage points within the feeder were also described for each model. All models were within the range of 'good feeders', with a feed spillage rate of 2-5.8% of offered feed. One feeder had an extremely high level of feed adherence to the pigs, due to a problem of feed dropping on the pigs' heads. The size of pig had an effect on feed wastage. Although large and small pigs spilled the same absolute amount of feed, spillage as a percentage of feed disappearance was greater for small (4.4%) compared to large (2.4%) pigs. Leavage within the feeder was greater for large than for small pigs. The differences between feeder categories (dry vs. wet/dry, single vs. multiple space) were not statistically detectable. Rooting and eating were the two behaviours most commonly associated with feed dropping onto the floor. The occurrence of feed spillage due to eating, fighting and stepping into feeder was affected by the size of pig ($P<0.05$). It is recommended that feeders be appropriately sized for the pigs using them.

Two tests were conducted to study the eating speed of grower/finisher pigs. In the first test, hungry pigs were allowed access to each model for a set period of time. Although no differences among feeder categories (dry vs. wet/dry; single vs. multiple space) were detected for eating speed in this test, large pigs ate faster than small ones ($P < 0.05$) and lever-operated feeders resulted in a lower eating speed than non-lever feeders ($P < 0.05$). The second test compared eating speeds of pigs fed a fixed amount of either premixed wet feed or dry mash feed. Pigs on premixed wet feed ate about 3 times faster than did those on dry feed ($P < 0.05$).

Five ergonomic studies were conducted using a specially designed feeder on which the lip height, feeder depth (front to back), width, and feeding shelf height could be adjusted. Pigs were tested at various weights from 22 to 96 kg. The effects of pig size, feeder depth and lip height on the incidence of pigs stepping into the feeder was evaluated in a factorial design. Within the constraints of the experimental design, with limits placed on feeder depth and lip height, small pigs stepped into the feeder more often. The most significant design feature of the feeder for this behaviour was feeder depth. Stepping in was more common as feeder depth was increased, but the point at which it began varied with the size of pig. Grower pigs stepped into a feeder with a depth of 20 cm, but large pigs did not do so until the depth was 30 cm or more. Lip height had only a minor influence on stepping-in, and only at critical depths that depended upon pig weight. The appropriate feeder depth for each weight group of pig could be approximated by observing their normal eating behaviour when no feeder lip was used. The distance from the toe of the pig to its snout increased with pig weight and was similar to the feeder depths resulting in the lowest frequency of stepping-in. A final factor related to feeder dimensions is the restriction the feeder lip places on accessing feed at the front of the feeder. This restriction decreases as pigs grow, but should be accommodated in feeder design by providing a slope behind the lip of the feeder. Although some feeders provided protective side panels on their feeders which define eating spaces, these panels forced pigs to position themselves approximately perpendicular to the feed access point. Two studies examined the angles of the body and head while pigs ate. Pigs prefer to stand at an angle of approximately 30° to the feed access, but in restrictive feeders will turn their heads to obtain some angled approach. Pigs also rotate their heads approximately 45-55° while eating to improve access to the feed. These features should be considered in future feeder design.

Introduction

Feed amounts to over 60% of the total cost of swine production. At the grower/finisher stage, as management becomes less intensive and the overall facility simpler, the proportion of feed cost can be even greater. Grower/finisher feeders play an important role in cost control, and are a central focus at this stage of pig production.

Despite their important role in production systems, many models of feeders coming into the commercial market represent virtually untested designs that have been intuitively developed by innovative producers and equipment manufacturers. Numerous modifications of these primary feeder designs have further complicated the selection process in terms of distinguishing quality differences. Both pork producers and manufacturers in the industry must make decisions without research information on which to base their judgment. Again, an intuitive selection among the commercialized feeders is a common practice in today's market place, which can substantially influence the profitability of an operation. In addition to the capital cost of feeders, there are other hidden, long term effects, such as feed efficiency, feed waste, environmental consequences, labour costs, management intensity, animal health, etc. For example, producers using a grower/finisher feeder that wastes 5% of feed, have to bear 1.8% more total input cost through wasted feed than those using a feeder that wastes only 2% of feed, without any increase in production. They also need to handle more waste and increase labour for cleaning.

To avoid gambling on this heavy capital investment, producers and manufacturers need a professional guide based on systematic evaluations of feeders. Unfortunately, the information leading to such a guide is not systematic, and its availability is usually too sparse to be pieced together to give an overview of today's feeder market. In view of the lack of comprehensive information on feeders, a multi-faceted study was conducted to evaluate 12 grower/finisher feeders, representing 4 major types that predominate in the current feeder market.

Objectives

Overall objectives:

(1) to provide pig producers and swine equipment manufacturers with systematic information on the major types of feeders available in the market;

(2) to develop a knowledge base that can be used to improve feeder design and evaluation procedures;

(3) to enhance domestic manufacturing and export of swine equipment, and thus

(4) to improve the efficiency and competitiveness of the Canadian pork industry.

Objectives for specific studies:

(1) to describe the physical features (configurations, dimensions, capacities, and other specifics) of the feeders, and to empirically describe the pigs behaviour at the feeders;

(2) to evaluate the production performance and carcass quality of pigs using these feeders;

(3) to determine overall and constituent (i.e., spillage, leavage and adherence) feed wastage of the feeders;

(4) to assess maximum eating speed of pigs at each of the tested feeders;

(5) to study the feeder preference of pigs within feeder type and between feeder types;

(6) to investigate the eating ergonomics of pigs on the feeders and at different pig body weights;

(7) to determine the effect of feeder design on eating behaviour.

Chapter 1: Feeder Descriptions

■ Summary

Twelve commercial feeders are included in this chapter which describes the physical features of the feeders and feeding movements of pigs. The individual feeders were classified into 4 groups: single-space dry, multiple-space dry, single-space wet/dry, and multiple-space wet/dry. The physical properties of the feeders included 15 specific features. Pig behaviour at the feeders was studied by direct observation and categorized as 'Feeder competition' and 'Eating style'. Feeders that provided less than 34 cm of feeding width resulted in crowding with market weight pigs. However, feeding spaces wider than 39 cm increased the frequency of two pigs eating simultaneously. Side panels more than 34 cm long provided better protection to pigs while eating, reducing the frequency of displacements from the side. Pigs often twisted their heads while eating from the shelf of wet/dry feeders, and both their heads and bodies when eating from unprotected multiple space dry feeders. Small pigs frequently stepped into feeders which were more than 27 cm deep (lip to feed), and those from which pigs ate from an angled body position. Pig behaviour pertinent to specific topics of the feeder studies is presented in the relevant chapters following in this report.

Physical Features of the Feeders:

Dry Feeders

Feeder	Domino	PSC	ACO (2)	Hog-Slat	Better	Koenders
Feed form	dry, pellet or mash	dry, pellet or mash	dry, pellet or mash	dry, pellet or mash	dry, pellet or mash	dry, pellet or mash
Feeding space	single space	single space	2 spaces	4 spaces	2 spaces	4 spaces
Material	plastic	aluminum	plastic body and polymer concrete base	stainless steel	plastic	plastic
Feeding sides	one-sided	one-sided	one-sided	two-sided	one-sided	one-sided
Protection (head)	yes	yes	yes	no	yes	no
(shoulder)	no	yes	yes	no	yes	no
Width (outside)	345 mm (14")	345 mm (14")	597 mm (24")	1022 mm (40")	724 mm (29")	864 mm (34")
(feeding)	305 mm (12")	295 mm (12")	285 mm (11") x 2	240 mm x 4	305 mm (12") x 2	193 mm (8") x 4
Depth (outside)	375 mm (15")	465 mm (18")	502 mm (20")	622 mm (25")	356 mm (14")	305 mm (12")
(inside)	270 mm (11")	230 mm (9")	300 mm (12")	216 mm (9")	280 mm (11")	265 mm (10")
(protection)	270 mm (11")	385 mm (15")	400 mm (16")	none	350 mm (14")	none
Height (outside)	750 mm (30")	880 mm (35")	800 mm (32")	775 mm (31")	890 mm (35")	905 mm (36")
(feeding)	676 mm (27")	660 mm (26")	635 mm (25")	open on top	660 mm (26")	open on top
(lip)	152 mm (6")	155 mm (6")	203 mm (8")	130 mm (5")	152 mm (6")	165 mm (7")
Area occupied per pen	0.13 m^2	0.16 m^2	0.29 m^2	0.32 m^2	0.26 m^2	0.26 m^2
Feed capacity (mash feed)	26 kg	40 kg	56 kg	136 kg	63 kg	100 kg
Water supply	none	none	none	none	none	none
Gap adapter	1 handle on the top of front panel, locked in a phone dial device	none	none	4 turning screws, 2 for each side, easy to adjust	none	2 handles deep in trough, hard to reach when the feeder is full
Feed gap - type	adjustable between	fixed feed gap	fixed feed gap	adjustable between	fixed feed gap	adjustable between
- range	0-40 mm	20 mm	42 mm	0-30 mm	30 mm	0-75 mm
Agitator	round steel bar	flat metal; almost impossible for pigs to move it when the hopper is full.	None	none	none	none

Feeder	*Domino*	*PSC*	*ACO (2)*	*Hog-Slat*	*Better*	*Koenders*
Feeding area	flat plastic surface surrounded by right angled corners; floor level	flat metal surface surrounded by right angled corners; floor level	polymer concrete bowl; rounded corners; bottom of the bowl is about 30 mm above floor level.	long flat metal surface divided by 3 steel bars to form 4 feeding spaces; floor level	2 plastic bowls with no corner at the bottom, each covered by a plastic ring on top; close to floor level	plastic inward-sloped surface; divided by 3 bars to form 4 feeding spaces; floor level.
Feeder	*Domino*	*PSC*	*ACO (2)*	*Hog-Slat*	*Better*	*Koenders*

▪ Physical Features of the Feeders:

Wet/Dry Feeders

Feeder	*ACO(1)*	*Crystal Spring (1)*	*Dyna-Fab*	*Crystal Spring (2)*	*Tube-O-Mat*	*AQUA*
Feed form	wet/dry	wet/dry	wet/dry	wet/dry	wet/dry	wet/dry
Feeding space	single space	single space	single space	multi-space	multi-space	multi-space
Material	plastic body with polymer concrete base	stainless steel	plastic	stainless steel	plastic tube with metal feeding platform	stainless steel
Sides	one-sided	one-sided	one-sided	two-sided	two-sided	two-sided
Protection (head)	yes	yes	yes	yes	no	no
(shoulder)	yes	no	yes	no	no	no
Width (outside)	470 mm (19")	304 mm (12")	440 mm (17")	615 mm (24")	600 mm (24")	762 mm (30")
(feeding)	325 mm (13")	302 mm (12")	390 mm (15")	305 mm (12")	590 mm (23")	380 mm (15")
Depth (outside)	413 mm (16")	390 mm (15")	444 mm (17")	295 mm (12")	200 mm (8")	229 mm (9")
(feeding)	280 mm (11")	290 mm (11")	410 mm (16")	250 mm (10") from shelf	195 mm (8")	280 mm (11")
(protection)	400 mm (16")	290 mm (11")	410 mm (16")	250 mm; open to the other side at the bottom	none	open to the other side at the bottom
Height (outside)	960 mm (38")	1020 mm (40")	980 mm (39")	790 mm (31")		915 mm (36")
(feeding)	590 mm (23")	590 mm (23")	690 mm (27")	790 mm (31")		915 mm, (36")
(lip)	220 mm (9")	110 mm (4")	147 mm (6")	130 mm (5")	150 mm (6")	135 mm (5")
Area occupied per pen	0.19 m^2	0.12 m^2	0.20 m^2	0.36 m^2	0.24 m^2	0.35 m^2
Feed capacity (mash feed)	52 kg	33 kg	48 kg	53 kg	continuous feed supply	69 kg
Water supply	left back corner over a drinking bowl, a pushing disk	middle, close to the bottom of feeding surface, nipple drinker pointing down and to front.	left back corner; nipple horizontally located, pointing to front.	middle, on dividing bar; one nipple drinker for each of two feeding spaces, pointing to bottom	on either side of feed pipe along fence, and over drinking reservoirs.	1 nipple for each feeding space; each nipple shared by 2 sides; located close to and pointing down to the feeding surface
Gap adapter	none	yes	yes	yes, adjusting the height of feeding shelf	yes, adjusting the height of feeding pipe over the feeding area.	none

Feeder	*ACO(1)*	*Crystal Spring (1)*	*Dyna-Fab*	*Crystal Spring (2)*	*Tube-O-Mat*	*AQUA*
Feed gap type	Fixed	Adjustable	Adjustable	Adjustable	Adjustable	Adjustable
- range	44 mm	0-55 mm	amount of feed per drop	0-100 mm	0-50 mm	amount of feed per drop
Agitator	rod, left-right swinging at the back of feeding area	none	none	none	none	1 agitator for each feeding area
Feeding area	polymer concrete semi-bowl; sloping from left, right, and front towards the back of the feeder.	Stainless steel; sloping inward from front and back	plastic; down- and inward from 4 directions; the bottom area is 220 x 220 mm.	(1) feeding shelf - 305 x 30 mm in area, and 260 mm from the bottom (2) feeding reservoir - front side inward to form a flat feeding surface of 305 x 180 mm	stainless steel platform with 2 drinking reservoirs on both sides.	stainless steel flat surface; 4 feeding holes connected at bottom but separated above 100 mm by steel between adjacent spaces, and by central water pipe or feed reservoir between two feeding sides
Feeder	*ACO(1)*	*CrystalSpring(1)*	*Dyna-Fab*	*Crystal Spring (2)*	*Tube-O-Mat*	*AQUA*

Pig behaviour at feeder:

Competition

Dry feeders.

Domino	*PSC*	*ACO (2)*	*Hog-Slat*	*Better*	*Koenders*
Competition at feeder is usually severe. Two feeder competition strategies were observed: 1) jumping or climbing on the eating pig, which generally assured a high rate of success; 2) pushing from one side of the eating pig. It appeared that side pushing from the fence side is more frequent and successful in gaining access. Retaliation was more likely to follow side pushing than jumping or mounting. Second pig may gain access, but frequently both pigs fought, giving way to a third party. The feeder is not high enough. A pig may reach and eat on the top of feeder when it is fully filled by stepping on the back of another pig.	The style of competition is very similar to that in Domino feeder. This feeder provides deeper side panels, which offers more head protection for the eating pig. Feeder displacement occurred most frequently by mounting the eating pig.	Less fighting at feeder observed, compared to Domino and PSC feeders. Shoulder and head of eating pig shielded by panels on both sides. Pigs waiting to eat may lift rear part of eating pig. Such an action occasionally distracted and caused the eating pig to turn around, but was in most cases ignored. 'Jumping on top' was infrequently seen, and much less successful than in Domino and PSC feeders. Two small pigs occasionally squeeze into one feeding hole. The side panels block or thwart attempts of other pigs to displace the eating pig from the side. Outward arc over feeding holes prevented other pigs from 'top jumping' on the front part of eating pig.	Competition was uncommon. Feeder spaces were rarely full. Pigs seldom mounted each other for feeding space. Predominant strategy was 'side pushing'. Pigs changed feeding spaces often. Head butting or other minor conflicts occurred frequently between neighboring pigs, but severe fights were uncommon.	The style of competition resembles that in ACO(2) feeder, due to the design similarity of these two feeders.	Similar to Hog-Slat. Competition level was generally low.
Domino	*PSC*	*ACO (2)*	*Hog-Slat*	*Better*	*Koenders*

■ Pig behaviour at feeder:

Competition

Wet/Dry Feeders.

ACO (1)	*Crystal Spring (1)*	*Dyna-Fab*	*Crystal Spring (2)*	*Tube-O-Mat*	*AQUA*
Pigs tended to wait for access to feeder rather than compete. Rate of disturbed eating was low. Large number of accesses made without fighting. Might be related to high efficiency of feeder use due to long meal duration (water supply may cause this). Forceful feeder displacement was side pushing. Frequently observed that third pig 'sneaked' into during fighting of previous occupant and second pig	Eating pig more readily displaced by other pigs, especially when head raised to eat from shelf. Seemed difficult for occupant to resume eating after fighting. Most successful strategy appeared to be pushing from side of occupant	Feeder provides widest single feeding hole. Two or even three small pigs could squeeze into the feeder. Competition focused on bottom of feeder. However, feed lever often involuntarily triggered by pig in top position. Feed may drop on head of pig eating at the bottom. This may cause a disassociated reward to rival eating at the bottom, not to pig that triggered lever. Unique indication of severe feeder competition, when feed seen spread on forehead of most pigs.	Similar to Crystal Spring (1).	The majority of accesses were through natural approaches. No 'jumping on top' observed. Side push between two eating pigs was normal means of accessing feeding platform when feeding area crowded.	Approach style of small pigs differed from large pigs. Small pigs competed by pushing or squeezing while large pigs usually jumped or climbed on eating pig. Pigs tended to go deep into the feeder during competition. Repeatedly stepped into feeder, triggering water nipple causing water accumulation. Water accumulation not as frequent when feeder used by large pigs.
ACO (1)	*Crystal Spring (1)*	*Dyna-Fab*	*Crystal Spring (2)*	*Tube-O-Mat*	*AQUA*

▪ Pig behaviour at feeder:

Eating style

Dry Feeders.

Domino	*PSC*	*ACO (2)*	*Hog-Slat*	*Better*	*Koenders*
Pig displacement rate at feeder appeared high. Normal feeding style was 'head-down' to floor level. When reaching toward feed gap, pig usually needs to tilt its head at 30-40° angle to gap. Feed licked or nibbled up from the feed gap or from the vicinity. Large pigs usually did not step into the feeder, but small pigs did. Some pigs ate from top of feed hopper by climbing on top of another pig. Pigs could easily use agitator	Pigs protected from side to a certain degree due to deep side panels. Pigs normally placed front legs outside feeder lip (located inside front-most edge of side panels). Shape of agitator not desirable. When the feeder full. feed pressed flat agitator, making it nearly immovable. Area of agitator is small, making it difficult to move. When agitator lodged at one side of feed gap, pigs could not eat from that side.	Eating pigs protected by side panels. Feeder visit duration long due to protection. Pigs ate with no or slight head tilting. Front legs positioned outside feeder for medium and large pigs, but small pigs tended to put one or both feet in feeder. Feeding hole seemed too narrow to accommodate pigs close to market weight. Front part of large pig is tightly wedged into feeding hole during eating. Environment (light and air quality) inside feeder hole might be uncomfortable.	Pigs ate with bodies perpendicular to feeder when all feeding holes occupied. When fewer pigs eating, they tended to eat at an angle, which frequently changed in degree. Single pig would eat at angle to feeder, or position body parallel to feeder with one foot in feeder. Changing feeding holes was frequent regardless of number eating. Severe competition for feeder occurred only when most pigs eating. Minor conflict more frequent at this feeder than at single space feeders. Brief head or snout butting common.	Eating patterns very similar to those at ACO(2). Edge covering feeding bowls, intended to prevent feed waste, effectively prevented pigs from stepping into feeder. May make it difficult for pigs to eat. Head tilting greater than in ACO(2). Pig's body usually perpendicular to feeder length. Pigs with body weights below 60-70 kg sometimes stand at slight angle (less than 30° from partition panel). Larger pigs rigidly confined by side panels. Pigs seldom stepped into feed bowls.	Some similarities to eating style in Hog-Slat. Large pigs had difficulty reaching feed gap due to narrow feeding holes divided by plastic bars. Bars were at pig's eye position, and little room to avoid bar contact, which may cause discomfort. Some pigs (about 30%) had slight abrasions near eyes. Feeder fouling occurred. Dung was usually pushed to either end of feed trough, causing feed jam or 'dead' corners. Pigs would not use site until cleaned. As a result, feeding activity mainly concentrated at middle sections of feeder.
Domino	*PSC*	*ACO (2)*	*Hog-Slat*	*Better*	*Koenders*

■ Pig behaviour at feeder:

Eating style

Wet/Dry Feeders

ACO (1)	*Crystal Spring (1)*	*Dyna-Fab*	*Crystal Spring (2)*	*Tube-O-Mat*	*AQUA*
Feeder provides fluid feed flow due to wide feed gap. Pigs did not need to lick up or nibble feed from feed gap. Little or no head tilting during eating. Lip height seemed high for young pigs. To reach the bottom of bowl, they regularly stepped into feeder. Medium sized pigs sometimes stepped into feeder to gain firm position during competition. Pigs at or close to market weight did not step into bowl. Feeding hole has insufficient size for market weight pigs. They need to make effort to squeeze bodies in. The upper arch of feeding hole has two sharp corners that created pressure lesions on shoulders of large pigs. More than half of pigs had such lesions when they were close to market weight. Pigs frequently switched between eating from bowl and drinking from adjacent drinker or water reservoir. Meal duration appeared to be longer than at other feeders.	Pigs had to tilt heads at considerable angle to eat from shelf. Width of feeder appeared slightly too narrow for large pigs to do so. Pigs mostly fed from shelf rather than from bottom of feeder. When fresh feed was available at bottom, they tended to eat there. Feed may be pushed or blown off shelf, but most feed consumed on shelf. Water sometimes accumulated at bottom but not as frequently as in Crystal Spring (2). Frequency of movements of hind legs seemed related to degree of difficulty in getting feed from feed gap.	Feed supplied by pushing lever attached at bottom of feed hopper. Different patterns of lever pushing: (1) for small pigs, non-eating pigs usually pushed lever accidentally with head or ears during competition; (2) for large pigs, eating pig pushed with their top of head or ears, but not with snout; (3) when undisturbed, pigs would use snout to push lever. Required pig to withdraw one step from eating position. Feed was consumed from bottom, mixed with water in varying degrees, from completely dry to liquid form.	Eating pattern similar to that in Crystal Spring (1). Water more frequently accumulated. Bottom eating tended to push feed forward, leading pigs to trigger nipples in centre. Feed gap sometimes jammed with wet feed resulting from water brought by pig's mouth or snout after drinking. Feed jamming usually occurred at one or both corners of feed gap. Jam was frequent when feed gap adjusted to a width below ¾".	Open space can comfortably accommodate 3-4 large pigs. When single pig ate, it adopted position with snout at angle to feed gap under pipe. Feed generally present in band no more than 35 mm around pipe. Rest of feeding platform free of feed most of time. Mash feed was mainly licked up, combined with nibbling. When pigs' snouts contacted pipe, feed generally flowed out of gap. Pigs did not often root feed pipe in order to obtain feed.	Pigs quickly learned to operate feed agitators. Although agitator could be pushed deliberately by pig's snout, it could also be pushed by ears or head. Agitator operation less coordinated when several pigs feeding. Feed that dropped down was first consumed on square pipe, especially during competition, but amount so consumed was small. Feed on pipe or at bottom could be pushed to opposite side of feeder by pigs' snout, tongue and ears, or blown by nose. When no feeder competition, pigs preferred to eat from bottom. Most feed was mixed with water in varying degrees. Small or medium sized pigs frequently stepped into feeder, especially during competition. Water nipples sometimes activated by feet, causing water accumulation. Amount of water so accumulated could be much greater than that of 'snout-triggered' water. Feed might be carried away from the feeder on pigs' ears.
ACO (1)	*Crystal Spring (1)*	*Dyna-Fab*	*Crystal Spring (2)*	*Tub-O-Mat*	*AQUA*

Chapter 2: Production Performance

■ Summary

Twelve commercial feeders were evaluated for their effects on production traits - average daily feed intake (ADFI), average daily gain (ADG), feed efficiency and carcass quality - of grower/finisher pigs. Each feeder was used by 4 pens of 12 pigs in 12-wk trials under an incomplete block balanced design. Feeders were classified according to their feed form (dry vs. wet/dry) and space (single vs. multiple space). There were 2 single-space dry (SS-D), 3 single-space wet/dry (SS-WD), 4 multiple-space dry (MS-D), and 3 multiple-space wet/dry (MS-WD). ADG and ADFI were 5% greater with wet/dry feeders than with dry ($P<0.05$). The effect of wet/dry feeders on growth was only evident during the final 8 wk of the trial ($P<0.05$). ADFI tended to be higher with wet/dry feeders throughout the trial ($P<0.05$). Pigs using single and multiple space feeders did not differ in either gain or intake during any of the trial periods ($P>0.05$). Feed efficiency did not differ among feeder classes. Dry feeders yielded a slightly higher (1%) lean percentage of carcass than did wet/dry feeders ($P<0.05$).

■ Introduction

The quality of a grower/finisher feeder is dependent upon a number of factors: its effect on production performance, capital cost, durability, feed wastage and hygiene, pig feeding speed and feeding space allotment, pig-feeder interaction and ergonomic harmony, pig health, ease of management, etc. To pork producers, production performance of a feeder is a primary concern. The quality of a feeder, in turn, is highly dependent on its design features. Among them, feeding methods (wet, dry or wet/dry; pellet or meal) and space provision (single or multiple feeding holes) have been the focus of most studies on grow/finish feeders.

A feeder that offers a built-in water supply appears to have an advantage of higher ADFI and growth rate (Walker, 1990a). Newton (1990) reported that pigs ate 12% more feed and grew 8.7% faster on wet feed than those on dry feed based on sorghum-soybean or maize-soybean. In Walker's study (1990b) these figures were 7.3% and 11.4%, respectively, using single space feeders. Similar results were obtained by many other researchers (Patterson, 1989; van Loozen, 1990; Payne, 1991; Froese and Yacentiuk, 1992; Rantanen, *et al.*, 1995). A few studies have reported no difference between wet/dry and dry feeders (e.g., Rantanen et al., 1996). Another widely accepted merit of wet/dry feeders, is that total water use is substantially lower than for dry feeders (Peer, 1990; van Loozen, 1990; van Cuyck, 1992; Froese and Yacentiuk, 1992; Miyawaki et al., 1994). However, as Patterson (1991) subsequently argued, production differences between wet/dry and dry feeding may not be due to a single factor. Feed form, pellets or mash, has been confounded in some of these studies, and pigs at different ages may react differently to distinctive feeding methods. The beneficial effects of wet feeding were not detected at the weanling stage (Reese, *et al.*, 1990). For whatever reasons, feed conversion of pigs on wet/dry feeders tend to be poorer (van Cuyck, 1992) or no better than that on dry feeders (Froese and Yacentiuk, 1992). Another apparent drawback of using wet/dry feeders is that it may increase fat deposition. Walker (1990b) measured a backfat increase from 12.9 to 14.0 mm as a result of wet feeding.

Feeder space has been another focus for many studies in feeder evaluation. According to Albar and Granier (1989), 20 pigs could be accommodated on one single-space feeder with a nipple drinker. Walker (1991) even managed to accommodate as many as 30 pigs, and claimed that there was no effect on growth rate or carcass backfat, with a feed conversion efficiency at a middle point between 10 and 20 pigs/feeder. Space allotment highly depends on pig eating speed or the way pigs eat, and ultimately on the features of feeder design. Each of many individual factors such as feed flow rate, water availability and feeder competition, etc., may determine the number of pigs per feeding space. A single space feeder may also differ from a multiple space feeder on feeding motivation due to social facilitation among pigs.

A major shortcoming of the previous feeder trials, comparing wet/dry to dry, and single-space to multiple-space feeders, is that only one model of each feeder type was used in each study. The model used may not have been typical of that class of feeders. In light of this, this study included several feeder models in each of the 4 feeder types - single-space dry, single-space wet/dry, multiple-space dry and multiple-space wet/dry, in an attempt to draw some general conclusions regarding the effect of feeder types on pig performance. Presented in this chapter are the results of the production trials.

■ Objectives

(1) To assess production performance - feed intake, daily gain and feed conversion rate - of grower/finisher pigs using different types of feeders;
(2) To evaluate the effect of feeder type on carcass quality.

■ Experimental Methods

Room and Pens

The study was conducted in an 'engineering' room at the Prairie Swine Centre, accommodating 12 pens. Pens had fully slatted concrete floors and spindle penning. Each of the 12 pens measured 4.8 x 2.1 m (16 x 7 ft). Each pen contained 12 pigs with an average space allowance of 0.86 m^2/pig (9.3 ft^2/pig), or approximately 0.042 $m^2/kg\ BW^{.667}$ at the end of the trial. Four blocks or turns of the room were used. A total of 48 pens were involved in the study, representing 4 pens per feeder. Not all feeders could be assigned to each block, due to the two sided feeders that fed 2 pens at once, but as many feeders as possible were included in each room turn. The trial period for each pen was 12 wk.

Feeders

Twelve models of commercially available feeders (Table 2.1) were included in the study. Feeders were classified as dry if no water was available in the feeder, and as single space if only one market weight pig could eat at a time from the feeder. Feeders were installed as part of, or adjacent to, the pen division, approximately 1.6 m from the back of the pen. A single nipple drinker was mounted between the feeder and the rear wall for all dry feeders and the wet/dry feeders (Dyna-Fab and the ACO (1) feeders) whose manufacturers recommended an additional water source. No additional water source was provided for pigs using either Crystal Spring feeder, the Aqua feeder or the Tube-o-Mat feeder. All single space feeders and the Crystal Spring multiple space feeder were oriented such that pigs stood parallel to the pen division while eating. In the case of single space feeders, the pigs faced the rear of the pen while eating. The Hog Slat, Crystal Spring multiple space, Aqua and Tube-o-Mat feeders fed two pens at a time. Feed hoppers were enlarged on some feeders to accommodate sufficient feed for a day. A feed hopper equipped with an agitating rod and motor was installed above the Tube-o-Mat feeder.

Animals

The pigs were Pig Improvement (Canada) stock. Castrated males and females were mixed and allocated evenly among the pens. The average weight of the pigs at the beginning of each block was approximately 25 kg. The pigs were fed a meal (5/32 in. screen) diet based on barley and soybean meal, in a two phase feeding program. For the first 6 wk of the trial the diet provided 3.26 mCal/kg and contained 16.8 % crude protein, and for the final 6 wk, 3.21 mCal/kg and 16.1 %. Pigs were weighed on d 0, and at 2-wk intervals thereafter for 12 wk, when the largest pigs were approaching market weight, and ADG determined for each 2-wk period. ADFI was summarized for the same 2-wk periods. Feed weighbacks did not include wet feed in the feed pans of wet/dry feeders. In the case of two pens sharing the same feeder,

Table 2.1 Feeders included in the evaluation study.

Feeder	Model or Description	Feed form	Space
PSCI	Experimental	Dry	Single
Domino	F-H1	Dry	Single
Crystal Spring	F3050 (12 in)	Wet/Dry	Single
Dyna-Fab	Finishing	Wet/Dry	Single
ACO (1)	Food & Drinker	Wet/Dry	Single
Better	Finisher 2-hole	Dry	Multiple
ACO (2)	ATS 32, 2-hole	Dry	Multiple
Hog Slat	4-hole (40 in)	Dry	Multiple
Koenders	4-hole (34 in)	Dry	Multiple
Aqua	30 in	Wet/Dry	Multiple
Crystal Spring	F3250 (24 in)	Wet/Dry	Multiple
Tube-o-Mat	Egebjerg	Wet/Dry	Multiple

intake was considered to be proportional to gain, resulting in identical efficiencies for both pens. Intake data for one 2-wk period had to be excluded during one trial due to technical difficulties. Malfunction of the feeding system resulted in the loss of intake data for the Tube-o-Mat feeder on several occasions. These were considered missing values in the analysis of ADFI. Feed efficiency was determined over the entire 12-wk period. For pens that had missing ADFIs, data were estimated to allow calculation of efficiency.

■ Statistical Analysis

Four blocks or turns of the room were used. A total of 48 pens were tested in the 4 blocks, representing 4 pens per feeder. Since the room could accommodate only 12 pens, not all feeders could be assigned to each block, due to the two-sided feeders that fed 2 pens at once. The experimental plan was an incomplete block balanced design. Data were analyzed as a split plot design when time effect was of a concern. Pen was considered the experimental unit. When the two main experimental factors - feed form (dry vs. wet/dry) and feeder space (single vs. multiple) - were tested, feeder (model) within form and space was used as the main error term. The sub-plot included weigh period (1-6) and used the feeder by period as the error term. Block effects were removed in the model. Data were analyzed using the GLM procedure of the SAS package.

■ Results and Discussion

Dry vs. Wet/Dry

The overall average daily gain (ADG) for the entire trial, across all feeders, was 895 g/d (1.97 lb/d). The average daily feed intake (ADFI) averaged 2.74 kg/d (6.03 lb/d). The feed efficiency (FE, feed/gain) was 2.96 [or 0.338 (gain/feed)]. ADG was approximately the mid-point of gains for barrows and gilts as the pens were of mixed gender. The feed used was barley based, so feed efficiencies were poorer than would be obtained using corn or wheat based diets. These results were well within the range obtained in trials at the Prairie Swine Centre using this genotype of pigs.

ADG and ADFI were over 5% higher with wet/dry feeders, compared to dry feeders (Table 2.2), but feed efficiency did not differ between dry and wet/dry feeders over the entire trial. When all feeders were plotted in their type clusters (Fig. 2.1), according to their feed form and feeder space, there was very little overlap between classes on ADG and ADFI. The trend for ADG was multiple-space wet/dry > single-space wet/dry > multiple-space dry > single-space dry feeders. ADFI followed the same pattern. Wet/dry feeding resulted in an improved growth rate and a higher feed intake. Compared to ADG and ADFI, feed efficiency (feed/gain) was not very consistent within a feeder group. Even within one model of feeder, pens differed considerably in efficiency, which indicates that efficiency is highly variable among pens.

Table 2.2 ADG, ADFI and efficiency over 12 wk: comparisons between dry and wet/dry, and between single and multiple space feeders

Item	Dry	Wet/Dry	Increase	P	Single	Multiple	P
ADG							
kg	0.87	0.92	5.7%	0.02	0.88	0.90	ns
lb	1.92	2.02		0.02	1.94	1.99	ns
ADFI							
kg	2.66	2.82	6.0%	0.01	2.69	2.77	ns
lb	5.85	6.20		0.01	5.92	6.09	ns
Feed efficiency							
feed/gain	3.040	3.067		ns	3.040	3.077	ns
gain/feed	0.329	0.326		ns	0.329	0.325	ns

To determine the effect of feeder type on different sized pigs, the data were divided into three 4-wk periods, and each period was analyzed separately as an independent data set. For the first 4 wk, ADG was essentially identical for dry and wet/dry feeders (Fig. 2.2). There was little variation among the feeders. During wk 5-8 of the trial, wet/dry feeders had a numerically higher ADG than dry feeders, but the difference was not statistically significant ($P>0.10$). But during the final 4 wk, ADG was significantly higher for the wet/dry feeders ($P<0.01$). The patterns of ADFIs for these periods were very similar to that of ADGs. Despite a pattern of higher ADFI for wet/dry feeders throughout the trial, the differences were only modestly significant during wk 9-12 ($P<0.10$). FE did not differ for any of the 4 wk periods between wet/dry and dry feeders ($P>0.05$).

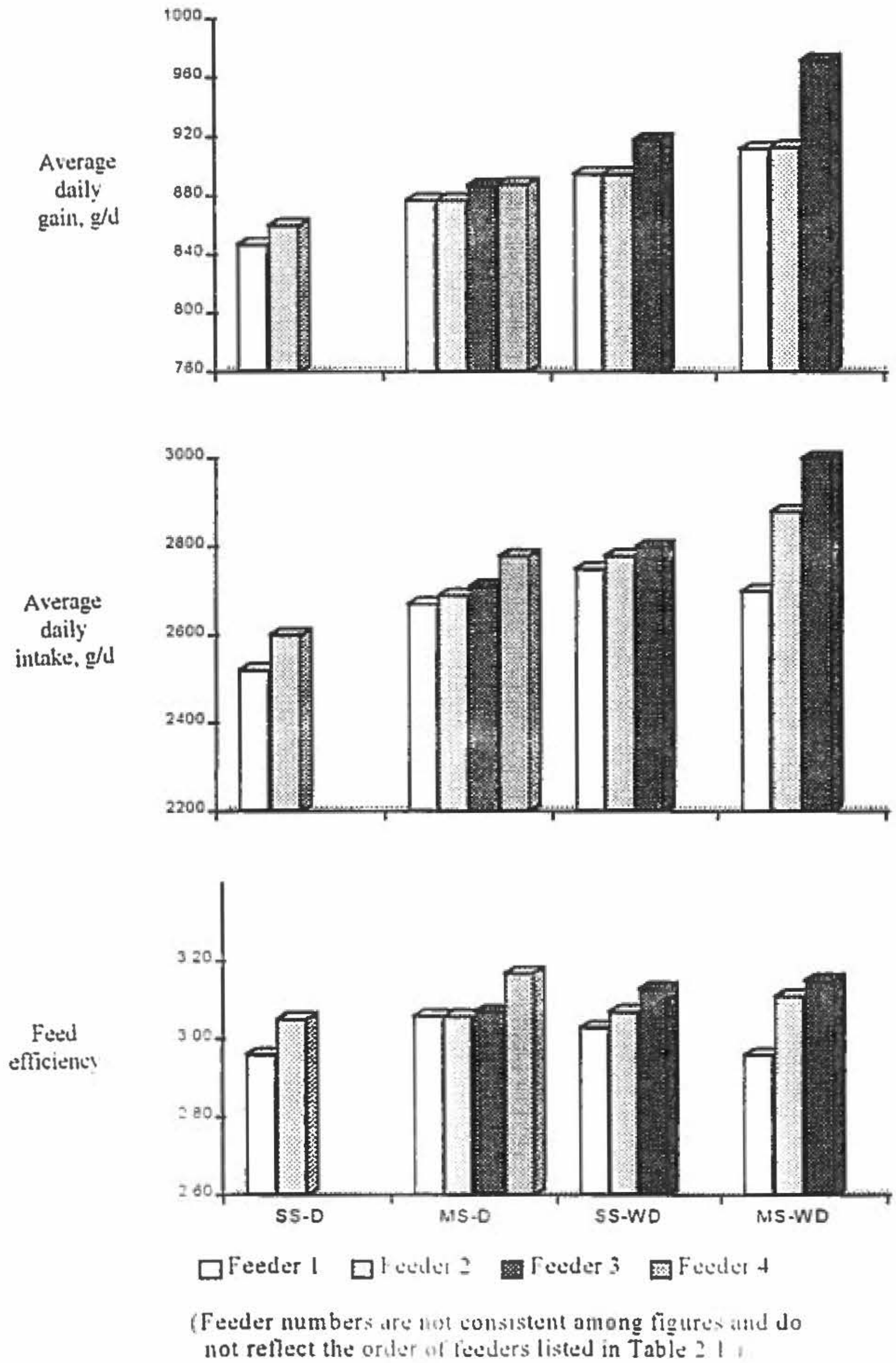
Single vs. Multiple Space

Neither ADG nor ADFI differed between single and multiple space feeders over the 12-wk study. ADG was slightly higher ($P<0.05$) for single space feeders during the first 4 wk (Fig. 2.3), but shifted to be in favor of multiple space feeders during the second 4-wk period ($P<0.10$). During the final 4 wk there was no significant difference. ADFI did not differ between single and multiple space feeders during any of the 4-wk periods of the study. FE did not differ overall nor during any individual 4-wk periods between single and multiple space feeders. Feed efficiency varied substantially within each class of feeder, and among pens for individual feeders.

The single space feeders used in the study provided protection to the head and shoulders of the feeding pig. This protection, during wk 1-4 of the trial when social disputes are most common, may have contributed to the slight increase in gain early in the trials. However, as multiple space feeders tended to produce more gain thereafter, the overall ADG and ADFI were not significantly different between single and multiple space feeders (Table 2.2).

Carcass Evaluation

The carcass quality of the pigs tested was basically the same for all feeder types (Table 2.3). Dry feeders yielded a higher lean percentage than did wet/dry feeders. Among the 4 feeder classes, dry multiple-space feeders resulted in 1% more lean than did wet/dry single-space feeders. Such a result has also been reported by Walker (1990b).



(Feeder numbers are not consistent among figures and do not reflect the order of feeders listed in Table 2.1.)

Figure 2.1. Average daily weight gain, daily feed intake and feed efficiency on 4 types of feeders over 12 week period

Figure 2.2. Comparisons of average daily weight gain, daily feed intake between dry and wet/dry feeders over time

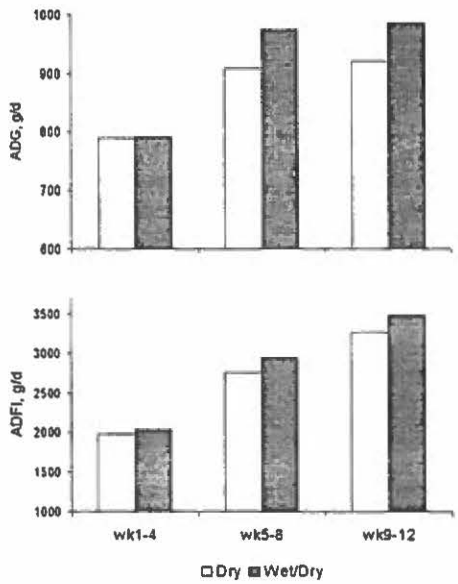


Figure 2.3. Comparisons of ADG, ADFI between single- and multi-space feeders at four week periods

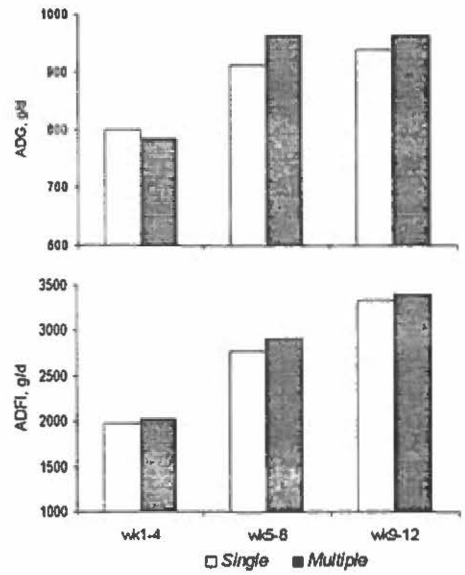


Table 2.3. The effect of feeder types on the carcass quality of pigs.

Feeder type	Carcass wt.	Shipping wt.	Lean		Fat	Index
	(kg)	*(kg)*	*(kg)*	*(%)*	*(kg)*	
Dry	83.4	105.4	56.9	57.0[a]	21.9	108.1
Wet/Dry	83.3	105.4	55.5	56.3[b]	23.0	107.1
Single	83.4	105.4	56.1	56.5	22.5	107.6
Multiple	83.3	105.5	56.4	56.8	22.4	107.6
Dry-Single	83.6	105.6	57.4	56.8[ab]	22.0	108.3
Dry-Multiple	83.2	105.3	56.4	57.2[a]	21.9	107.9
Wet-Single	83.2	105.2	54.7	56.1[b]	23.1	106.5
Wet-Multiple	83.5	105.6	56.3	56.4[b]	23.0	107.3

Means in each class with different superscripts differ at $P < 0.05$.

■ Discussion

The results of ADG and ADFI comparisons of wet/dry and dry feeders further support the findings of previous studies (Patterson, 1989; Newton 1990; van Loozen, 1990; Walker, 1990a; Payne, 1991; Froese and Yacentiuk, 1992; Rantanen, et al., 1995), which found that wet/dry feeding had an advantage of higher ADG and ADFI.

Newton (1990) reported that pigs ate 12.0% more feed and gained 8.7% faster on wet/dry feed than those on dry feed based on sorghum-soybean or maize-soybean. In Walker's study (1990b), ADFI and ADG were increased 7.8% and 11.5%, respectively, using single space wet/dry feeders compared to dry feeding. Our figures are 6.0% for ADFI and 5.7% for ADG (Table 2.2). The palatability of wet feed may be the key factor that leads to a higher ADFI, while the high ADG is merely a consequence of ADFI. The higher ADG and ADFI performance in the wet/dry feeders may be related to the physical form of the feed. Meal or mash diets appear to generate a larger difference between wet/dry and dry feeders than does pelleted feed (Rantanen et al., 1995). These results suggest that the advantages in ADG and ADFI in our study using meal diets may not have been as great if we had used pelleted diets.

Although the higher ADFI on wet/dry feeders contributed to a higher ADG, the increased growth was lower in lean tissue. Thus intake exceeded that required for maximum lean tissue growth. The diets for both wet/dry and dry feeders were identical, and were formulated according to expected intake based on previous studies using dry feeders. Diets for wet/dry feeders should be formulated based on expected intakes in that situation, in order to better match growth requirements. Situation specific formulations may improve carcass characteristics and allow for less costly ingredients in the diet. Otherwise, wet/dry feeders will have a disadvantage in terms of carcass characteristics that must be considered by the producer in selecting his feeding equipment. Wet/dry feeders may be most advantageous with genotypes that produce very lean carcasses and/or are known for poor appetites.

Small pigs did not respond to wet/dry feeders as well as large pigs, which suggests that the greatest advantage in using wet/dry feeders will be achieved on pigs close to market weight. The animals in this study averaged approximately 100 kg at the end of the trials. However, market weights are higher in many regions of Canada and the U.S. and an additional 2-4 weeks may be added to the finishing period. This means that the potential improvements to ADG and ADFI when wet/dry feeders are used may be greater in the industry than observed in this these trials.

Overall no single characteristic of feeders, dry vs. wet/dry or single vs. multiple space, consistently affected feed efficiency. Although efficiency is usually correlated with intake in rapidly growing animals, it is also affected by feed wastage and tissue composition. Wastage in turn is affected by management, maintenance of the equipment, and the eating style of individual pigs. It would appear that efficiency is a critical feature to be considered during design of pig feeders, but does not affect the decision to select wet/dry compared to dry feeders.

Feeding space restriction can lead to poor weight gain and greater weight variation (Petherick and Blackshaw, 1987). However, there has not been general agreement on an optimal pig/feeder space ratio. English et al. (1988) once recommended 4 pigs per feeding space, but such an allotment may be too luxurious to be practical, and feeder design may have improved since that time. Studies have shown that ADG is not affected if a single space feeder is shared by as many as 20 (Albar and Granier, 1989) or even 30 pigs (Walker, 1990a). Therefore, it is not surprising that there were no differences between single space and multiple space feeders in this study when a maximum of 12 pigs shared a feeder.

In the study of feeder space allowance, a critical parameter is the occupation rate of the feeding space. Should a feeder be fully occupied during a significant portion of the day, pigs may spend an excessive amount of energy attempting to access the feed resource. A restless pen may also develop due to the resulting social disturbance. Under such a situation, ADG and feed conversion rate could be lowered. In Walker's study (1990a), feeders were occupied for 55, 82 and 92% of the 24-h observation period with 10, 20 and 30 pigs per single space feeder, respectively. The feeder occupation rate in the current study was relatively low, within a range of 45-83% over

24 h, or 59.3 $\pm$ 12.7% averaged over the 12 feeders (*see Chapter 7*). Therefore, feeder space allowance in this study, i.e. 12 pigs per feeding hole for the single space feeders or 6 or fewer pigs per feeding hole for the multiple space feeders, would not appear to lead to over-crowding at feeders. Differences in gain between single and multiple space feeders would be more likely as group size increases beyond 15-20 animals.

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Chapter 3. Feed Wastage

■ Summary

Twelve commercial feeders were evaluated for their feed wastage due to feed spillage on the floor, feed leavage on and in the feeder, and feed adherence to the pig that was subsequently wasted. Both quantitative and qualitative methods were used. The data were compared among feeder types and individual feeders. The floor spillage patterns and the leavage points within the feeder were also described for each individual feeder. As far as feed spillage is concerned, all the tested feeders were within the range of 'good feeders', with a feed spillage rate of 2-5.8% of offered feed. One feeder had an extremely high level of feed adherence to the pigs, due to a problem of feed dropping on the pigs' heads. The size of pig had an effect on feed wastage. Although large and small pigs spilled the same absolute amount of feed, spillage as a percentage of feed disappearance was greater for small (4.4%) compared to large (2.4%) pigs. Leavage within the feeder was greater for large than for small pigs. The differences between feeder categories (dry vs. wet/dry, single vs. multiple space) were not statistically detectable. Rooting and eating were the two behaviours most commonly associated with feed dropping onto the floor. The occurrence of feed spillage due to eating, fighting and stepping into feeder was affected by the size of pig ($P<0.05$). It is recommended that feeders be appropriately sized for the pigs using them.

■ Introduction

Feed costs comprise 60-70% of the total expense budget for a swine operation, and the grower-finisher phase accounts for the majority of this expense. Therefore, any reduction in feed wastage from grower and finisher feeders will contribute significantly to the profitability of the industry. Early investigations reported that feed wastage from ill-designed feeders could be as high as 25% (Gill, 1964; Hovarth and Elliott, 1964). Considerable progress in controlling wastage has been made in the past decade. Although the wastage from feeders currently used in the industry may still range from 4-30% of offered feed (Payne, 1991), only feeders with a feed wastage of less than 8% should be considered acceptable. As little as 1.5% waste has been reported from some feeders (Taylor and Curtis, 1989).

Hutson (1995) believes that much wastage results from poor feeder design, and that improvement of feeder design can reduce waste. Many factors such as feed form (dry vs. wet, pellet vs. mash), feeder configuration (dimension, shape, space separation), and the number of feeder spaces (single vs. multiple space) may affect feed wastage. These factors usually interact with one another, and all need to be considered in a single design.

Wastage is, in essence, a result of the interaction between pig and feeder. Hardware design of a feeder works merely to accommodate its users in a way that lower wastage can be achieved. A marked reduction of feed wastage can be accomplished by design changes based on specific pig behaviors (Taylor, 1990). The pig's social activities, such as aggression at the feeder, also have a great impact on waste. For example, frequent withdrawal from a feeder to fight can cause a high level of feed spillage (Walker, 1990). After head and nose barriers were installed to lower aggression levels, a reduction in feed spillage was observed for pigs on a pelleted diet (Baxter, 1991). However, the same design modifications did not appear to reduce waste when meal feed was provided (Walker, 1990). Similar behavioral studies on grower pigs have resulted in the development of more efficient multiple-space dry feeders (Baxter, 1989).

Feed can be wasted in different ways: spilled onto the floor, caught in inaccessible places to decay, or adhering to the pig only to fall off later. The multiple sources of loss make the quantification of feed wastage a complex problem. Technically it is difficult to separate wasted feed from feces, urine and saliva of pigs in conventional facilities. In addition, there is also a lack of sophistication in the evaluation methods, which often fail to identify the various sources of feed wastage.

■ Objectives

(1) To refine the methodology used for feed wastage evaluation, i.e., to classify and assess various sources of feed wastage under three categories: feed spillage, feed leavage and feed adherence;
(2) To determine the level of wastage in each category for different feeder types, as well as for individual feeder designs;
(3) To determine the relationships among elements of pig eating behaviour, pig size, and feed spillage.

■ Experimental Procedure

Feed Wastage

The study was conducted on 12 feeders, representing 4 main types of grower/finisher feeders in the current market (dry-single space, wet/dry-single space, dry-multi-space and wet/dry multi-space). Feeders were managed based on previous experience, with gaps of adjustable feeders set at approximately 1.5 cm (5/8 in) and feed drops at approximately 6 grams. The test used 2 sizes of pigs: small pigs averaged 24.8 $\pm$ 3.5 and 49.8 $\pm$ 7.4 kg, and large pigs averaged 83.4 $\pm$ 3.0 and 98.3 $\pm$ 4.1 kg, at the beginning and end of the test periods, respectively. Two groups of each sized pigs were studied on each feeder. Four experimental pens, each measuring 2.4 x 2.4 m and accommodating 5 pigs of mixed sex, were used. The walls of each pen were solid plastic panels, while the floor was plastic coated expanded metal. Pigs were allowed 2 d to acclimate themselves to the new environment and mash feed after they were moved into the test pens. They were also allowed a day to learn to operate each new feeder when it was introduced to replace the previous one.

Feed disappearance from a feeder was measured over a period of 48 h. Feed wastage was evaluated by both qualitative and quantitative approaches. The qualitative evaluation included direct observations of the dispersion patterns of feed spillage and the primary locations within each feeder that could not be cleaned by pigs. After a feeder had been used for 2 d, dispersion patterns of feed spillage were observed by checking the feed spilled on the plastic coated perforated floor, and on collection trays and the room floor beneath the pen. Locations of feed leavage were noted during collection of inaccessible feed from the feeders. The quantitative results included the amounts of feed *spillage*, feed *leavage* and feed *adherence*, which were collected as follows:

Spillage was collected with a galvanized steel tray, measuring 1500 mm long, 1000 mm wide and 60 mm deep. The tray was placed under the pen floor for 2 d. Feed spilled on the pen floor was brushed into the tray prior to the collection of spillage. Feed spillage in the tray was manually separated from the other waste, and gathered into a plastic bag. The samples were stored in a freezer until the end of the experiment. To keep the moisture level of the samples close to that of normal feed, the samples were defrosted and dried in an oven at 50 ^{0}C, and placed for at least 12 h at room temperature, prior to weighing. A similar amount of normal mash feed underwent the same weighing process as a control.

Leavage is defined as the amount of residual feed in a feeder that can not be accessed by pigs. Each feeder was cleaned by vacuuming at the beginning of the test. A small amount of feed, depending upon the size of the pigs, was added to the feeder, and pigs were allowed access to the feeder for 3 h. During this period the pigs removed all of the accessible feed. Leavage was then scraped into a plastic bag and the samples weighed following the same procedure as for spillage.

Adherence is defined as the amount of feed left on a pig's body, such as on the snout, ears, face, head, shoulder, or feet, after eating. Feed was withheld for 3 h before each test, to increase the pigs' appetite. Each pig was cleaned, allowed to eat for 30 s, and then restrained. Feed adhering to the pig's body was brushed off into a collection tray, and weighed. Adherence data were only collected from small pigs.

Behaviour Associated with Feed Waste

During each of the feed wastage studies described above, the pigs were observed to determine behaviour associated with spillage. The action patterns of eating pigs were monitored by a camera mounted on the top of the feeder. Another camera was placed under the floor, monitoring any feed drops due to pig activities. The images from these two cameras were then merged onto one video screen for viewing. A pen was so monitored for 6 h, at a speed of 20 frames/second. The behavioural patterns associated with spillage of feed were classified as: *backing* - pig was retreating from the feeder; *eating* - pig was eating without significant body movement; *fighting* - pig was engaged in aggression with another pig; *rooting* - pig was rooting outside of the feeder; and *stepping* - pig placed a foot in-and-out of the feeder. To study the effect of side protection of a feeder on feed wastage due to pig fighting, feeders were classified into two categories - protected feeders and non -protected feeders. The protected feeders had panels on both sides that were deep enough to hide the pig's head while it was eating. These feeders included SS-D-1, SS-D-2, MS-D-1, MS-D-2, SS-WD-1, and SS-WD-3 feeders. The non-protected feeders were those that offered little or no protection (such as separating bars)
for the sides of the eating pig. These included MS-D-3, MS-D-4, SS-WD-2, MS-WD-1, MS-WD-2, and MS-WD-3 feeders.

Statistical Analysis

All data were analyzed using the *GLM* procedure of SAS (SAS Institute Inc., 1990). Feed consumption, spillage and leavage data were analyzed as a *CRD* factorial design for individual feeders.

$$Y_{ijk} = \mu + T_i + S_j + TS_{ij} + R_k + \varepsilon_{ijk}$$

where, *T*= Treatments (Feeders), *i*= 12; *S* = Size of pigs, *j*= 2; *R*= Replications, *k*= 2.
And for feeder types, the data were analyzed as

$$Y_{ijkl} = \mu + F_i + P_j + S_k + FP_{ij} + FS_{ik} + PS_{jk} + FSP_{ijk} + R_l + \varepsilon_{ijkl}$$

where, *F*= Feed form, *i*= 2; *P*= Feeder space, *j*= 2; *S* = Size of pigs, *k*= 2; *R*= Replications, *l*= 2.

Feed adherence data were analyzed for individual feeders, according to the model

$$Y_{ijk} = \mu + T_i + P_j + R_k + \varepsilon_{ijk}$$

where, *T* = Treatments (Feeders), *i*= 12; *P* = Periods, *j* = 2; *R*= Replications, *k*= 4.
and for feeder types analysis

$$Y_{ijkl} = \mu + F_i + S_j + FS_{ij} + P_k + R_l + \varepsilon_{ijkl}$$

where, *F*= Feed form, *i*= 2; *S* = Feeder Space, *j*= 2; *P*= Periods, *k*= 2; *R*= Replications, *l*= 4.
Behavioural data were subject to ANOVA analyses based on percentage values.

■ Results

Analysis of Feeder Types

Feed Wastage. There was a significant difference in feed disappearance between large and small pigs (**Table 3.1**), but the amount of feed spilled by large pigs was similar to that by small pigs. Therefore, feed spillage as a percentage of total feed consumption differed significantly between the two size groups (4.4 vs. 2.4% for small and large pigs, respectively). Feed leavage differed between the two size groups (**Table 3.1**). The amount of leavage for large pigs was about 4 times that for small pigs. This difference in leavage between large and small pigs might be because, (1) large pigs had a reduced ability to clean dead corners or edges due to bigger snouts; and (2) large pigs could reach and deposit feed on a larger area of feeder surface. Interactions between pig size and feeder form or space were not significant.

There were no differences between multiple-space and single-space feeders in spillage, percentage of feed spilled, or feed leavage (P > .05, **Table 3.1**). More feed was spilled from wet/dry feeders than from dry feeders (**Table 3.1**), but as more feed disappeared from wet/dry feeders, no significant difference in spillage as a percentage was found between the two feed forms. Further analysis indicated that the higher spillage on wet/dry feeders was primarily due to the greater loss from single-space wet/dry feeders (Table 3.2). Feed leavage was lower for the single-space dry feeders compared to the other three types (Table 3.2).

Table 3.1 Effects of pig size, feeder space and feed form on feed disappearance, feed spillage and feed leavage.

	Pig Size			Feeder Space			Feed Form		
Feed	Large	Small	P	Multiple	Single	P	Dry	Wet/dry	P
Disappearance *(g/d/pig)*	2931	1969	*0.01*	2418	2481	*ns*	2409	2491	*ns*
Spillage *(g/d/pen)*	345	377	*ns*	332	391	*ns*	314	408	*0.05*
(%)	2.4	4.4	*0.01*	3.1	3.6	*ns*	3.0	3.7	*ns*
Leavage* *(g/feeder)*	77	18	*0.01*	53	43	*ns*	47	48	*ns*

* For the two sided feeders, the data represent leavage for each side.

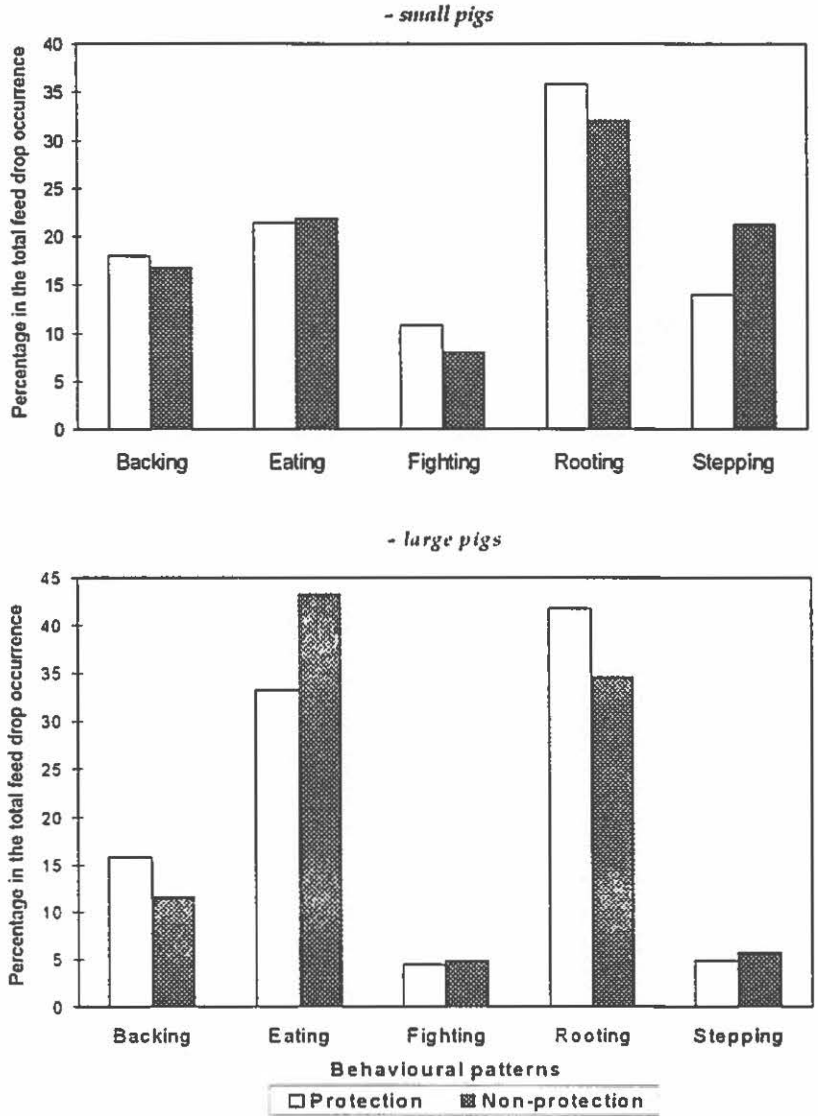
Table 3.2 Comparisons of feed disappearance, feed spillage and feed leavage among 4 types of feeders.

	Multi-space		Single-space	
Feed	Dry	Wet/Dry	Dry	Wet/Dry
Disappearance *(g/d/pig)*	2532	2547	2384	2580
Spillage *(g/d/pen)*	333[a]	365[ab]	292[a]	489[b]
(%)	3.5	2.9	2.7	4.5
Leavage* *(g/feeder)*	62[a]	51[ab]	32[b]	54[a]

Feeders with different superscripts differ, at P< .05.
*For the two sided feeders, the data represent leavage for each side.

Behavior Associated with Feed Wastage. Rooting was the behaviour most frequently associated with feed wastage for both small and large pigs, accounting for more than 30 and 35% of wasting events for each pig size, respectively (Fig. 3.1). Eating behaviour was also a primary source of wastage for large pigs, exceeding 35% of wasteful movements compared to less than 25% for small pigs (P<.01). These eating movements did not involve the pig stepping back from the feeder. A greater proportion of the wasteful movements involved stepping into the feed for small (20%) than for large pigs (9%, P<.05). Fighting was not a common source of feed wastage, although it was more frequent for small (11.5%) than for large pigs (7.0%, P<.05)). There were no significant differences in the relative frequency of any wasteful behaviour - backing, eating, fighting, rooting and stepping - between the side protected feeders and the non-protected feeders, for either small or large pigs.

Figure 3.1. Pig behaviour associated with feed waste on feeders with or without side protections for feeding holes



Analyses of Individual Feeders

Feed wastage. **SS-D-1.** This feeder had a low level of spillage, as well as of leavage (Table 3.3). The relatively small size of this feeder does not permit much head movement, and even though rooting was a common source of wasted feed, the amount was small. Spillage occurred under only a small area of the floor (Fig. 3.2). The feeding surface of the feeder is small and made of polished plastic material, which seemed to reduce feed leavage on the surface.

Table 3.3 Total feed disappearance, feed spillage, leavage and adherence of 12 individual feeders

	Disappearance	Spillage		Leavage	Adherence
	(g/d/pig)	*(g/d/pen)*	*(%)*	*(g/feeder)*	*(g/visit)*
SS-D-1	2578^{ab}	297^{bc}	2.4	26^{ef}	1.46^{b}
SS-D-2	2190^{b}	287^{bc}	2.9	37^{def}	1.23^{b}
MS-D-1	2510^{ab}	442^{abc}	5.8	41^{cdef}	1.63^{b}
MS-D-2	2427^{b}	313^{bc}	2.8	79^{a}	1.05^{b}
MS-D-3	2140^{b}	346^{abc}	3.1	67^{ab}	0.89^{b}
MS-D-4	2658^{ab}	244^{c}	2.0	67^{ab}	1.09^{b}
SS-WD-1	2493^{ab}	490^{ab}	4.8	65^{abc}	1.24^{b}
SS-WD-2	2239^{b}	416^{abc}	5.0	45^{bcdef}	1.76^{b}
SS-WD-3	3008^{a}	561^{a}	3.7	51^{bcd}	3.64^{a}
MS-WD-1	2541^{ab}	411^{abc}	3.3	53^{bcd}	1.30^{b}
MS-WD-2	2554^{ab}	320^{bc}	2.5	50^{bcde}	1.04^{b}
MS-WD-3	2113^{b}	249^{c}	2.8	22^{f}	1.38^{b}
Overall Mean			3.42	50.2	1.47

Means in the same column with different superscripts differ at $P < .05$.

SS-D-2. Spillage from this feeder was below average (Table 3.3). The result might be explained in a similar way as for the SS-D-1 feeder: pigs were not allowed much head movement, and rooting was a less frequent behaviour than for SS-D-1. Spillage was located under a small area of the floor (Fig. 3.2). The feeder also had a low leavage. The leavage points of the feeder were found at both corners where the front panel joins the side panels, and at the two ends of feed gaps. The shorter depth of the feeder may have contributed to the marked shift from wastage during backing to eating in small and large pigs.

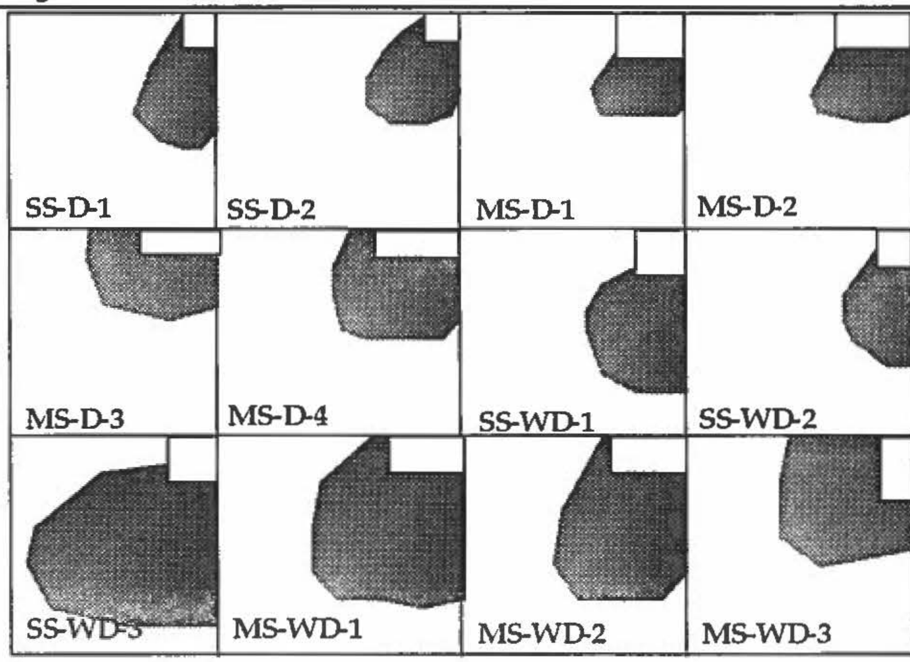


Figure 3.2 Feed Spillage Floor Patterns of 12 Feeders

MS-D-1. Feed spillage was relatively high for this feeder (Table 3.3) but was restricted to a small area beneath the floor (Fig. 3.2). This is surprising considering the earlier report of very low spillage from this feeder (Baxter, 1991). However, these differences may be due to our use of mash rather than the pelleted feed, and our inclusion of a test with small pigs. Rooting was the primary behaviour associated with wastage, particularly for the small pigs. As with other feeders (e.g. SS-WD-3), the model used in the study was specifically designed for finishing pigs, with smaller versions available for growers. These results demonstrate the importance selecting the most appropriate size of feeder for the pigs being fed. Among the dry feeders, the amount of feed adhering to the pigs following a meal was relatively high.

MS-D-2. The feeder was furnished with a curved horizontal lip to cover the edge of its feeding bowl, which might have contributed to its below average spillage (Table 3.3). Spillage was over a small portion of the floor, immediately in front of the feeder (Fig. 3.2). However, the leavage at this feeder was particularly high. Most leavage was found on the upper part of the feeding bowl, a location that pigs could not reach. The typical shift of wasteful behaviours from stepping-in to rooting was observed for small and large pigs.

MS-D-3. Spillage from this feeder was moderate, but leavage was among the highest of the 12 feeders (Table 3.3). The feeder had similar design features to the MS-D-4 feeder, but spillage appeared to be higher. The feeder lip of the MS-D-3 is lower than the MS-D-4, which might have contributed to the difference. The low feeder lip may also have contributed to the greater proportion of eating related spillage for large pigs. Leavage at the two ends of the feeder trough of this feeder was much less severe than that of the MS-D-4 feeder.

MS-D-4. The lowest percentage of spillage was found in this feeder (Table 3.3). The deep feed trough and the narrow space for each feeding hole might be responsible for the results. The feeder usually had substantial amounts of feed leavage. The whole feeding trough was sometimes coated with wet feed. This might be due to the nature of feeder materials, but more likely due to its hard-to-access design. Pigs might have to lick harder to get feed, and more saliva could then be deposited to the surface to form a leavage coating. Severe leavage was found in both ends of its long trough. Under normal operating conditions, these ends tended to collect spoiled feed.

SS-WD-1. Feed spillage from this feeder was relatively high (4.8%) compared to the other feeders. For small pigs, there was relatively more fighting and backing associated feed waste than for other feeders. Spillage also extended under a larger area of the floor compared to the dry single space feeders (Fig. 3.2).

The polymer concrete used for the base of the feeder seemed to attract wet feed and resulted in a thick layer of leavage. A substantial amount of leavage was collected from the side surface of the feeding bowl. The rounded corners of the bowl reduced the amount of feed leavage in those areas. Wet feed was occasionally seen to accumulate at back of the feed gap. The water reservoir of the SS-WD-1 usually contained some feed along with water. The caking effect of the feed made this a difficult feeder to clean.

SS-WD-2. This single space feeder resulted in relatively high spillage and adherence, and moderate leavage (Table 3.3). Spillage occurred during stepping-in for small pigs but shifted to eating and rooting for large pigs. The greater feeder depth, compared to SS-WD-1, may have contributed to this shift. The high level of adherence may have been due to the need to access dry feed with a wet snout during feeding bouts. The areas under the feed platform and around the nipple accumulated leavage deposit. Both ends of the feed gap were occasionally plugged with wet feed. Leavage was also found in the gap between the hopper wall and the adjusting panel above the feed gap. Compared to plastic feeders, the surface of this feeder was not heavily coated with leavage feed.

SS-WD-3. This feeder resulted in a moderate level of feed spillage (Table 3.3). Feed was observed dropping onto the head of pigs as they ate, leading to a high level of feed adherence (Table 3.3). The feeder requires a pig to root up the lever for feed delivery, and then put its head down to eat at the bottom. However, when feeder competition level was high, there were two unexpected feeder operations: *a*) the eating pig frequently triggered the feed lever by the back of its head or by its ears, dropping feed on itself; *b*) when two pigs squeezed in, the one on top might press the lever during its struggle to reach the bottom, which dropped feed on the pig at the bottom. The width of this feeder was such that two small pigs would attempt to eat simultaneously, resulting in the second style of wastage. Wastage was more common during eating for small pigs than for large. The feed that dropped onto the pig's head was subsequently carried away when the pig moved away from the feeder, and widely spread over a large area of the pen (Fig. 3.2). It should be noted, that the model used in the study was designed for finishing pigs, and that the manufacturer recommends a smaller version for grower pigs.

Leavage in this feeder was moderate (Table 3.3), despite the feeder's large interior surface. The streamlined shape of the trough bottom, with rounded corners, seemed to be successful in eliminating feed deposits in corners or edges. Most leavage was collected from the back corner beside and around the nipple drinker. The corner was frequently visited, but difficult for pigs to clean due to space limitation. Leavage also accumulated at the back of the hopper opening. This area was difficult to inspect and clean.

MS-WD-1. Spillage, leavage, and adherence were in the middle range for all tested feeders (Table 3.3). Feed sometimes dropped onto the pig's snout, mostly onto its tip, but only a little feed was carried away from the feeder. This was perhaps because they used the nipple drinkers within the feeder, which washed the feed off before they retreated from the feeder. Spillage was spread over a large area of the pen, as with most wet/dry feeders (Fig. 3.2). Leavage was found mostly at the corners between the front and partition panels, and above the horizontal, square water pipe, especially at its points of joining to the side walls. The bottom of the feeder was usually without leavage under the experimental condition, under which pigs cleaned all accessible feed due to the pre-trial feed deprivation. However, under normal conditions, a large amount of feed was occasionally seen to have accumulated in the feeder, and water in the feeding area was severely contaminated. Stepping-in was a common wasteful behaviour which may be related to its above average feeding depth.

MS-WD-2. This feeder had moderate levels of spillage and leavage (Table 3.3). The amount of adherence was low, particularly when one considers that the single-space model (SS-WD-2) had high levels of feed sticking to the pig. The areas under the feed platform and around the nipple accumulated leavage deposits. Both ends of the feed gap were occasionally plugged by wet feed. Leavage was also found in the gap between the hopper wall and the adjusting panel above the feed gap. Compared to plastic feeders, the surfaces of these two feeders were not heavily coated with leavage feed. Technical problems resulted in loss of wasteful behaviour for small pigs, but the pattern observed for large pigs was typical of most feeders.

MS-WD-3. Spillage and leavage for this feeder were at the lower end of the corresponding ranges among all feeders (Table 3.3). The feeder was clean for most of time, but when it was fouled by feces, a large amount of spoiled feed mixed with water accumulated. The spillage pattern within the pen was similar to that for other wet/dry feeders (Fig. 3.2). The proportional distribution of wasteful behaviours was similar to the overall means for all feeders (Fig 3.1).

■ Discussion

Spillage

For all feeders, feed was spilled mostly in the vicinity of the feeder. The density of spilled feed gradually declined as the distance from the feeder increased. The dry feeders tended to have an area of dense feed spillage immediately beside the feeder, and the spillage area was smaller than that for wet/dry feeders. Williams and Moore (1993) also observed such a spatial pattern difference between wet/dry and dry feeders. This suggests that feed from wet/dry feeders is more likely to be carried on the pig's snout or other body parts further away from feeders. A pen with large pigs commonly had a larger spillage area than one with small pigs.

Because the actual spill area was sometimes larger than the area of the collection tray, the amount of spilled feed collected could be smaller than the true value. This was especially true when wet/dry feeders were used due to their having a more dispersed area of spillage. Accordingly, the spillage as a percentage would be greater than presented in this study. With a tray of unreported size, Williams and Moore (1993) determined that only about 74% of the wastage could be collected in the tray. However, a spill tray that fully covers a test pen may only result in less accurate measurement, because it is causing more mixture of spilled feed with urine, feces etc. Williams and Moore (1993) have suggested an alternative method of determining wastage which uses an internal marker (feed constituent).

Leavage

Leavage can be further divided into two types: physically inaccessible feed and coated feed. After pigs had cleaned the feeder, most of the remaining feed was physically inaccessible, usually at the feeder's corners and edges. Coated feed appeared to depend on the surface material of the feeder. Parts made of stainless steel generally attracted less feed. Parts made of polymer concrete, used in SS-WD-1 and MS-D-1, were usually covered by a thick feed coating. This may be related to the surface smoothness of different materials, but may also be related to the nature of these materials.

Wet/dry feeders usually appeared cleaner at the bottom of the trough than did dry feeders, although feeders were not necessarily wet at the time of leavage collection. It can then be assumed that water may help pigs to clean the surface. However, because wet feed could spoil quickly and be avoided by the pigs, an accumulation could occur until the feeder was cleaned by a stockperson. It is more important that wet/dry feeders do not have inaccessible areas in the feed trough compared to dry feeders, because of the potential for spoiled feed. Although all wet/dry feeders separated the water and feed access points, there was evidence in several that water had been transferred on the snout of the pigs or as a spray, and had caused some degree of feed blockage. It is suggested that wet/dry feeders be inspected more frequently than dry feeders to ensure feed access is maintained.

Adherence

There were no statistical differences detected between feed forms (dry vs. wet/dry) and between feeder space allowances (single vs. multiple) for feed adherence. However, there was a four-fold difference between the feeders with the most and least adherence. This amount of between feeder variation suggests that some aspects of design are involved. The major cause of feed adherence observed in the most troublesome feeder was the dropping of feed onto the animal. Such feed access mechanisms are common in wet/dry feeders but these results suggest that modifications should be made to drop the feed away from or below the pigs snout. The manufacturer of the feeder in question has done so in a more recent model.

Behavior Associated with Feed Waste

Feed wastage is closely associated with specific actions of pigs during eating. However, these actions can be influenced by various factors in the pigs' feeding environment, which include the design features of a feeder, social environment and pig sizes. Rooting was observed to be associated with feed dropping through the floor for both small and large pigs. Rooting behaviour is likely associated with attempting to apprehend feed from the floor after it has been removed from the trough. Two methods of controlling feed waste due to this behaviour seemed to be used by the manufacturers. The first was to present the pig with a large, relatively open and accessible eating area. Examples of this could be seen in the SS-WD-2 and MS-WD-2 feeders. Rooting, particularly among small pigs, was not a major cause of feed wastage for these feeders. The second approach was to use structures to keep the feed in the trough. The MS-D-4 feeder did this by having a deep feed trough. The MS-D-1 and MS-D-2 feeders designed the feeder access area to fit close to the throat of the pig. Among dry feeders, lip heights of less than 130 cm or greater than 160 cm seemed to result in a greater proportion of wasteful rooting movements among small pigs.

Stepping into the feeder was more often associated with feed waste for small than for large pigs. This behaviour appeared to occur more often if the distance from lip to feed exceeded 275 cm (Chapter 1). However, no consistent trend could be determined from the observations in this portion of the study. The drop in the relative importance of this behaviour with larger pigs is likely associated with the increase in body dimensions of the pig, making it less necessary to step over or into the trough to reach the feed access point.

Wastage associated with eating was more common for larger pigs than for small. This suggests that the larger pig may be standing too far back from the feed lip for the trough to catch feed drops while eating. Among dry feeders, a depth of trough (lip to feed) of less than 230 cm appeared to increase the frequency of this problem. Combining this observation with that for stepping, results in the suggestion that the distance from lip to feed access point should be between 240 and 260 cm. This recommendation would change if the feeder were only to be used on small or large pigs.

Pig fighting is generally considered a major contributor to feed spillage, and such waste can be reduced by head or shoulder barriers (Baxter, 1991). However, in our study, fighting associated waste was rare and was not related to the presence of head and shoulder protection. This may be due to the small number of pigs (5) assigned to the feeders in this study. Competition for feeding space would be low and, even among unprotected feeders, would not cause pigs to frequently enter and leave the feeder.

■ General Considerations

These studies have identified a number of causes of feed wastage and should allow manufacturers to make appropriate modifications to their feeders. However, it is also clear that wastage is a complex problem and all such studies have limitations that must be considered when applying the results. It was clear from our study that wastage differed with the size of pig, both in terms of amount and the nature of the loss. Although some of the feeder models used are recommended for both grower and finisher pigs, some are not, and the results would be biased against them. It should also be noted, when comparing these results with other studies, that size of pig is critical, with small pig wasting nearly double the percentage of large pigs.

The feeders in these studies were set to a predetermined feed gap and tested without further adjustment. Although the size of opening was based on previous experience with each model, the study did not address the effect of adjustment on degree of wastage. Several of the feeders used are non-adjustable and come equipped with a standard gap. Others allow adjustment and must be managed by the operator. Variation in results from study to study could be due to adjustment differences. Another management factor that applies to leavage is the periodic checking of the feed gap, particularly with wet/dry feeders.

Our studies were conducted using mash feed, and at least one previous study using pelleted feed reported quite different levels of wastage (Baxter, 1991). With pelleted feed there is also the issue of pellet quality, with pigs wasting a large proportion of the fines from poor pellets. We also identified the possibility that feeders that yield a large waste 'field', such as wet/dry feeders, are under estimated in terms of waste.

Finally, waste is the result of the interaction of pig behaviour with the feeder. Different pigs adopt different eating styles for the same feeder. The variation in behaviour results in variation in wastage. Intensive studies with relatively few pigs are prone to this type of error, which can lead to inflated values for waste from some feeders. Our observations confirm that adherence is greatly affected by eating style.

■ Conclusions

1) Feed spillage of the tested feeders was within a normal range of so-called 'good feeders' that are currently available on the market. But it should be noted that the presented values might be smaller than the true values, due to the fact that the spillage could not be completely collected by the trays used in the experiment.
2) Wet/dry feeders result in a larger field of spillage in the pen, but did not differ in percentage of feed spilled.
3) The size of pigs had an effect on the feed wastage. Small pigs spilled a greater percentage of their feed than did large pigs. However, large pigs left more feed in the feeder than did small pigs.
4) Rooting and eating activities were the two major actions influencing feed wastage through the floor.
5) The occurrence of feed wastage due to eating, fighting and stepping into the feeder, was associated with the size of pigs.
6) Feeder design should avoid the possibility that feed will drop unto a pig's snout or head.

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Chapter 4. Eating Speed

■ Summary

Two tests were conducted to study the eating speed of grower/finisher pigs. Test 1 investigated the eating speed of grower/finisher pigs on 12 commercial feeders, which fell into 4 classes: single-space dry, single-space wet/dry, multiple-space dry and multiple-space wet/dry. The study used pigs of 2 body sizes: small pigs were at a weight range of 41.1 ± 2.1 to 54.0 ± 4.5 kg, and large pigs at 85.5 ± 4.7 to 94.1 ± 7.7 kg. Measurements of eating speed were made on 5 individual pigs for each feeder. The results showed that *(1)* large pigs had a higher eating speed than small ones ($P < 0.05$); *(2)* there was no significant difference in eating speed between dry and wet/dry feeders, between single space and multiple space feeders, or among the four feeders classes ($P > 0.05$ for all); and, *(3)* lever-operated feeders showed a lower eating speed than non-lever feeders ($P \leq 0.05$). Test 2 compared eating speeds of pigs eating either premixed wet feed or dry mash feed. Pigs on premixed wet feed ate about 3 times as fast as those on dry feed ($P < 0.05$).

■ Introduction

Eating speed is a topic rarely addressed in pig feeder studies. However, information on pig eating speed can be used to determine appropriate pig/feeder ratios, or to deal with problems resulted from over-crowding at the feeder. Therefore, eating speed has a direct economic significance in the swine industry. The eating speed of pigs seems to be a function of multiple factors - social facilitation (Hsia and Wood-Gush, 1983), pig size (Hsia and Wood-Gush, 1984; Nienaber et al., 1990; Nielsen and Lawrence, 1993), pen design (Nielsen et al., 1996), or even housing environment, such as light or feeding schedule and ambient temperature (Nienaber et al., 1990). But during eating peaks or under an over-crowded situation, the ultimate factor reflecting the maximum capacity of a feeder is its maximum eating speed, which may be determined by features of the feeder. This maximum eating speed helps to understand the upper limit of pig/feeder allotment. Investigation of eating speed in a number of feeders may also identify desirable features facilitating eating speed, which are pertinent to certain feeders, and should be retained during the course of feeder evolution.

■ Objectives

(1) To determine the maximum eating speed of pigs using different feeder types and individual feeder models;

(2) To determine the maximum eating speed of pigs fed wet and dry feed.

■ Experimental Procedure

To fulfill the two experimental objectives, two experiments were conducted, designed to determine the effects of feeder design features and feed form on the maximum eating speed of pigs.

Experiment 1.

A total of 12 grower/finisher feeders were tested. The feeders may be classified as either wet/dry or dry feeders, or as single or multiple space feeders.

The experimental setting consisted of a pair of adjacent pens, each measured 2.4 x 2.4 m (8 x 8 ft). The two pens were enclosed and separated by solid plastic penning boards. An entrance door connected the two pens so that pigs could be moved between pens. One of these pens was used for trials on individual pigs, and the other for accommodating pigs waiting for the test. The trial pen had a raised plastic coated, perforated floor, and was equipped with a feeder and a nipple water drinker. The feeder was randomly taken from the pool of 12 feeders that would be subjected to the feeding speed test, and placed on the opposite side of the pen's entrance door, to reduce possible disturbance from the pigs in the waiting pen. Underneath the feeder was a galvanized steel collection tray, measured 1500 mm long, 1000 mm wide and 60 mm deep. The nipple water drinker was always provided in the pen regardless of the availability of a water source inside the feeders, and positioned at the corner away from the feeder to prevent the wasted water dropping into the feed collection tray. The waiting pen was equipped with a novel feeder for pigs to adjust to and a nipple drinker. Feed gaps of the feeders were set to 16 mm, if adjustable, and left unmodified if fixed. Lever-operated feeders were adjusted to a rate of 6 g per feed drop, as suggested by Morrow and Walker (1994).

Each feeder was tested on 5 small and 5 large pigs in the separate test episodes. Small pigs averaged 41.1±2.1 and 54.0±4.5 kg, and large pigs averaged 85.5±4.7 and 94.1±7.7 kg, at the beginning and end of the test periods, respectively. Measurements of eating speed were taken on individual pigs. All pigs were fed mash feed processed with a 4 mm (5/32") screen size, during the acclimation and test periods. During the acclimation period pigs were given a period of 24 h to adapt to the novel feeder. Prior to the actual test, they were deprived of feed for 6 h, to enhance their feeding motivation during the tests. The feeder was filled with 5 kg of mash feed and each pig was allowed to eat for 10 min. Timing began at the time when the pig actually touched the feed rather than when the pig entered the pen. When the pig stopped eating during the 10 min, timing was halted until it resumed. The remaining feed in the hopper, the residual feed on the feeding surface, and any spilled feed were vacuumed out and weighed back.

Eating speed was calculated as g/min. The experiment was considered a three-factorial design, when it was analyzed for feeder type difference

$$Y_{ijklm} = u + W_i + R_j + F_k + S_l + e_{ijklm}$$

where, W = pig Weight, I = 2; R = Replicates, j = 5; F = feed Form, k = 2; S = feeder Space, l = 2.

or considered as a two factor factorial when individual feeders were under a multiple comparison, using the Duncan's test.

$$Y_{ijk} = u + W_i + F_j + R_k + e_{ijk}$$

where, W = pig Weight, i = 2; F = Feeder, j = 11; R = Replicates, k = 5.

The eating rate from the two lever operated feeders was averaged, and compared to the average eating speed from the other 10 feeders in a contrast. All the data were analyzed using the GLM procedure in the SAS software (SAS Institute Inc., 1990).

Experiment 2

This test was conducted to further study the effect of feed form on eating speed, excluding the influence resulting from the design of individual feeders.

The pen layout remained the same as in Experiment 1. A Dyna-Fab feeder was selected as the test apparatus because of its wide and easy-to-clean, bowl-shaped feeding surface. The water supply to the feeder was disconnected for the tests. There were two experimental treatments - pre-mixed wet feed and dry feed. In either treatment, the feeding bowl of the feeder was filled with 500 g of mash feed to start. In the treatment using wet feed, the feed was mixed with 500 ml of water immediately before the test on each pig. As in Experiment 1, pigs were deprived of feed for 6 h prior to the test. They were then allowed to eat either pre-mixed wet feed or dry feed until all the feed in the trough was consumed. Time required for a pig to consume the 500 g feed was recorded. A total of 10 pigs from the large group were randomly selected for the test on each of the two feed forms.

The eating speed was converted to the format of g/min to be comparable to the measuring unit in Experiment 1. The data was then analyzed using a two sample T-test.

■ Results

No interactions were found between pig size and feed form, between pig size and feeder space, and between feed form and feeder space ($P > 0.05$). Eating speeds did not differ between multiple-space and single-space feeders, or between wet/dry and dry feeders ($P > 0.05$). Large pigs ate at least 6 g/min or 22% faster than small pigs (**Table 4.1**), based on the data pooled over all feeders. There was also no appreciable difference among the four feeder types: single-space dry, multiple-space dry, single-space wet/dry and multiple-space wet/dry, in any groups of pigs (**Table 4.2**).

The mean eating speeds of the two pig groups varied among the 12 individual feeders (**Table 4.3**). For the small pigs, the highest speed was 41.6 g/min. and the lowest 31.4 g/min (or about 32% slower). The corresponding numbers for the large pigs were 53.8 and 33.2 g/min (or 62% slower).

The variability among the feeders was greater for large pigs, which indicates a more profound effect of feeder design on large pigs than on small pigs.

For large pigs, the eating speed was slower when they were at the two lever-operated feeders (33.8 g/min, Table 4.4), compared to when they were at the non-lever-operated feeders (44.6 g/min, P < 0.05). But there was no difference found (P > 0.05) between lever-operated feeders (35.9 g/min) and non-lever-operated feeders (34.4 g/min) for small pigs.

Table 4.1 Comparisons of eating speed (g/min) between pig sizes, feeder spaces and feed forms

	Pig Size			Feeder Space			Feed Form		
	Large	Small	*P-value*	Multiple	Single	*P-value*	Dry	Wet/Dry	*P-value*
Speed	43.5±1.2	35.6±1.2	*0.01*	40.4±1.1	38.7±1.3	*0.33*	39.3±1.2	39.7±1.1	*0.76*

Table 4.2 Comparisons of eating speed (g/min) among 4 feeder types.

	Multiple-space Dry	Multiple-space Wet/Dry	Single-space Dry	Single-space Wet/Dry
Pooled	40.7	40.0	37.9	39.6
Large pig	45.6	42.1	42.8	44.6
Small pig	36.0	38.0	33.9	34.5

There were no significant differences (P>0.05) among the types.

Table 4.3. The range of pig eating speeds (g/pig/min) at individual feeders

Feeder number	Overall (n=10)	Duncan's Test*	Small pig (n=5)	Duncan's Test	Large pig (n=5)	Duncan's Test
MS-D-2	44.0	a	40.2	ab	47.8	abc
SS-D-1	33.8	b	32.7	ab	34.8	bcd
SS-D-2	41.9	a	35.1	ab	48.7	ab
MS-D-1	38.4	ab	31.4	b	43.9	abcd
MS-D-2	38.7	ab	32.9	ab	44.4	abcd
MS-D-3	38.9	ab	34.0	ab	45.0	abcd
MS-D-4	41.2	ab	38.3	ab	44.2	abcd
SS-WD-1	44.7	a	35.6	ab	53.8	a
SS-WD-2	39.9	ab	33.6	ab	46.1	abcd
SS-WD-3**	34.1	b	34.4	ab	33.8	cd
MS-WD-1**	36.3	ab	39.3	ab	33.2	d
MS-WD-3	45.1	a	41.6	a	48.6	ab

* Different letters in the Duncan's multiple comparisons stand for a Significance at $P < 0.05$.
** Lever feeders

Table 4.4. Comparisons of eating speed (g/min) between lever and non-lever operated feeders in the two groups of pigs

	Large pigs		Small pigs	
	Lever	Non-lever	Lever	Non-lever
Speed	$33.8+4.6^b$	44.6 ± 1.4^a	34.4 ± 2.8	35.9 ± 0.9

Comparisons were made within pig group. Means with different superscripts differ, $P<0.05$.

In Experiment 2, the eating speed of large pigs was 42.2 ± 7.3 g/min. when they were fed dry mash feed, and 123.7 ± 30.5 g/min when they were fed premixed wet feed. The eating speed on the pre-mixed feed was nearly 3 times as fast as on the dry mash feed ($P < .01$).

■ Discussion

The comparison between dry feed and the premixed wet feed showed that eating speed was greatly increased when pigs were offered wet feed. Although the eating speed may vary with the feed/water ratio, wet or liquid feeding can certainly accelerate pig feeding. However, when pigs were fed on wet/dry feeders the eating speed remained basically the same as when they were on dry feeders. There are several possible reasons for this lack of effect. The wet feed test was conducted with pre-mixed feed and water, while pigs using wet/dry feeders must access feed and water separately before mixing. The time taken to access feed and water, and to mix the two could slow the eating process. A second explanation is that the hungry pigs, after several hours of deprivation, were sometimes observed to eat without accessing water throughout the entire 10 minute test period. Although this test did not demonstrate a difference between wet/dry and dry feeders, it did demonstrate that design features do affect eating speed.

It was readily understandable that space allowance of feeders did not influence eating speed of pig as the animals were tested individually. Some multiple space feeders were actually used as single space feeders, because the feeding holes were completely separated by side panels, e.g., the MS-D-1 and MS-D-2 feeders. This result should not be generalized to the usual feeding environment where more than one pig is allowed to eat at a time, as eating speed in that situation may be altered due to social facilitation and competition.

The feeders that require operation of a lever to drop feed might also be expected to slow their eating speed. The size of the feed drop is a key influencing factor. Larger feed drops could speed up eating, but may lead to greater feed waste. Previous research has indicated that a feed drop of 6 g was adequate to maintain maximum intake (Morrow and Walker, 1994), but may not necessarily be adequate to ensure a maximum eating speed. A study that investigates the relationship between eating speed and feed drop dose is still needed if eating speed is of concern. The dropping lever should also be made easy for a pig to operate because eating speed is influenced by the effort, thus time, required to obtain feed. Lever operation seemed to have a different impact on pigs of different sizes. The non-significant result for eating speed of small pigs between lever and non-lever feeders indicated that small pigs were less affected by lever operation. A drop size of 6 g may not be adequate for large pigs to maximize their eating speed.

Eating speed is closely related to the body size of pigs (Hsia and Wood-Gush, 1984). Gravas (1984) suggested that the optimal feeding speed for the 30-90 kg pigs in a biofix feeding system, based on reduced aggression at feeder, was $-106 + 37.3\ ln$ BW. According to this formula, the large pigs in our study should eat at a speed of 62 g/min. This value is slightly higher than that observed in the feeder test, but well below that for wet feed. Hsia and Wood-Gush (1984) indicated that eating speed is proportional to body weight. Their pigs ate at a rate of approximately 0.78 g/min per kg of body weight The data of Gonyou *et al* (1991) supports this conclusion. as their pigs ate approximately 0.30 g/min per kg of body weight throughout the grow/finish period. However, small and large pigs in the present study ate at quite different speeds when expressed on a body weight basis (0.77 and 0.48 g/min per kg of body weight respectively).

Wet feed can substantially increase eating speed, and thus reduce feeder occupation time. This result suggests that a liquid feeding system would accommodate more pigs per feeder trough. But with water/feed ratios much higher than that used in this study (commercial systems often provide 3-5:1 ratios), liquid feeding may have lower eating speeds because of the large volume of water included.

A consideration in interpreting this study is that the pigs were very hungry and may have avoided the effort of combining water and feed in their haste. Eating under production conditions may be more leisurely and allow greater difference among feeders to be expressed. The results of the behaviour studies under production conditions presented in Chapter 7 are relevant in this regard.

■ Conclusions

(1) Eating speed was significantly affected by the size of pigs. Large pigs ate faster than small ones.

(2) Design features of feed form (dry vs. wet/dry) and feeder space (single vs. multiple) of the tested feeders did not influence the pigs' eating speed under the specified experimental conditions.

(3) Premixed wet feed can greatly increase a pig's eating speed, compared with dry feed.

(4) Lever-operated feeders had a lower eating speed than non-lever-operated feeders on large pigs.

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Chapter 5. Pig Preference

■ Summary

Pig preference was studied on various designs of the grower and finisher feeders that represent the major types prevailing in the current feeder market. The experiment used 12 grower and finisher feeders, which included 2 single-space dry, 3 single-space wet/dry, 4 multiple-space dry and 3 multiple-space wet/dry feeders. A group of 5 pigs weighing 50-60 kg formed a test unit to be tested in multiple free choices arrangement. The amount of feed removed from a feeder served as an indicator of the pigs' choice for a feeder. The test was conducted in the two sequential phases: within-type and between-type selections. The pigs clearly showed their preference for certain feeders over the others, within or between feeder types. The MS-WD-4 tube feeder was most favored by pigs, while the shelf-feeding feeders appeared to be less attractive to them.

■ Introduction

In the past, feeder design mainly reflected the producer's concerns of hygiene, economy, durability and ease of management (Baxter, 1991). There has been a historical neglect of the physical and social requirements of pigs during their use of equipment. Such negligence has been reproached recently, and there is a trend to incorporate the animals' perspective into the process of equipment design (Matthews and Ladewig, 1994; Stolba and Wood-Gush, 1984). One means to bring designs into line with the animals' requirements is the use of preference tests (Phillips et al., 1991). Preference testing requires specialized methodology and appropriate interpretation of the results (e.g., Duncan, 1978; Dawkins, 1983; van Rooijen, 1983; Hutson, 1984; Duncan, 1992; for recent review, see Fraser et al., 1993). However, a multiple free choice test can yield informative data, and is a technique which reflects an animal's subjective sentiment (Duncan, 1981; Craig and Adams, 1984). For this reason, preference tests are frequently employed for revealing the pig's perception of its environment, and applied to test various equipment or housing environments (Stolba and Wood-Gush, 1984; Morrison et al., 1987; Phillips et al., 1988, 1991, 1992; Rohde Parfet and Gonyou, 1991).

We realized that the pigs' perspective, although likely reflecting short-term benefits, should be taken into account when a feeder's quality is assessed. The information revealed in a preference test should be extracted and applied as part of the new concept of animal-centered equipment design. Therefore, supplementing the assessments of feeder design on production performance and feed wastage, a preference test of feeders was conducted as part of the systematic evaluation of commercial feeders.

■ Objectives

(1) To determine a feeder favored pigs by comparisons either within or across the four major types of feeders - single space dry, single space wet/dry, multiple space dry and multiple space wet/dry feeders;
(2) To investigate the design features preferred by the pigs.

■ Experimental Procedure

Arrangement

The experimental room accommodated 3 testing pens. Each pen measured 4.8 x 2.4 m, was enclosed by plastic panels and paved with a raised plastic coated, perforated metal floor. The room was illuminated between 0700-1900 h. A total of 12 feeders were classified into 4 types according to their feeder space allowance and feed forms (2 single-space dry, 4 multiple-space dry, 3 single-space wet/dry and 3 multiple-space wet/dry feeders). Each feeder type formed a range of options for the multiple free choice tests in phase I. The feeders included were described in Chapter 1, and hereby labeled as SS-Dry-1 for the first single space dry feeder, as MS-WD-2 for the second multiple space wet/dry feeder, etc. Feed gaps in all gap-adjustable feeders were set to 16 mm, or 5/8". The gaps of the non-adjustable feeders were left unmodified. Lever-operated feeders were set to disperse 6 g per feed drop, based on the information provided by Morrow and Walker (1994). A separate water source was always provided in the pen regardless its availability in the feeders.

The experiment was conducted in two sequential phases: **I**) *within-type selection*, and **II**) *between-type comparisons*.

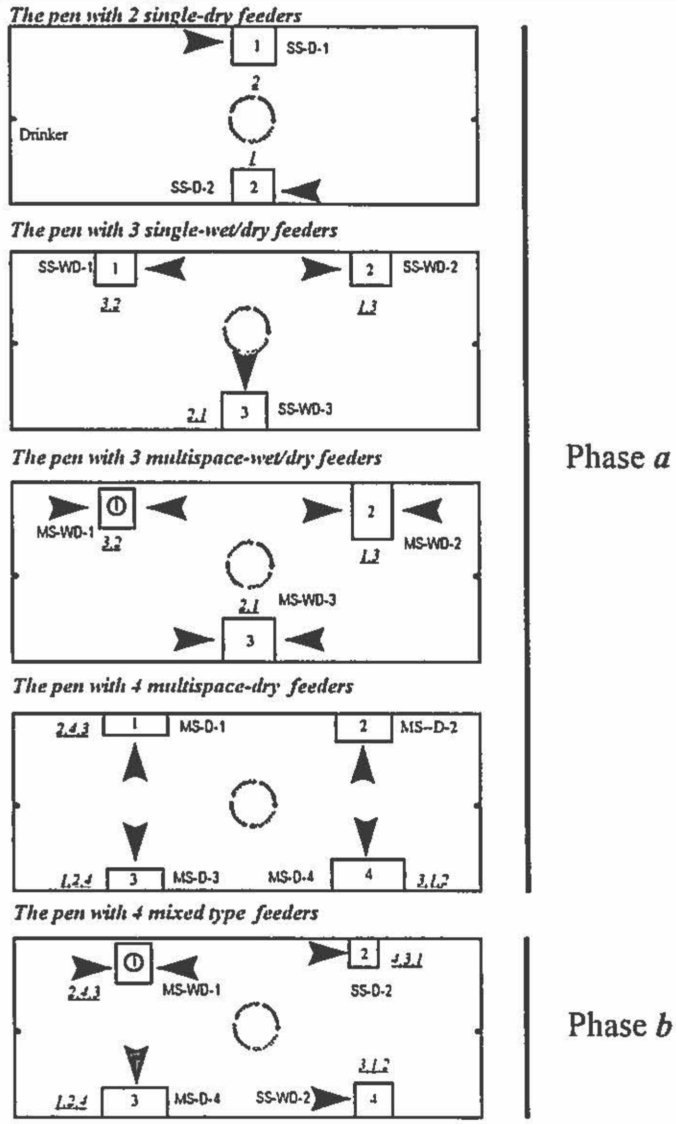


Figure 5.1. Pen layout, feeder position and rotation sequence for the two stages
(Italic numbers: rotating sequence; rotating direction; feeder access

I) ***Within-type Selection***. To select a feeder within the feeder type that was favoured by pigs, all feeders of one type (2, 3 or 4 feeders, varying with feeder types) were accommodated in the same pen (Fig. 5.1.). To avoid unbiased feeder access due to zonal or room effects, such as dunging pattern differences and uneven illumination, etc., the feeders were positioned in the near-middle zone of the pen, in a manner as close to each other as possible. Each individual feeder was tested in all the possible locations during each test. For the feeders with only one access side, the placement ensured that the access side would always point to the middle of pen. This aimed to reduce the possible confounding effect of the spatial memory-based or area-concentrated searching behavior that is exhibited by many animals (Benhamou, 1994), and to ease the minor concern on the illumination preference of pigs (Baldwin and Start, 1985). For the two-sided feeders, the placement of the feeders ensured that both sides of the feeders would be freely accessible by pigs. Two nipple drinkers were provided, each mounted on the walls at the end of the pen, as shown in Figure 5.1. Feed disappearance from each feeder was collected, after pigs had been in the test for a 24 h period. The feed wastage was estimated only when it was great. Therefore, the amount of feed disappearance may not be the actual feed intake of the pigs.

II) *Between-type Comparisons*. After phase I was completed, the data were analyzed to determine the most preferred feeder in each of the four feeder types. The 4 feeders, so selected, were subsequently used to form a new range of feeders for the multiple free choice test among these feeder types. The conditions for this test - pen layout, feeder position, rotation route, the number of replicates and repeated measurements, and the number of pigs, etc. - resembled the conditions for the four feeders test in phase I.

Animals

Thirty pigs, weighing 50-60 kg, were used in 2 batches. Each batch of 15 pigs was randomly allotted to the 3 pens in the room, with 5 pigs in each pen. Pigs in a pen were mixed sex, 3 females and 2 males, or vice versa. The 5 pigs were fed on all of the feeders that belonged to a certain feeder type. Before the data collection commenced, there was a 24 h acclimation period. During this period, one day's expected feed ration for 5 pigs, approximately 12 kg, was equally divided among the feeders in a pen. Without using all feeders available in the pen, the pigs would be short of feed. Therefore, the pigs were forced to learn how to use every feeder. On the trial days, each feeder in a pen was filled with 15 kg of mash feed, an amount sufficient for all the pigs to feed from the feeder if they so desired. Feeders with a small hopper capacity were re-filled during the day. After 24 h, the remaining dry feed in the feeder was vacuumed out and weighed back. The amount of residual wet feed in the feeder was estimated and discarded.

After the test on one feeder type, the pigs were tested on the feeders of another type, and so on, until each group evaluated all four feeder types. All pigs were weighed at the beginning and the end of the trial phase.

■ Data Analysis

The experimental arrangement resulted in a total of 6 replicates for each preference test. For the first stage, the results were analyzed within each feeder type. The repeated measures of feed disappearance after each rotation of the feeders were averaged to generate a single number. Because the total daily feed consumption of 5 pigs in a pen was constant, and the feed disappearance from one feeder was dependent on that from the other feeders in the same pen, a non-parametric statistical test was chosen. Friedman's randomized block analysis of variance (Zar, 1984) was conducted on the ranked data:

$$\chi_r^2 = \{12/ban^2(na+1)\} \sum_{i=1}^{a} R_i^2 - 3b(na+1)$$

where χ_r^2 = Friedman's statistic; a = number of feeders (2-4), b = replications (6); n = the number of observations per cell, which represents the number of different positions in the pen of a feeder in each replication; R_i = rank sum of i replications for each feeder.

■ Results

Pigs strongly preferred certain feeders to the others within any of the classified feeder types (P < .01 for types, Fig. 5.2). Pigs in the multiple-space wet/dry feed pen ate virtually all the feed from the MS-WD-3 feeder. Less contrast was observed among the feeders in the multiple-space dry feeder group. It was still obvious, however, that the MS-D-3 feeder was preferred. In the group of single-space wet/dry feeders, the SS-WD-3 feeder slightly outperformed the SS-WD-1 feeder, but both had several times higher feed disappearance than the SS-WD-2 feeder. Compared to the above three feeder groups, the two single-space dry feeders were relatively close to each other in their feed disappearance. However, the SS-D-1 feeder was still significantly preferred over the SS-D-2 feeder (P < .01).

The above results indicated that the SS-D-1, MS-D-3, SS-WD-3 and MS-WD-3 were the four feeders most preferred by pigs in the feeder groups they belonged to. The test among these four feeders further suggested that the MS-WD-3 feeder was the overall favorite feeder for pigs under the experimental conditions (P < .01, Fig. 5.3). The feed disappearance from the MS-WD-3 was 9.28 kg/d/pen, compared to 2.99 kg/d/pen from the MS-D-3, 0.73 for the SS-D-1, and 0.80 for the SS-WD-3.

Figure 5.2. Pig preference for a feeder in each feeder type, as indicated by feed disappearance (P<0.05 for every feeder type)

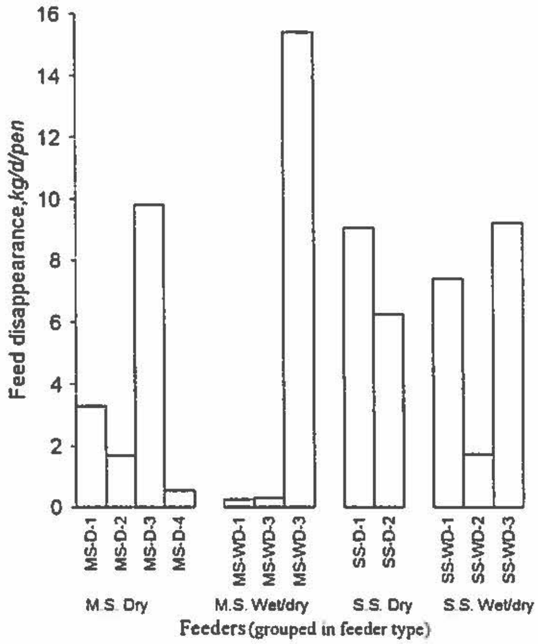
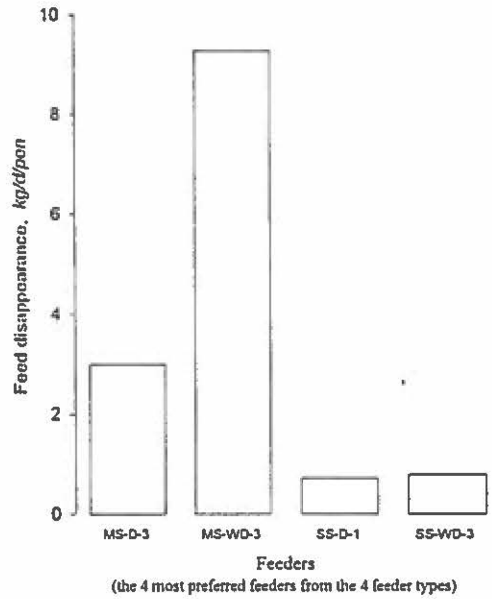


Figure 5.3. Pig preference to the four feeders that was most favored by pigs in each of the four feeder types (P < 0.05)



■ Discussion

Many environmental and social factors might have affected the pig's choice for a feeder. One of them might be the openness of a feeder's feeding surface. This might be indicated by the high feed disappearance from the two multiple space feeders - MS-WD-3 and MS-D-3 (Fig. 5.3.). There might be a higher social facilitation on these feeders than the other two single space feeders, but a higher degree of comfort during eating would be another advantage on these feeders. This might be explained by the big difference in feed disappearance between the two very similar designs - MS-D-3 and the MS-D-4 feeders (Fig. 5.2). These two multiple space dry feeders both have provided a long trough space, accommodating up to 4 pigs at a time. The basic configurations of feed areas of these feeders are also very similar. However, the MS-D-4 feeder has a deep trough, which places the separation bars in a position where a pig's eyes may be touched, causing unpleasant contacts during eating. This was another example that a small design difference can substantially affect the animal's well-being and productivity, as some researchers have already noticed (Curtis et al., 1989; Hurst et al., 1989; Rohde Parfet et al., 1989). Such a slight design difference may not be immediately noticed without obvious signs of bodily injury. It may not affect the pigs' productivity, but certainly affect the pigs' psychological well-being. In fact, many currently marketed grower and finisher feeders more or less have similar problems, and a preference test might be a subtle and more efficient way to diagnose and rectify these problems. A high visibility of feed in a feeder might attract pigs to eat from it. With a flat feeding surface and with the transparent plastic tube, the MS-WD-3 feeder certainly offers such a visual advantage.

The two lever operated feeders - the MS-WD-1 and SS-WD-3 feeders, performed differently within their own feeder groups. In the multiple-space wet/dry group, the MS-WD-1 feeder had the lowest feed disappearance. One reason was largely because of the presence of the MS-WD-3 feeder, which was just so attractive to the pigs that it captured almost all feed consumption of them. With this strong masking effect, the results of the other feeders cannot be compared in a valid manner. Such an inter-dependent relationship between choices indicated a limit of the use of preference tests, and a special caution must be taken in the interpretation of test results. In contrast, the SS-WD-3 feeder performed well in its single space wet/dry group.

The presence of the MS-WD-3 feeder in the multiple space wet/dry feeder group would very likely be one reason for the lower rate of feed disappearance on the MS-WD-2 feeder. But the fact that neither of the two similar feeders, SS-WD-2 and MS-WD-2, were favorite choices of the pigs might have reflected a common design feature shared by the two feeders - an undesirable height of the feeding shelves. As the previous research has indicated, pigs usually prefer to eat at floor or near floor level (Baxter, 1991). The pigs feeding on these feeders were required to raise their heads at least 260 mm from the floor, which would possibly make the pigs uncomfortable, if not cause them a fatigue over a period of time. This may well explain the reduced amount of feed disappearance on these feeders.

Because of the difficulty of making all-feeder comparisons among the 12 feeders, the preference tests had been restricted within a group ranging from 2 to 4 feeders. Therefore, the results of preference so obtained should strictly apply to the tested groups, to be more specific, only the tested feeders. A less preferred feeder in one feeder group could have been a favorite one in another feeder group if it had been placed among the feeders from another feeder group.

■ Conclusions

Among the 12 tested feeders in this study, the MS-WD-3 feeder was the overall favorite choice of pigs. The shelf feeding on the two feeders was not preferred by pigs at the body size used in the study.

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Chapter 6. Ergonomics

■ Summary

Five ergonomic studies were conducted using a specially designed feeder on which the lip height, feeder depth (front to back), width, and feeding shelf height could be adjusted. Pigs were tested at various weights from 22 to 96 kg. The effects of pig size, feeder depth and lip height on the incidence of pigs stepping into the feeder was evaluated in a factorial design. Within the constraints of the experimental design, with limits placed on feeder depth and lip height, small pigs stepped into the feeder more often. The most significant design feature of the feeder for this behaviour was feeder depth. Stepping in was more common as feeder depth was increased, but the point at which it began varied with the size of pig. Grower pigs stepped into a feeder with a depth of 20 cm, but large pigs did not do so until the depth was 30 cm or more. Lip height had only a minor influence on stepping-in, and only at critical depths that depended upon pig weight. The appropriate feeder depth for each weight group of pig could be approximated by observing their normal eating behaviour when no feeder lip was used. The distance from the toe of the pig to its snout increased with pig weight and was similar to the feeder depths resulting in the lowest frequency of stepping-in. A final factor related to feeder dimensions is the restriction the feeder lip places on accessing feed at the front of the feeder. This restriction decreases as pigs grow, but should be accommodated in feeder design by providing a slope behind the lip of the feeder. Although many manufacturers provide protective side panels on their feeders which define eating spaces, these panels also force pigs to position themselves approximately perpendicular to the feed access point. Two studies examined the angles of the body and head while pigs ate. Pigs prefer to stand at an angle of approximately 30° to the feed access, but in restrictive feeders will turn their heads to obtain some angled approach. Pigs also rotate their heads approximately 45-55° while eating to improve access to the feed. These features should be considered in future feeder design.

■ Introduction

A well designed grower/finisher feeder can improve many aspects of pig production such as feed wastage, hygiene, pig health and comfort, ease of management, space occupation, and economical use of materials. A key to accomplishing success in feeder design is to accommodate the eating pigs' physical and behavioural requirements, which can be facilitated through consideration of the ergonomics of eating in pigs. However, such ergonomic information is not readily available to feeder designers and so shape and dimensions of feeders are routinely based on the designer's intuition and experience.

Some spatial parameters of feeders, such as width and height, can be determined using documented measures of pigs (Petherick, 1983a,b; Baxter and Schwaller, 1983; Curtis et al., 1989; Hurnik and Lewis, 1991). However the information from these studies is insufficient for all aspects of feeder dimension and design as several key dimensions such as throat height, neck length and thickness were not included. In addition, body measures are usually posture-specific and measures taken from these studies cannot be readily applied to eating pigs.

Baxter (1991) suggested that pigs should be provided with sufficient space to eat in a natural posture. But a feeder with sufficient space yet without an ergonomic layout - appropriate shape, angle and height - may still restrict a pig's access to feed or create an uncomfortable eating environment. For example, pigs may be able to access feed above their shoulders, but rarely want to use a feeder with feed distributed at that level (Baxter, 1991), and requiring them to do so may cause a reduction in feed intake (Heitman and Bond, 1962). Thus, the quality of feeder space can be as important as its quantity. In dealing with such a problem, ergonomic studies that are commonly used in designing cars, housing or furniture for humans can be adapted to study pigs.

■ Objectives

The specific objectives of this study were to:

1. To determine ergonomic measures of the interaction among feeder dimensions and pig body postures.
2. To determine dimensional criteria which limit pigs from stepping into the feeder, but facilitate reaching the feed access point and cleaning of the feeder.

■ Methodology

Feeder and Pens

An experimental feeder was constructed to facilitate the frequent adjustments required in this study (Figure 6.1). The feeder measured 45 (width) x 45 (depth, front to back) x 90 (height) cm in its outside dimensions. A side panel, the feeder lip and the feed shelf were detachable and adjustable. These parts were attached to the frame of the feeder with sliding tracks and wing-nuts. The back wall and one side of the feeder were constructed of transparent plexiglass to allow behavioural observations. The top of the feeder could be opened and a camera mounted overhead to videotape an eating pig from above. Transparent rulers and protractors were glued to the side and back of the feeder to determine positions and angles of the feeder parts and of the pig while eating.

The testing area consisted of three adjacent pens used for holding, testing and observation (Figure 6.2). The holding pen was equipped with a multiple space, dry feeder and two nipple drinkers, and held pigs when they were not being tested. The test pen was used only during actual tests and provided the test pig with access to a nipple drinker and the experimental feeder. The feeder was recessed into the wall in one corner between the test and observation pens. Cameras were mounted within the observation pen so that an eating pig could be videotaped from three orthogonal positions: above, beside, and behind the feeder. Illumination was provided by ceiling lights and two additional spot lights that could be positioned as necessary to facilitate observation and videotaping.

Animals

Eleven pigs, of mixed gender, were used in the studies. Between tests they were maintained in the holding pen. Tests were conducted at four weight ranges (BW), when pigs averaged 22.6±2.6, 48.4±4.8, 71.7±5.6, and 95.7±6.8 kg. The average increment of pig weight between tests was 24.4 kg. Pigs were deprived of feed for 4 hr prior to testing to ensure sufficient motivation to eat was present during each test. Five tests were conducted.

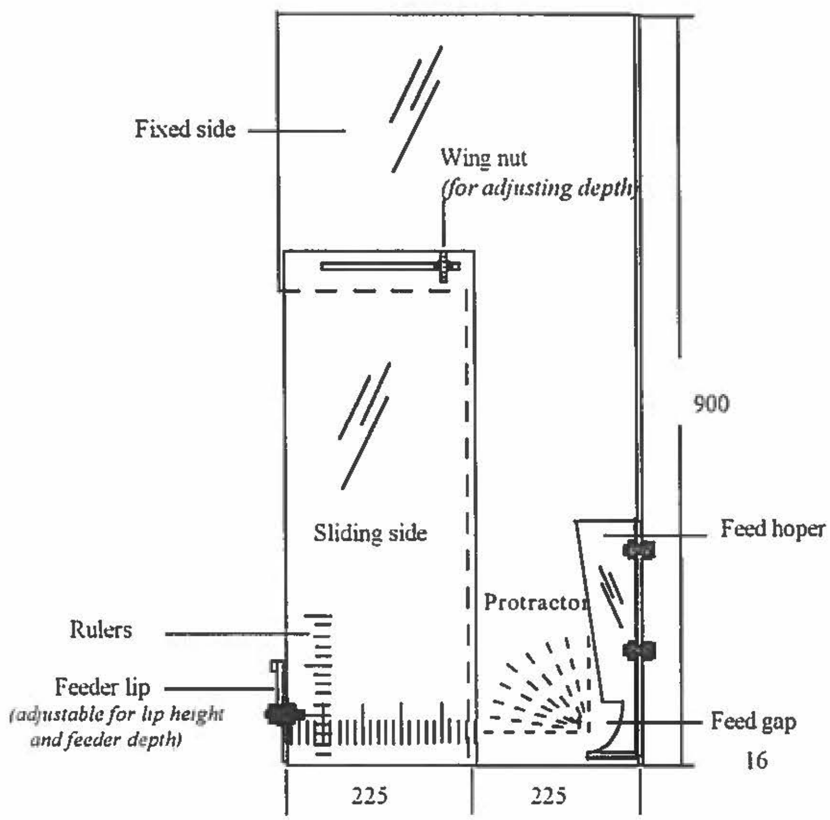


Figure 6.1. The experimental feeder used in the ergonomic study. View of transparent side; measurements in mm.

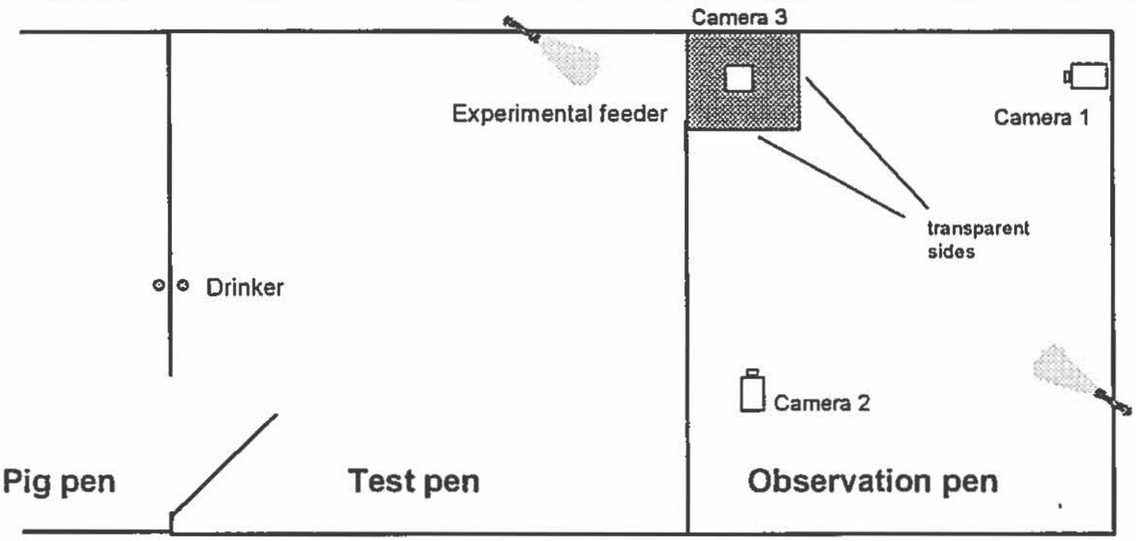


Figure 6.2. Diagram of pens used in ergonomic study.

Stepping Into the Feeder

This test investigated the effects of feeder depth (feeder lip to feed access point) and lip height on the occurrence of pigs stepping into the feeder (step-in). The test was organized as a 4 (depth) x 5 (depth) x 4 (BW) factorial using depths of 10, 20, 30 and 40 cm; lip heights of 0, 5, 10, 15 and 20 cm; and the four BW of pigs. The height of the feed access point was standardized at floor level. Feeder width (inside dimension between side panels) was set according to the recommendations of Baxter and Schwaller (1983) and Baxter (1991) at 6.71 (cm) x $BW(kg)^{.34}$, which is 110% of shoulder width. The resulting widths were 19.4, 25.1, 28.7, and 31.6 cm, at the four BWs studied. The feed gap was set at 1.6 cm following conventional management practices.

Each pig was allowed to eat for 30 sec, during which time it was recorded if the pig did or did not step into the feeder. Repeated step-ins during one observation were not taken into account. The number of pigs (of the 11 tested) with step-ins at each depth/lip height/BW combination was analyzed using Chi-square procedures.

Normal Reach

This test examined the distance pigs reach while eating without restrictions from the feeder. The test was conducted at all four BWs using the same feeder widths as in the 'step-in' test, but the feeder lip was removed. While the pig was eating, the distance from the tip of its most forward toe to the feed access point was measured. This distance was analyzed using the GLM procedure of SAS (1990).

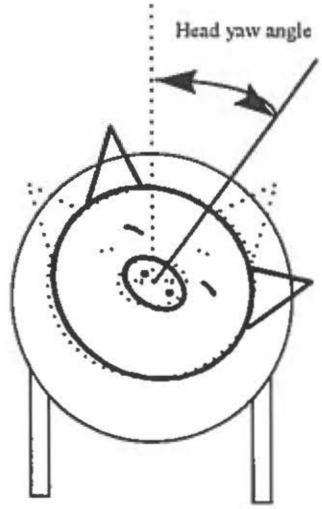
Eating Zone

This test examined the ability of pigs to clean the edges and corners of the feeding surface. Only 5 pigs were tested at each BW. Lip height and feeder width were standardized at 10 and 45 cm, respectively. Prior to the test the bottom of the feeder was overlaid with a thin layer of feed (approx. 100 g). The pig was then allowed to clean the feeding surface as thoroughly as it could. While the pig was eating, the occurrence of throat touches on the feeder lip was recorded and the distances between the lip of the feeder and the point the pig was reaching into the feeder measured. Once the pig was finished eating, the area of residual feed on the feeding surface was measured and the shape of the area drafted.

Position of Pig's Head

This test investigated the effect of the height of the feeding shelf on the position of the pig's head while eating. The study was organized as a 7 (shelf height) x 4 (BW) factorial with shelf heights of 0, 10, 20, 30, 40, 50 and 60 cm and the four BWs previously mentioned. For lower BW treatments some shelf heights were excluded due to the inability of the pigs to reach the feed. Feeder widths were set according to BW as in the step-in test. Head yaw angle and head entrance angle were measured while the pig was eating from the feed shelf at different heights. Head yaw angle was defined as the degree of rotation of the head from the vertical (Figure 6.3a). The measurement disregarded the direction of the rotation. Head entrance angle was defined as the angle between the feed shelf and the longitudinal axis of the pig's head, disregarding the body angle of the pig (Figure 6.3b).

Pigs were allowed to eat for 30 sec, during which time the maximum yaw and head entrance angles while the pig was eating from the shelf were recorded. Behavioural patterns were monitored by both direct observations and video recording. Both head yaw and head entrance angles were measured to the nearest 5°. The data were analyzed using the GLM procedure of SAS (1990) with an emphasis on trend analysis between shelf height and head angles.



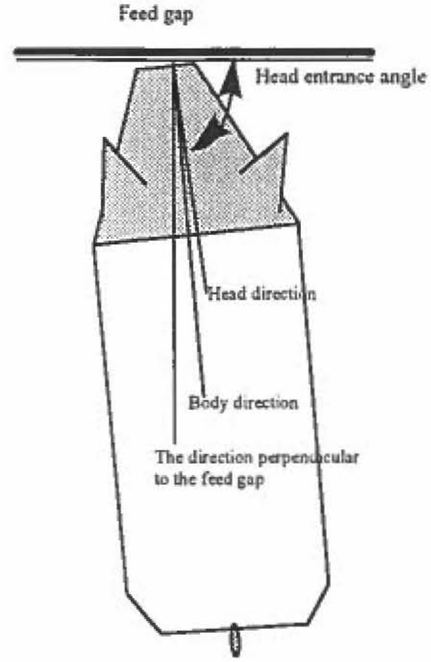


Figure 6.3. Illustrations of head yaw angle (a) head entrance angle (b) of eating

Body Angle

This test examined the natural body position of pigs when they are not restricted by a feeder. Pigs were tested at all four BWs. Feed was provided from a gap (1.6 cm) at floor level, which resulted in feed extending approximately 5 cm out from the wall. There were no restrictions to the sides of the pigs, allowing them to turn their bodies freely at any angle toward the wall. The angle between the feed gap (wall) and the body of the pig while it was eating was measured.

■ Results and Discussion

Lip Height and Feeder Depth

The incidence of stepping-in the feeder decreased as the weight of the pigs increased, from 66% of the time for 22.6 kg pigs to only 30% for 95.7 kg pigs (P<.01). Effects of lip height and feeder depth were examined for each weight class, and in all cases feeder depth significantly affected stepping-in (P<.01). For 22.6 kg pigs, all pigs stepped-in at feeder depths of 30 and 40 cm. Less than 10% of pigs stepped-in when feeder depth was 10 cm (Figure 6.4a). Stepping-in when the feeder depth was set at 20 cm was affected by lip height (P<.01), with the lowest frequency occurring when lip heights were 5 and 10 cm (Figure 6.5a). For the three heavier test weights, fewer than 10% of the pigs stepped-in at feeder depths of 10 or 20 cm, and all pigs stepped-in at the 40 cm depth, regardless of lip height (Figures 6.4b-d). Lip heights of 20 cm for 48.4 kg pigs (Figure 6.5b), and 15 or 20 cm for 74.3 kg pigs (Figure 6.5c) reduced the frequency of stepping-in at feeder depths of 30 cm. Lip height had no effect on stepping-in at the 30 cm depth for 95.7 kg pigs, although 20% of pigs did step-in (Figure 6.5d).

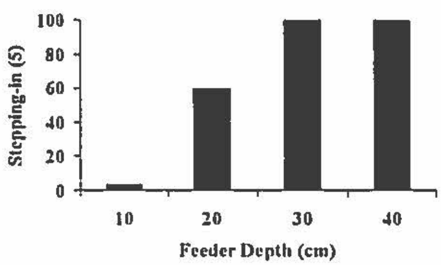


Fig. 6.4a. Pig weight 22.6 kg.

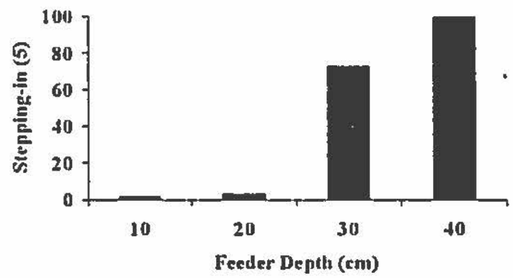


Fig. 6.4b. Pig weight 48.4 kg

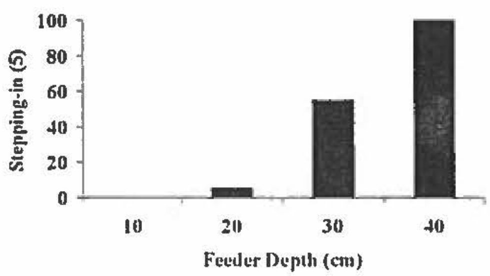


Fig. 6.4c. Pig weight 74.3 kg.

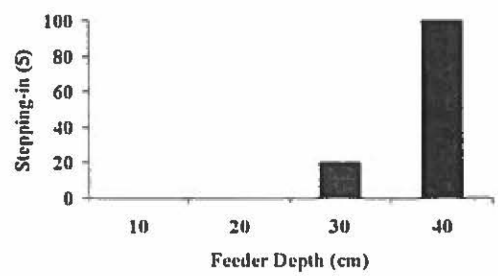


Fig. 6.4d. Pig weight 95.7 kg.

Figure 6.4. Effect of feeder depth on the incidence of 'stepping-in' for pigs at different test weights.

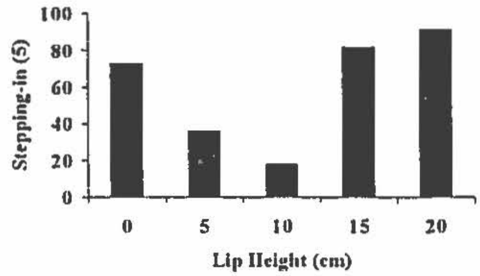


Fig. 6.5a. BW 22.6 kg; FD 20 cm.

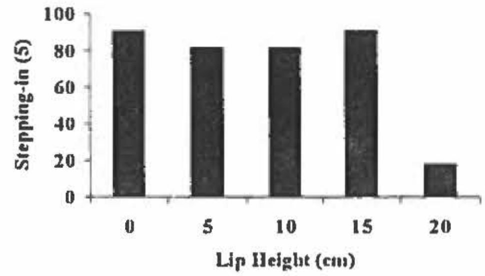


Fig. 6.5b. BW 48.4 kg; FD 30 cm.

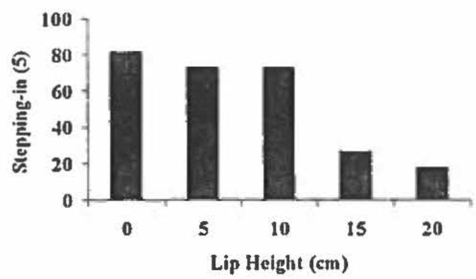


Fig. 6.5c. BW 74.3 kg; FD 30 cm.

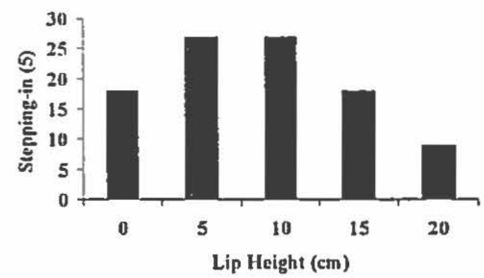


Fig. 6.5d. BW 95.7 kg; FD 30 cm.

Figure 6.5. Effect of lip height on the incidence of 'stepping-in' at critical feeder depths for pigs at different test weights

The normal reach (toe to snout) of the pigs increased with body weight, with mean (±SEM) values of 14.3 (±0.8), 22.4 (±0.8), 27.7 (±0.6), and 32.0 (±1.5) cm, for weights of 22.6, 48.4, 71.7 and 95.7, respectively. The relationship between normal reach and body weight can be expressed as the allometric equation: Normal Reach (cm) = -14.5 + BW^{333}(kg). During the analysis of the eating zone, when lip height was set at 10 cm, the zone behind the lip which could only be reached with the throat in contact with the feeder increased in depth from 10.0 to 20.0 cm, for 22.6 and 95.7 kg pigs, respectively.

The results of these three studies indicate that no combination of lip height and feeder depth is entirely suitable for the wide range of pig sizes considered. The normal reach determined for each weight class would appear to be an appropriate feeder depth in each case. At these depths approximately the back third of the eating space would be beyond the point at which a 10 cm lip would interfere with eating. Lip heights would have little effect on stepping-in at these feeder depths. However, a 32.0 cm feeder depth, as suggested for large pigs, would result in small pigs regularly stepping into the feeder, resulting in feed wastage. Conversely, a depth of 14.0 cm may be ideal for small pigs but would restrict eating by large pigs which could only access feed while contacting the feeder lip. It would seem that the best compromise would be a feeder depth between 20 and 30 cm, and a lip height of 10 to 15 cm. A sloping surface from the top of the feeder lip to a point 15 to 20 cm in front of the lip should prevent feed from accumulating in this difficult to reach location.

Head and Body Position

The average yaw angle of the pigs' heads while eating from a shelf was 46.7° (Table 6.1). Even when the shelf was at floor level, pigs rotated their heads an average of 42.6°. In general, the yaw angle increased as the shelf was raised to a maximum at a height of 20 to 30 cm, and then decreased with further elevation of the shelf. The smallest pigs (22.6 kg) could not eat from the shelf when it was 40 cm above the floor, and only the largest pigs (95.7 kg) could reach the shelf at heights of 50 cm. The height of these pigs at their shoulder would be approximately 42 and 68 cm, respectively (Petherick, 1983a). Although a precise recommendation is not possible due to the fixed heights used in the study, it would appear that shelf height does not become a limiting factor at up to 75% of shoulder height.

During the head yaw and angle test, when they were restricted by the sides of the feeding space, pigs held their heads at angles between 50 and 55° from the feed access point (Table 6.2). During the body angle test, when no restrictions were made to side movement, pigs positioned their bodies at angles of approximately 30°. In a typical feeder, with side restrictions, head yaw appears to be limited by head entrance angle, which appears to be limited by body angle. The use of side panels to reduce aggression at the feeder may restrict body position such that an unusual eating posture is assumed. Pigs eating from feeders without side panels often approach the feeder from an angle. Rather than forcing pigs to enter a feeder at a 90° angle to the feed access point, perhaps an angled approach should be considered.

Table 6.1. Comparisons of pig head yaw angles during eating between pig weight groups and feed shelf heights.

Shelf height (cm)	Pig weight (kg)* 22.6	48.4	71.7	95.7	Trend over weights** (*P*<0.05)
0	40.2^{aA}	39.2^{abA}	42.3^{cA}	48.9^{aB}	L
10	44.2^{bBC}	42.5^{aC}	48.2^{bcAB}	49.8^{aA}	L
20	52.3^{cA}	42.3^{aB}	54.5^{abA}	52.3^{aA}	C
30	52.7^{cA}	42.7^{aB}	57.7^{aA}	51.8^{aA}	C
40		35.5^{bA}	53.6^{abB}	40.5^{bA}	Q
50				42.3^{b}	not analyzable
Trend over heights** (*P*<0.05)	L	Q	L / Q	L / Q	

* Upper case superscripts are used for the comparisons within a row;
Low-case superscripts are used for the comparisons within a column;
Different superscripts indicate a statistical difference at $P < 0.05$.
** L = linear trend; Q = quadratic trend; C = cubic trend.

Table 6.2. Comparisons of pig head entrance angles between pig weight groups and feed shelf heights.

Shelf height (cm)	Pig weight (kg)* 22.6	48.4	71.7	95.7	Trend over weights** (P<0.05)
0	53.2	53.8	53.3^{ab}	53.2	no trend
10	54.0^{A}	52.0^{AB}	50.0^{bcB}	53.0^{AB}	no trend
20	57.3^{A}	51.8^{B}	48.6^{cB}	52.3^{B}	L / Q
30	56.9^{A}	52.3^{AB}	54.1^{aAB}	51.8^{B}	L
40		55.5	54.5^{a}	53.6	no trend
50				54.0	not analyzable
Trend over heights** (P<0.05)	L	Q	Q	no trend	

* Upper case superscripts are used for the comparisons within a row;
* Low-case superscripts are used for the comparisons within a column;
* Different superscripts indicate a statistical difference at $P < 0.05$.
** Trend analyses: L=linear; Q=quadratic; C=cubic.

Cleaning of the Feeding Space

The areas in the bottom of the feeder which remained covered with residual feed are illustrated in Figure 6.6. As expected, residual feed was found in the corners and edges of the feeding area. While feed was always left in the four corners of the feeding area, the amount remaining along the edges varied with location. The side edges were virtually clean for all sizes of pigs, but the back edge was most effectively cleaned by the two smaller sizes of pigs. This may be due to their small snout, or a more efficient turning of the head made possible by their relatively greater freedom of movement in a standard sized feeder. In contrast, larger pigs were better able to access feed near the lip of the feeder. Small pigs appeared to have difficulty reaching over the 10 cm feeder lip and consuming nearby feed. In general, large pigs tended to leave more feed in the corners and along the back edge of the feeding area, while small pigs left feed at the front.

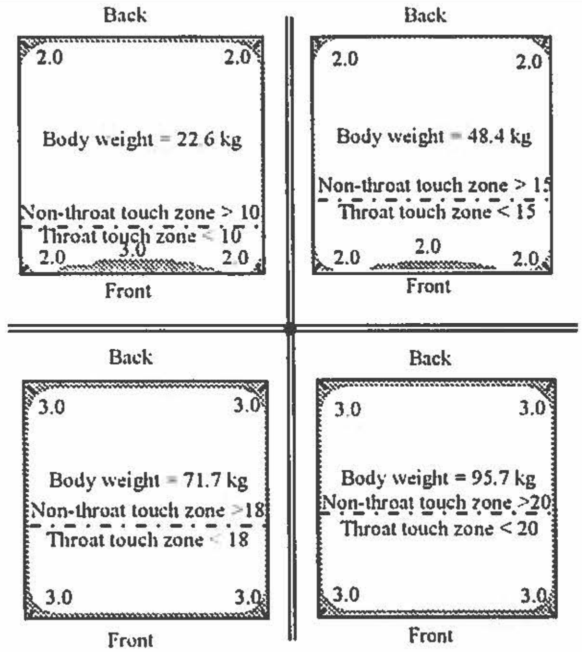


Figure 6.6. Pattern of residual feed left in feeders by pigs of different weight.

■ Conclusions

To reduce the incidence of stepping-in the feeder, feeder depth should be kept to a minimum. This minimum can be approximated by the normal reach (toe to mouth) of the pig while eating without a feeder lip. This distance is sufficient to provide the pig an eating zone well beyond the area that is difficult to access in front of the feeder lip. Ideal feeder depth is dependent upon the size of the pig, and varies from 14 to 32 cm for 22 to 95 kg pigs, respectively. Feeders intended for use by pigs throughout this range of weights should be 20 to 30 cm in depth, and have lip heights of 10 to 15 cm to minimize stepping-in.

Pigs do not position their bodies or heads perpendicular to the feed access point when eating. Unrestricted pigs stand at a 30° angle to the feed, and even when their body position is restricted, will turn their heads to a 45° angle. Pigs also rotate their head as they eat, approximately 50° from vertical. Protective side panels may better define an eating space and provide protection to the pig while eating, but they may also force pigs to stand at awkward angles while eating. Feeder designs which incorporate both protection and an angled position should be considered.

■ Implications

The ergonomic evaluation of the pig feeder in this study suggests specific dimensions for different weight pigs. Producers and feeder manufacturers should be aware that a single feeder will not be properly dimensioned for pigs throughout the entire grower/finisher period. A compromise in dimensions must be struck to accommodate a wide range of pig weights. The alternative is to use separate grower and finisher feeders, or other combination of pig weight classes, and select feeders well suited for each range. Manufacturers should also consider feeder designs which allow pigs to orient themselves at an angle other than perpendicular to the feed access point. Such designs may facilitate eating by the pigs, but need to be evaluated before being accepted by the industry.

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Chapter 7. Eating Behaviour

■ Summary

The eating behaviour of growing/finishing pigs was studied using twelve commercial feeders representing four design types: single-space dry, multiple space dry, single space wet/dry, and multiple space wet/dry. Pens of 12 pigs were videotaped for 24 hours near the beginning and end of the 12-week study. The total duration of eating varied from less than 75 to over 115 min/day per pig, and the number of displacements (entrances) from less than 30 to over 80 per pig per day, on the different feeders. Large pigs spent less time eating than did small pigs, but spent longer in the feeder per entrance. Wet/dry feeders also resulted in reduced eating time, with an increase in eating speed of approximately 25% compared to dry feeders. Pigs spent less time eating from single space feeders than from multiple space feeders, but this was associated with shorter durations per entrance into the feeder. The combined effects of single space and dry features in a feeder resulted in an average feeder occupancy rate in excess of 80%, which would be higher still for small pigs.

The majority of displacements did not involve force, and this was most evident for feeders with a low occupancy rate. Providing protection to the pig while eating tended to reduce the number of displacements but increase the proportion involving pushing or other force.

■ Introduction

A feeder's production performance relies on the actual use of the feeder by pigs. Decision making on issues such as pig/feeder ratio and management routine can be more accurately determined if the eating patterns of the pigs and the feeder time budget are taken into account. These in turn can influence purchasing decisions when new equipment is needed. English et al. (1988) once recommended 4 pigs per feeding space. Using today's feeders, such an allowance may be too luxurious to be practical. For example, Albar and Granier (1989) found that 20 pigs could be accommodated on one single space feeder with a nipple drinker, without depressing production performance. Walker (1991) even managed to accommodate as many as 30 pigs on a single space feeder, and claimed that there was no effect on growth rate or carcass backfat, with a feed conversion efficiency comparable to that of 10 or 20 pigs/feeder. Space allotment depends on the pigs' eating speed, and ultimately on the features of the feeder. Auffray and Marcilloux (1983) found that pigs ate at a constant rate throughout a meal when feed supply is continuous, but eating patterns may change as pigs grow. Common conclusions from several different studies (Bigelow and Houpt, 1988; Walker, 1991) are that large pigs spend less time eating and pay fewer visits to feeders, but have longer meal durations.

Temporal patterns of eating have also been reported (Auffray and Marcilloux, 1983; Walker, 1991; de Haer and Merks, 1992; Young and Lawrence, 1994). Individually housed pigs fed ad libitum may have several discrete meals a day following a diurnal cycle. Groups of pigs generally have two intensive eating periods; one in the morning and the second in the afternoon or evening

(Montgomery et al., 1978; Schouten, 1986; Feddes et al., 1989; Walker, 1991; Nienaber et al., 1991; Young and Lawrence, 1994). However, caution must be taken in interpreting these results as many factors can influence the temporal pattern. These factors may include management practices (feeding regime and human presence), light schedule (Feddes et al., 1989; Montgomery et al., 1978), social synchronization of feeding (Clayton, 1978; Hansen et al., 1982; Hsia and Wood-Gush, 1983), or even the methods used for recording the feeding behaviour (de Haer et al., 1992; Young and Lawrence, 1994).

■ Objectives

The objectives of this study were to determine the effects of feeder type on:
1. the temporal aspects of eating behaviour in pigs, and
2. the nature of displacements during eating by pigs.

■ Experimental Procedure

The study was conducted in an 'engineering' room at the Prairie Swine Centre. The room accommodated 12 pens. Pens had fully slatted concrete floors and spindle penning. Four blocks or turns of the room were used. A total of 48 pens were involved in the study, representing 4 pens for each of the 12 feeders studied. Not all feeders could be assigned to each block, due to the two sided feeders that fed 2 pens at once, but as many feeders as possible were included in each room turn. The trial period for each pen was 12 wk. Each of the 12 pens measured 4.8 x 2.1 m (16 x 7 ft), accommodating 12 pigs with an average space allowance of 0.86 m^2/pig (9.3 ft^2/pig), or approximately 0.042 m^2/kg $BW^{.667}$ at the end of the trial.

Twelve models of commercially available feeders (**Table 7.1**) were included in the study. Feeders were classified as dry if no water was available in the feeder, and as single space if only one market weight pig could eat at a time from the feeder. Feeders were installed as part of or adjacent to the pen division, approximately 1.6 m from the back of the pen. A single nipple drinker was mounted between the feeder and the rear wall for all dry feeders and the wet/dry feeders (SS-WD-1 and SS-WD-3) whose manufacturers recommended an additional water source. No additional water source was provided for pigs using the other four wet/dry feeders. All single space and the MS-WD-2 feeders were oriented such that pigs stood parallel to the pen division while eating. In the case of single space feeders, the pigs faced the rear of the pen while eating. The MS-D-3 and all MS-WD feeders fed two pens at a time. Feed hoppers were enlarged on some feeders to accommodate sufficient feed for a day. A feed hopper equipped with an agitating rod and motor was installed above the MS-WD-3 feeder.

Table 7.1. Details of feeders used for the observation of eating behaviour.

Feeder	Feeding space/ pen	Feed form	Feeder/pen
SS-D-1	1 space	Dry	1
SS-D-2	1 space	Dry	1
SS-WD-1	1 space	Wet/Dry	1
SS-WD-2	1 space	Wet/Dry	1
SS-WD-3	1 space	Wet/Dry	1
MS-D-1	2 spaces	Dry	1
MS-D-2	2 spaces	Dry	1
MS-D-3	4 spaces	Dry	1
MS-D-4	4 spaces	Dry	1/2
MS-WD-1	2 spaces	Wet/Dry	1/2
MS-WD-2	2 spaces	Wet/Dry	1/2
MS-WD-3	2 spaces	Wet/Dry	1/2

The pigs were Pig Improvement (Canada) stock. Castrated males and females were mixed and allocated evenly among the pens. The average weight of the pigs at the beginning of the trials was approximately 25 kg. The pigs were fed a meal diet (5/32 in. screen) based on barley and soybean meal, in a two phase feeding program. For the first 6 wk of the trial the diet provided 3.26 mCal/kg and contained 16.8 % crude protein, and for the final 6 wk, 3.21 mCal/kg and 16.1 %.

Each pen was videotaped for 24 h on two occasions, during weeks 3-4 (small pigs) and again during weeks 8-9 (large pigs) of the study. Each pen was monitored by two cameras. One camera was above the feeder to record the behaviour of pigs eating, and the other camera was installed on the ceiling above one end of the pen to observe the activities of pigs near the feeder, as well as in the whole pen. VCR recording mode was set to 24 h, which yielded 5.7 video images per second.

The time budget of feeder usage was determined by instantaneous observations at 10 min intervals. The number of pigs eating from the feeder during each observation was recorded and these data were used to determine the total duration of eating, the percentage of time feeder holes were occupied, and the percentage of time feeders were in use. For 10 min of each hour, the tapes were observed continuously and all displacements of pigs from the feeder recorded. Displacement behaviour was categorized according to how subsequent pigs gained access to the feeder as follows:

Unforced (UF)) - Feeder access without interference of the pen mates and with no pig previously occupying the feeder.

Sneak In (SI) - A pig accessed the feeder while the preceding feeder occupant fought with another pig for feeder access.

Jump-on-Top (JT) - A pig displaced the occupant pig by climbing or jumping on the occupant pig from either side or the back.

Push-from-Side (PS) - A pig forced the occupant pig away from the feeder by pushing the occupant pig from its sides. This category was further sub-divided for feeders in which eating pigs stood next to the pen division, into pushes from the open or wall side of the eating pig.

Root Up (RU) - A pig replaced the occupant pig by rooting up the occupant pig from the rear.

Data from the continuous observations were used to determine the number of entrances per day as well as the number and proportion of each type of displacement.

■ Statistical Analysis

Chi-square analysis was used to determine if there were differences in the proportion of unforced approaches between small and large pigs, and among feeders within small and large pigs. For feeders in which pigs stood along the pen partition while eating, the proportion of pushes from the wall and open side was compared among feeders using chi-square analysis. For all chi-square analyses the actual number of displacements observed, rather than the predicted daily totals, were used in the calculations. Data for Sneak-In, Jump-on-Top and Root-Up were lumped prior to analysis in order to achieve adequate frequencies for all cells.

The total duration of eating, number of feeder displacements, and occupancy rates for both feeder holes and feeders were analyzed using the PROC GLM of SAS (SAS, 1990). The model tested for the effects of pig size, feed form, feeder space and the interaction of feed form and feeder space. Pens were considered the experimental unit. The error term was feeder nested within form and space.

■ Results

Due to technical problems, only 68 of the potential 96 observation days were analyzed. The number of observations for feeders for small pigs ranged from 1 (1 feeder) to 4 (1 feeder). For large pigs, between 2 (3 feeders) and 4 (7 feeders) observations were made on each feeder.

The proportion of displacements which were Unforced was 71% overall, but this was higher for large than for small pigs (76 vs 68%; $P<.01$). Within both small and large pigs there were differences among feeders for the proportions of displacements that were Unforced, Pushed from Side, and Other (Figure 7.1). For feeders in which eating pigs stood along the pen partition, an average of 40% of the Push from Side displacements came from the wall side of the pig. This proportion varied among feeders, with the highest proportions for feeders that had longer side panels for protection of the pigs (SS-D-2, 57%; SS-WD-1, 45%; SS-D-1, 39%).

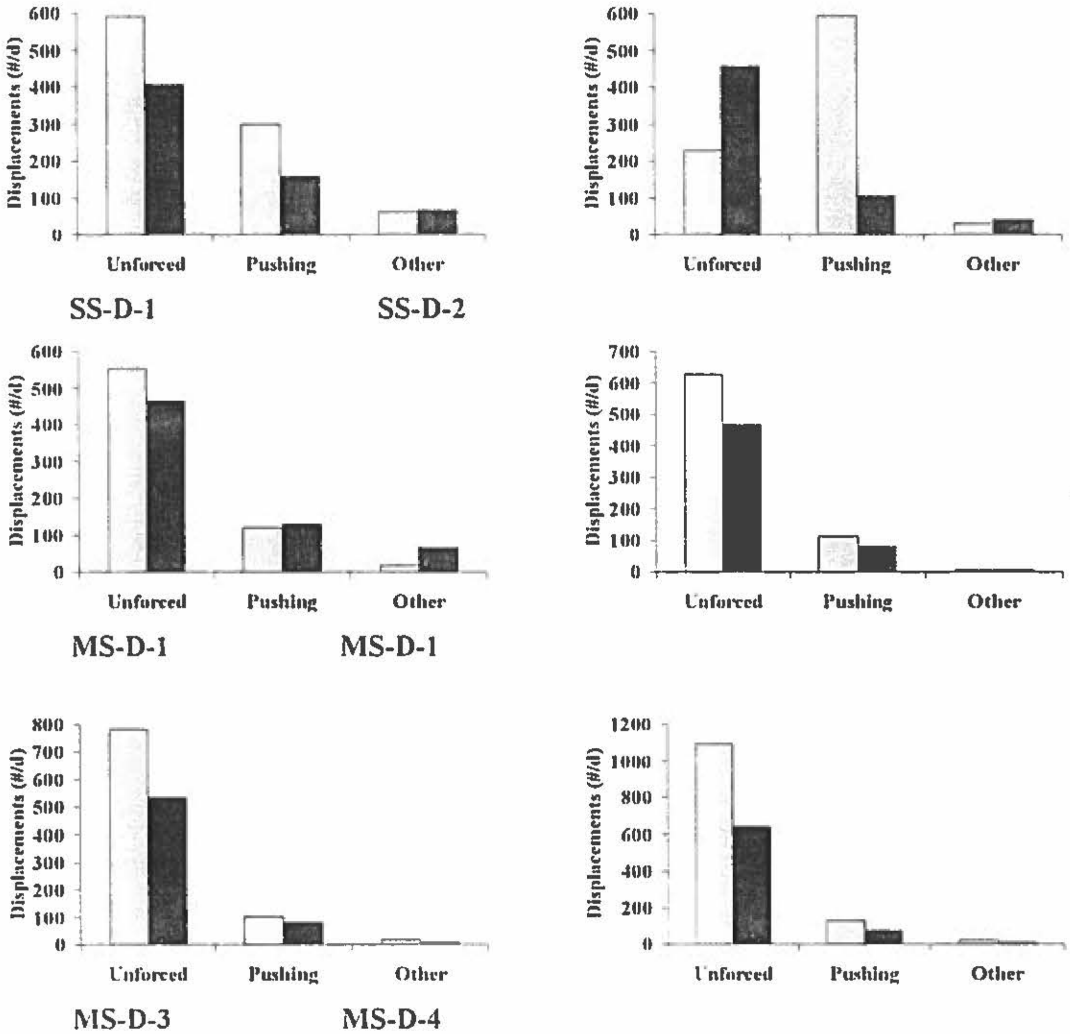

Figure 7.1a. Classification of displacements at the feeder for small (dark bars) and large (light bars) pigs fed from different models of feeders.

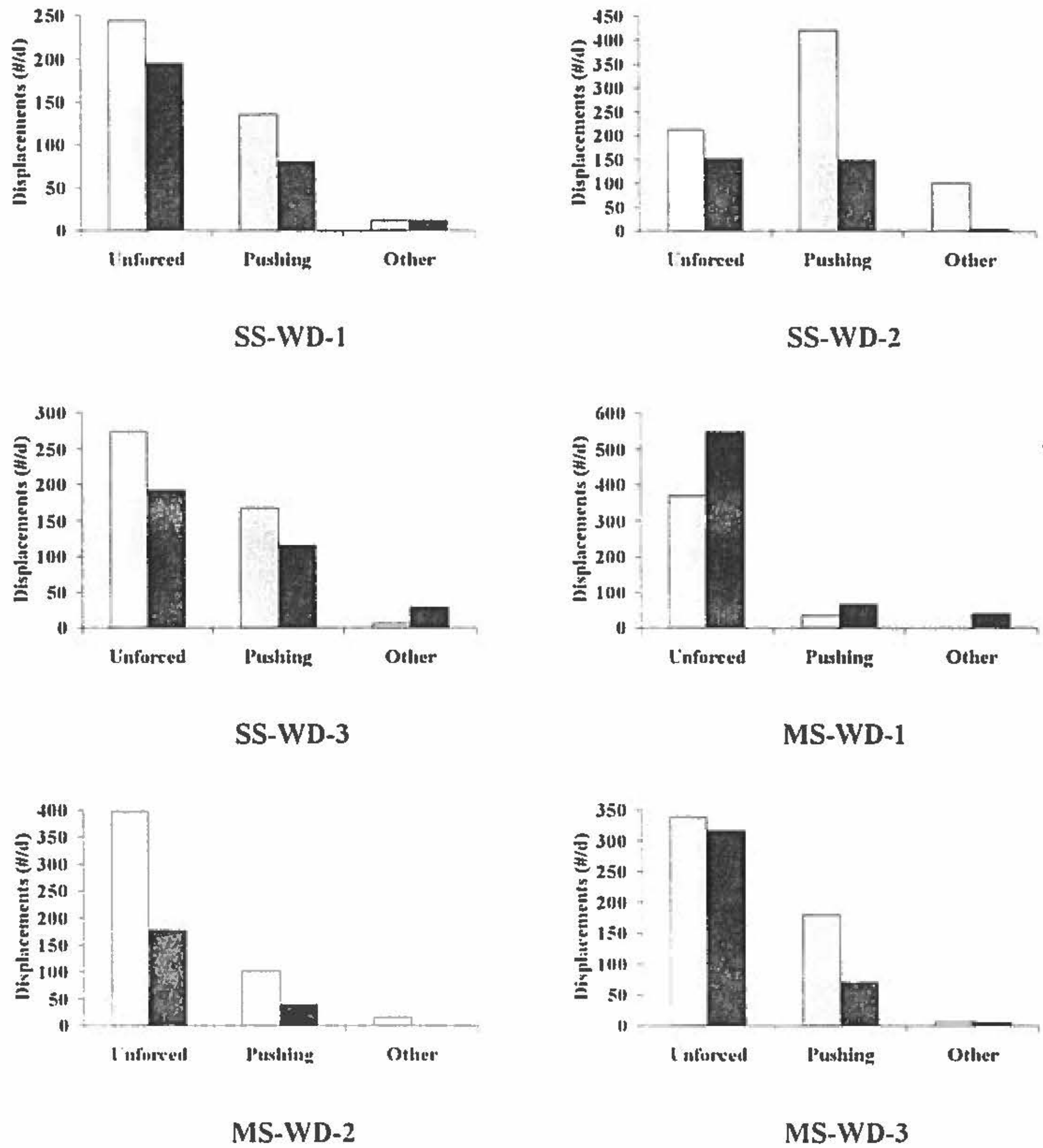

Figure 7.1b. Classification of displacements at the feeder for small (dark bars) and large (light bars) pigs fed from different models of feeders.

In addition to differing in the proportion of unforced displacements, small and large pigs differed in the total duration of eating, number of displacements, and occupancy rates for the feeder as a whole and for individual holes (Table 7.2). The decrease in total duration of eating from small to large pigs was 16%, and that of the feeder and hole based occupancy rates were of similar magnitude. It follows then that unforced displacements, in which pigs entered an unoccupied feeder space, should decrease from small to large pigs (11%). The decrease in number of displacements was of a greater proportion (24%). Eating time per displacement was 10% greater for large pigs than for small. All of these relationships would follow the initial observation that large pigs spend less time eating than small pigs. All other factors being equal, more large pigs than small pigs should be able to eat from a feeding space.

Table 7.2. Effect of pig size on eating behaviour and feeder occupancy.

Item	Pig size		
	Small	Large	Prob.
Total duration of eating (min*pig^{-1}*day^{-1})	102.0 ±4.68	85.6 ±3.46	.01
Feeder displacements (no.*pig^{-1}*day^{-1})	55.6 ±2.67	42.2 ±2.67	.05
Occupancy rate (feeder) (% of day)	64.3 ±1.91	54.1 ±1.39	.01
Occupancy rate (hole) (% of day)	53.3 ±1.96	43.1 ±1.45	.01

Pigs eating from wet/dry feeders spent less time eating than did those on dry feeders (Table 7.3). Given the decrease in time spent eating (17%) and a concomitant increase in intake (5%, Chapter 2), the actual eating rate (gm/min) was approximately 27% faster for wet/dry feeders. Although this finding contrasts with the results of Chapter 4, it is likely more reliable as its represents observations in a long term setting rather than a limited test situation. Less time spent eating resulted in fewer displacements and reduced feeder occupancy as well. However, as several of the dry feeders accommodated four pigs, the occupancy rate per hole was less for dry feeders. The reduction in eating time from wet/dry feeders should allow an increase in the number of pigs that could be fed from a feeding space. The time spent eating per displacement was much higher (36%) for pigs fed from wet/dry feeders than from dry.

Table 7.3. Effect of feed form on eating behaviour and feeder occupancy.

Item	Feed form		Prob.
	Dry	Wet/Dry	
Total duration of eating ($min*pig^{-1}*day^{-1}$)	104.1 ±4.5	86.3 ±4.5	.01
Feeder displacements ($no.*pig^{-1}*day^{-1}$)	60.1 ±3.25	36.7 ±3.25	.01
Occupancy rate (feeder) (% of day)	63.5 ±1.91	55.1 ±1.39	.05
Occupancy rate (hole) (% of day)	44.9 ±2.11	49.5 ±2.11	.05

As expected, the occupancy rates for feeders and feeder holes were much higher for single than for multiple space feeders (Table 7.4). Pigs apparently adjusted their eating speed in response to space restriction and spent less time eating from single space feeders. However, there was no significant difference in the number of displacements between single and two holed feeders, indicating that time spent eating per displacement would be less for single space feeders. When all factors are combined, total duration of eating was least for single space wet/dry feeders (Table 7.5), and this should be further reduced if only large pigs are considered.

Table 7.4. Effect of feeder space on eating behaviour and feeder occupancy.

Item	Feeding spaces			Prob.
	One	Two	Four	
Total duration of eating ($min*pig^{-1}*day^{-1}$)	84.0 ±5.94	97.6 ±5.94	111.5 ±5.94	.01
Feeder displacements ($no.*pig^{-1}*day^{-1}$)	45.2 ±3.69	40.8 ±3.58	52.4 ±4.20	ns
Occupancy rate (feeder) (% of day)	71.5 ±2.15	50.3 ±1.96	56.9 ±2.86	.01
Occupancy rate (hole) (% of day)	68.1 ±2.80	38.7 ±2.80	21.5 ±2.80	.01

Table 7.5. Eating behaviour of pigs and feeder occupancy rates for twelve commercial feeders.

Feeder	Total duration of eating (min*pig^{-1}*day^{-1})	Feeder displacements (no.*pig^{-1}*day^{-1})	Occupancy rate (feeder) (% of day)	Occupancy rate (hole) (% of day)
SS-D-1	92.0	66.0	76.1	75.5
SS-D-2	97.6	60.8	83.3	81.2
MS-D-1	98.9	56.2	54.1	39.7
MS-D-2	101.0	54.3	53.4	40.8
MS-D-3	107.3	63.5	55.2	20.9
MS-D-4	117.8	81.5	58.6	21.6
SS-WD-1	72.5	28.3	62.8	60.9
SS-WD-2	74.9	43.5	60.7	60.6
SS-WD-3	80.4	32.7	66.3	66.7
MS-WD-1	79.1	44.3	46.8	31.9
MS-WD-2**	97.5	60.8	51.0	35.4
MS-WD-3	109.8	38.3	56.6	43.3

**** Only one feeding space was observed. Reported values have been extrapolated.**

The eating behaviour of pigs on both SS-D-1 and SS-D-2 was typical of that expected based on feeder space and feed form (Table 7.5). Those eating from SS-D-2 spent slightly more time eating and had fewer displacements than those on SS-D-1, and this might be attributed to the longer side protection of the former. Pushing from the side was the primary means of displacements for small pigs on SS-D-2, while pigs on SS-D-1 tended to wait for the feeder to be empty.

Pigs eating from MS-D-1 and MS-D-2 displayed very similar behaviour which might be expected considering the similarity of the designs. MS-D-3 and MS-D-4 feeders provided little protection from other pigs and consequently there were more displacements than on MS-D-1 and MS-D-2. The pigs on the unprotected feeders also spent more time eating, although this could be attributed at least in part to their larger number of feeding spaces and low occupancy rate for feeder holes.

Pigs eating from the three single space wet/dry feeders differed little in their behaviour. Total eating time and displacements were the least among the four feeder types. All of these feeders provided protection to the head and shoulders of the pigs while eating, and there was a high proportion of displacements due to pushing rather than unforced.

Data from the MS-WD-2 feeder were limited to observations of just one side of the feeder. The extrapolated values must be considered unreliable, although they are similar to that of MS-WD-1. Although MS-WD-3 resulted in relatively few displacements, the pigs spent a considerable amount of time eating. The infrequency of displacements may be attributed to the lack of divisions in the feeder and pigs could continue to eat even when pushed to one side. There was a higher proportion of displacements due to pushing for MS-WD-3 than for MS-WD-1. The total duration of eating and feeder occupancy rate for MS-WD-3 was in fact similar to those for MS-D feeders.

■ Discussion

Three factors were found to affect total duration of eating and the ratio of eating duration to displacements. Large pigs and wet/dry feeding both reduced total duration of eating and resulted in longer eating episodes. The reduction in eating time meant that the feeder was less likely to be in use and probably reduced the demand from other pigs. As a result, pigs were able to continue to eat longer during each entrance to the feeder. The opposite was true for the third factor affecting total duration of eating. Single-space feeders resulted in a decrease in time spent eating. However, the reduction in feeding space meant that the feeder was less frequently unoccupied and there was a high demand by other pigs to enter. As a result, eating time per displacement was shorter in single-space feeders than in multiple space feeders. This latter situation may be indicative of overcrowding and a potentially stressful situation. However, the former situations, large pigs and wet/dry feeders, represent opportunities to increase the number of pigs per feeder.

Protection of the pigs while eating affected the number of displacements pigs performed each day. Well protected feeders resulted in fewer displacements than did those with little protection within the same feeder class. However, displacements from well protected feeders frequently involved pushing or other forms of forced entry.

■ Implications

The number of pigs that can eat from a feeder is an important factor to consider when equipping a barn. As large pigs spend less time eating per day, more could be fed from a single feeding space than small with small pigs. In a combined grow/finish pen, the limiting factor is the number of small pigs that could eat from the feeder. If separate grower and finisher barns are used, fewer feeding space would be required for large pigs. The number of pigs per feeding space can also be increased if wet/dry feeding is used. The results suggest an increase of approximately 25% should be possible.

The behaviour of the pigs responds to the number of feeding space available. Pigs ate more quickly when fed from a single space feeder, but were still able to consume adequate amounts of feed in this study. The point at which feeding space limits intake and growth was not evident in this study. The occupancy rate of over 80% for single space dry feeders suggests that no more than 20% more pigs (a total 14-15) could be accommodated, but it may be that pigs would be able to further adapt if crowded to that extent. Provision of a second feeding space allowed pigs to adopt a less intensive feeding strategy.

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