

A system for providing protein for pigs in intermediately sized grower/finisher barns

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Feddes, J.J.R., Ouellette, C.A. and Leonard, J.J. 2000. A system for providing protein for pigs in intermediately sized grower/finisher barns. *Can. Agric. Eng* 42:209-213. Blend feeding attempts to eliminate excesses and deficiencies in dietary protein associated with conventional phase feeding of growing pigs (20 to 110 kg) by meeting their protein requirements on a daily or weekly basis. An increase in carcass lean percentage and a reduction in feed intake and excreted nitrogen are the primary benefits of blend feeding. Blend feeding systems are becoming more common in new facilities, but a simple inexpensive system that is easy to retrofit to existing, intermediate sized grower barns (~800 growing pigs) is still not available. A prototype blend feeding system has been constructed using mechanical weigh drops (proportioning) and staggered dumping into a single flexible coil delivery auger (mixing) in tandem with feed proximity sensors and computer controlled valves (distribution). When an empty feeder is detected, via a feed proximity sensor, a batch of feed mixture is prepared and directed to the correct feeder by computer controlled valves. The required protein concentration in the feed is achieved through one-kg weigh drops of 12 and 20% protein feeds in the proper ratio, i.e. 18% protein = 1:3 ratio. Alternate dumps of the two feeds ensures that adequate mixing occurs in the delivery auger. Five trials were conducted at three different feed ratios: 1:1, 3:1, and 1:9. The 15 blended batches were analyzed for batch size and protein content accuracy and protein content coefficient of variation (CV). The nominal batch size was 40.4 kg and the mean batch size error was 1.47 kg (± 0.47) or 3.64%. The average batch protein content error was 0.63%. Comparing the economics of this system with a commercially available one for a 800-feeder barn (2000 pigs/year), the cost/pig place is \$41.75 and \$65.25, respectively, if cost recovery is assumed over one year. If the producer installs the components of the system, the cost/pig place is \$28.00.

En adoptant un système d'alimentation multiphase, on tente d'éliminer les excès et les carences en protéines que l'on retrouve dans l'alimentation en phase conventionnelle des porcs à l'engraissement (20 à 110 kg), en ajustant la demande en protéines sur une base journalière ou hebdomadaire. L'alimentation multiphase permet d'augmenter le pourcentage de viande sur les carcasses, de réduire la prise d'aliments et la quantité d'azote excrétée. Dans les nouvelles installations, les systèmes d'alimentation multiphase sont de plus en plus courants. Cependant, il n'existe pas de système simple et peu coûteux qui pourrait facilement être adapté à des installations existantes de taille moyenne (~ 800 porcs en croissance). On a construit un prototype qui utilise un système mécanique de pesée des quantités de moulée (pour les proportions) et de dépôt étalé, dans une vis de distribution simple flexible en forme de spirale (mélange), couplé avec des senseurs de proximité des aliments et des valves

contrôlées par ordinateur (distribution). Si les senseurs détectent qu'un distributeur d'aliments est vide, une certaine quantité du mélange de moulée est préparée et acheminée vers le bon distributeur par les valves contrôlées par ordinateur. On obtient la bonne concentration de protéines en mélangeant, dans les bonnes proportions, des quantités de 1 kg de deux moulées ayant respectivement 12 et 20% de protéines, pour obtenir un mélange ayant 18% de protéines = rapport 1:3. Des dépôts alternés des deux moulées permettent d'obtenir un mélange adéquat dans la vis de distribution. Cinq essais ont été faits à des taux différents: 1:1, 3:1 et 1:9. On a analysé le poids, la précision dans la teneur en protéines et le coefficient de variation de la teneur en protéines des 15 lots obtenus lors des essais. Le poids nominal des lots était de 40.4 kg et l'erreur moyenne était de 1.47 kg (± 0.47) ou 3.64%. L'erreur moyenne sur la teneur en protéines était de 0.63%. Si on compare ce système avec un système commercial disponible pour un bâtiment comprenant 800 distributeurs d'aliments (2000 porcs par année), le coût par emplacement est de 41.75\$ pour ce système contre 65.25\$ pour le système commercial, si on suppose que la récupération des coûts se fait en 1 an. Si le producteur installe lui-même les composantes du système, le coût par emplacement est de 28.00\$.

INTRODUCTION

The rate of protein deposition (lean growth) in growing pigs decreases with age while their appetite (feed intake) increases. Thus, the dietary protein requirements of the pig change daily. It is not economical or practical to formulate or handle more than three or four different diets throughout the growing period. Although a three (or more) phase feeding program is an improvement over the traditional two-phase step feeding program, a 16% protein grower diet (20-55 kg live mass) followed by a 14% protein finisher diet (55-107 kg live mass) results in wasted protein and other nutrients because, at times, the diet exceeds nutrient requirements while, at other times, nutrients may become limiting. This results in decreased pig performance, increased costs of production, and unnecessary excretion of nitrogen, which may have a negative impact on the receiving environment (Gadd 1992a). Providing more diets throughout the growth cycle provides more flexibility in nutrient intake. Through computer technology, it is feasible to implement blend feeding where the blend of feed ingredients delivered to pigs can be changed on a weekly basis or more frequently if required.

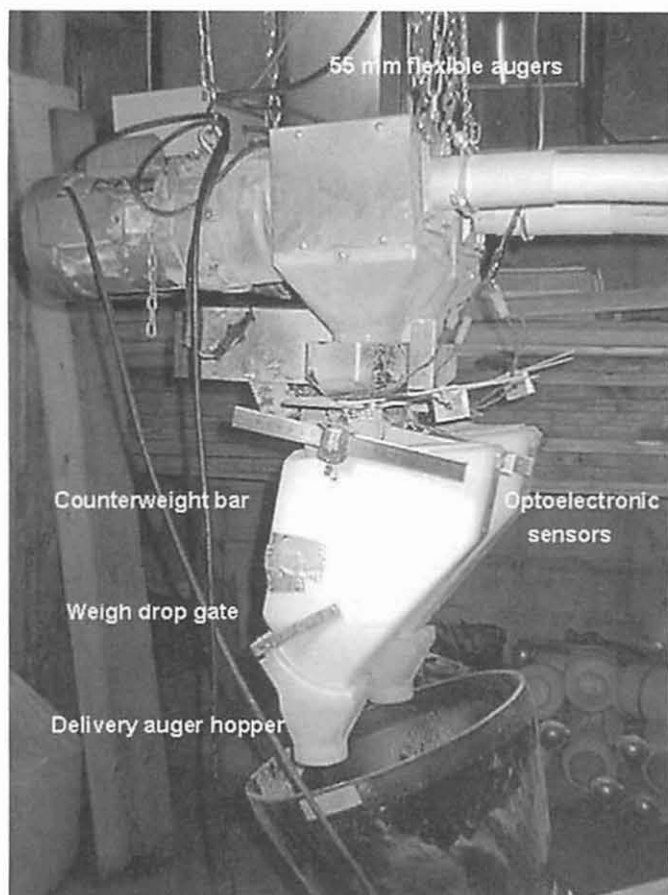


Fig. 1. Weigh drops.

An economical blend feeding system could utilize two base diets, one high protein (~20%) and one low protein (~12%), that are blended on-farm to a specified protein content according to weight and/or gender. Each base diet is assumed to be formulated for energy, vitamins, and minerals. Distribution of the blended diet to each group within the piggery must be kept simple. In an all-in-all-out system, all animals are fed similar diets unless the pigs have been separated by gender. In a continuous system, each group requires a different diet because of both weight and/or gender differences. Despite the potential

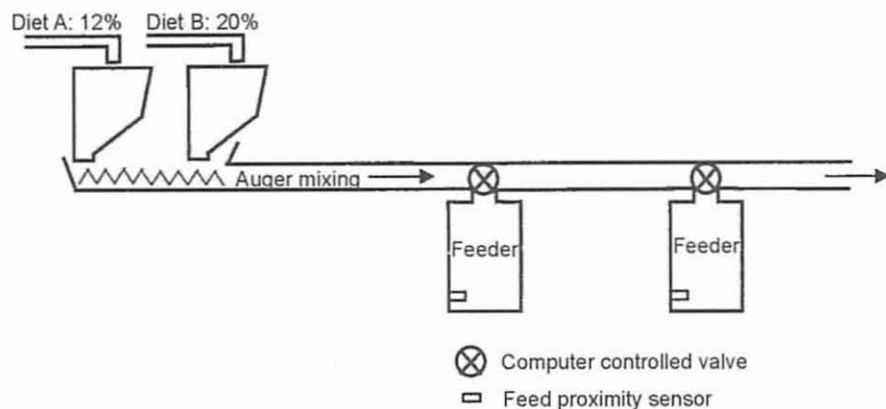


Fig. 2. An alternate blend feeding system.

advantages of blend feeding, the simple blending of feeds and the distribution of blended feed to the respective weight- and gender-related pens of pigs presents some significant engineering problems (Gadd 1992b).

Blend feeding systems are becoming more common, but are generally introduced into larger, new facilities. With commercially-available systems, the blend computer begins to prepare diets at a preset interval, usually daily, or via feeder sensors. The computer determines a diet based on pig age and calculates diet amounts based on the number of pigs per pen. The feed to be blended is proportioned into a mixer which is mounted on load cells monitored by a computer to measure the amounts being mixed. Once the desired feed amounts have been delivered to the mixer, the mixer operates for a predetermined mix time. After mixing, the feed is drained into a cable disc conveyor to be delivered to the pen feeders. An advantage of the cable disc conveyor is its complete displacement of the feed through the pipe. This allows the blend computer to track, via a sensor, the position of a diet in the feed delivery line and allows several diets to coexist in the line simultaneously. The computer operates pen feeder valves to be open if that particular pen is to receive the blended diet. Should some of the diet not get delivered because of lower than expected feed consumption or a malfunctioning feeder valve, it returns to be captured in a clean-out bin that has a feed sensor monitored by the blend computer. If feed is detected in the clean-out bin the blend computer will cease operation and activate an alarm for operator assistance.

A simplified, less expensive and easy-to-retrofit blend feeding alternative is still not available for existing, intermediate sized feeder operations (~800 pigs). Such a system requires the following elements: proportioning, mixing, and distribution. A prototype blend feeding system with these features has been constructed using mechanical weigh drops (proportioning) and controlled dumping into a single, flexible coil, delivery auger (mixing) in tandem with feed proximity sensors and computer controlled valves (distribution) (Fig. 2). The prototype and tests that have been conducted on its performance are described in detail below.

DESCRIPTION

Proportioning

Proportioning was achieved by two weigh drops that meter feed from two bins on a mass basis (Fig. 1). The two bins (A and B) held feed with 12 and 20% protein, respectively. The weigh drops were calibrated to deliver 1 kg increments of feed into a delivery auger. The weigh drops used (Model C-50609, Cablevey, Oskaloosa, IA) were modified for automatic feed dropping. For automatic control, a computer-controlled solenoid was used to open and close the weigh drop's gate when an optoelectronic sensor was interrupted by the upward movement of a counterweight bar. Each weigh drop was supplied with feed by a 56-mm O.D. flexible coil auger.

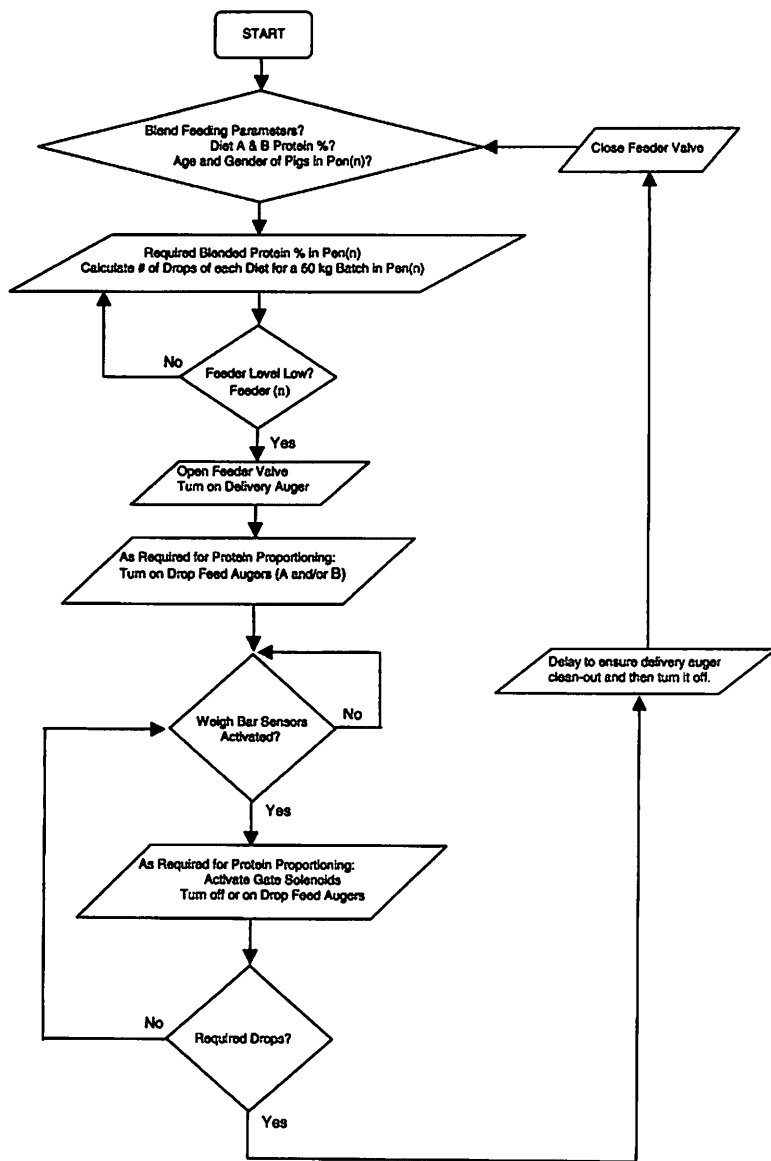


Fig. 3. Flow chart of blend feeding system.

Mixing

The two weigh drop mechanisms were interfaced with a computer and controlled by software to ensure that diets A and B were dropped in the required ratio in order to optimize mixing. For example, during a 3:1 trial the proportioning system dropped 1 kg of one diet into the delivery auger for every 3 kg of the other diet.

Distribution

A single distribution line, in conjunction with feed proximity sensors and automated in-line valves, would be used to deliver the required diet to specific feeders that would be located in each pen of pigs. In the prototype system, a single feeder was used to test this concept. Two proximity sensors were installed in the trial feeder, one optoelectronic and one capacitive, to evaluate their performance. Upon detection of no feed by both feed proximity sensors, the feeder's computer-controlled valve was opened and a batch of feed was proportioned and delivered.

Feed proximity sensors

A 30-mm threaded 3-wire DC capacitive sensor (Stedham Electronics Corporation, Reno, NV) and an infrared opto-electronic bin sensor (Agron Enterprises Inc., Saskatoon, SK) were installed at the base of a cylindrical trial feeder to detect the absence of feed. Installation in a pig barn feeder would require a universal mounting plate so that the sensor wiring could be run up the inside of the feeder and inside its drop spout to avoid pig contact.

Computer controlled valve and auger system

The computer controlled valve (Model 75, Chore-Time Equipment, Milford, IN) was an electric outlet drop. Once the feeder becomes empty, a signal from the level sensor initiates the blending of the new batch. The appropriate valve is opened and the feed is conveyed to the feeder. In this prototype, a 75-mm O.D. flexible coil auger, 3 m in length, delivered the proportioned feed to the feeder and would be adequate for a larger system.

Control system

An IBM compatible computer (Zenith 386) and a QUICKBASIC software program (DOS) operated two custom-designed electronic interfaces via a parallel port and an RS-232 serial port. The parallel interface operated the auger motors, weigh drop solenoids, and weigh drop optoelectronic sensors. The other interface monitored the feed proximity sensors and opened or closed the computer-controlled valve as required. The two interface circuits were housed in separate control boxes and indicator lights were mounted in the two control boxes to indicate the operating status of the various blending system components. In an installed system, each valve and feeder would require a separate, addressable feeder control box. These could be mounted conveniently on the ceiling adjacent to the feeder/valve installations.

The blend feeding system flow chart is shown in Fig. 3. When an empty feeder is detected, via a feed proximity sensor, a 50-kg batch is prepared and directed to the correct feeder by computer controlled valves (Fig. 2). The diet's protein concentration is achieved through 1 kg portions being dumped in the proper ratio from Bin A (12% protein) and Bin B (20% protein). For example, an 18% protein batch would require three drops from Bin B for every drop from Bin A. Once the weigh drop has dumped feed in the required protein concentration ratio into the delivery auger, the batch is mixed by the action of the auger as it is conveyed to the empty feeder.

System testing

Any blend feeding system must be capable of accurately proportioning, properly mixing, and delivering a specified diet to a particular feeder. The prototype blend feeding system was tested with low (LO) and high (HI) protein content diets which were formulated at the University of Alberta's Edmonton Research Station Feed Mill. Five trials of the blend feeding system were conducted at three different LO:HI ratios: 1:1, 3:1, and 1:9. The nominal or target size of each batch in these trials was 40.4 kg. After the delivery of each batch to the feeder, the actual batch mass was recorded and ten 400g feed samples were

Table I. Proportioning batching error.

Treatment	Number of samples	Mean batch amount (kg)	Error (kg) ¹
1:1	5	41.49, ±0.23	1.09
3:1	5	42.42, ±0.28	2.01
1:9	5	41.71, ±0.22	1.31
All treatments	15	41.87, ±0.47	1.47

¹Batch size = 40.4 kg

collected from the base of the feeder at 4 kg intervals as the feeder was emptied for later protein content analysis (Leco Nitrogen Analyser, FP-28, Leco Corp, St. Joseph, MI). An additional 25 trials were conducted with a 1:1 ratio and the same 40.4 kg batch size to assess the reliability of the entire system. The testing was performed in a laboratory setting, however, further testing in a swine barn is necessary.

RESULTS AND DISCUSSION

Proportioning

The mean overall batch size error of the proportioning components was 1.47 kg or 3.64 % (Table I). During testing with the various ratios, the batch size changed minimally indicating that the weigh drops maintained their calibration with use. The additional 25 reliability trials operated each of the weigh drops 500 times without any problems. The average batch size for the reliability trials was 41.0 kg (±0.43kg). Table II shows the protein batching error based on a LO protein content of 12.3% and a HI protein content of 20.1%. The average protein content error for all the trials was 0.63 %. The reliability of the corrected LO and HI protein contents was verified by a control batch mixed in a vertical mixer (RM25 Vrieco, Zelhem, The Netherlands) at a ratio of 1:1. The predicted protein content of 16.20% compares well with the actual value of 16.16%.

Mixing

To test the mixing performance of the blend feeding system, the 10 samples collected for each of the 15 protein content batching trials were analyzed for their protein content to determine each trial's mixing coefficient of variation (CV). A given diet with a mixing CV of less than 10% is considered adequately mixed (Nowak 1990). By alternating or staggering the 1 kg feed drops during proportioning it was possible to achieve an acceptable

Table II. Blended feed protein contents.

Treatment	Number of samples	Mean protein content (%)	Desired protein content (%)	Protein content error (%)
1:1	50	17.14, ±0.58	16.20	0.94
3:1	50	14.91, ±0.91	14.25	0.66
1:9	50	19.61, ±1.37	19.32	0.29
Overall	150	-	-	0.63
Control		16.16	16.20	0.04

Table III. Mixing coefficient of variation for different blends of 12 and 20% protein.

Treatment	Number of samples	Average protein content (%)	CV(%)
1:1	50	17.14	3.41
3:1	50	14.91	6.12
1:3	*	18.15	6.12
1:9	50	19.61	7.01
9:1	*	13.08	7.01
Overall	150	-	5.98
Control		16.16	2.62

* estimated from reciprocal ratios

mixing CV of less than 10% with a flexible coil distribution auger (Table III). Using reciprocity of mixing ratios, the measured results for 3:1 and 1:9 ratios are the results of 1:3 and 9:1 ratios as well. The mixing trials demonstrate that a wide range of protein contents (13.1 to 19.6%) can be mixed for the blend feeding of grower pigs without exceeding the critical CV of 10%.

Distribution

For all 40 trials, the delivery feed auger and the computer-controlled feed valve operated satisfactorily. Both feed proximity sensors operated each time the feeder became empty throughout the 40 trials. There was a concern that a build-up of feed dust would interfere with the operation of the optoelectronic proximity sensor but that was not the case. Ultimately, the choice of which feed proximity sensor to use will be based on price, ease of installation, and maintenance issues rather than performance.

BLEND FEEDING SYSTEM ECONOMICS

To illustrate the costs of the alternate blend feeding system as previously described, two cost scenarios are discussed, namely, customer assembled vs turn-key for an 800 grower/finisher barn. If each pen in this barn contains 15 pigs and each pen is serviced by a single feeder, the system would require 53 feeders. Table IV lists the various material and/or labour costs of the necessary equipment components for both the University of Alberta and a commercially available system. With the customer assembled option, a customer can reduce costs by assembling and installing the system. The figures for the turn-key option in Table IV are estimates of a contractor cost to install and commission the system. In comparison with the approximate costs of a commercially available system, the alternate blend feeding system would allow existing, intermediate-sized feeder barns to take advantage of blend feeding benefits at a reduced cost/pig place (\$41.75 vs. \$65.25) over a one-year payback period. If the customer wished to install the system, the cost/pig place is further decreased to \$28.00 vs. \$65.25. This comparison in costs clearly shows that this system is potentially cost effective for intermediate-sized barns. Note that all costs are based on 1998 prices in Western Canada.

Table IV. Blend feeding system cost comparison for an 800-pig feeder barn.

System	Item	University of Alberta		Commercially available	
		Turn-key	Mail order	Item	Turn-key
Proportioning	Change 75 mm flexible auger to 55 mm (2)	\$1150	\$850	Computer and load cell interface	\$11,700
	Weigh drop supports (2)	\$300	\$200	Control unit	\$6900
	Weigh drops (2)	\$120	\$120	Mixer c/w load cells	\$6100
	Weigh drop modification kits (2)	\$350	\$150		
	Weigh drop optoelectronic sensors (2)	\$100	\$60		
	Weigh drop solenoids (2)	\$200	\$100		
Distribution	Addressable feeder valve control box (53)	\$7950 (\$150/feeder)	\$5300 (\$100/feeder)	Disc/cable drive, piping and corners	\$3300
	Electric feeder valve (53)	\$10,600 (\$200/feeder)	\$7950 (\$150/feeder)	Feeder valve	\$15,600 (\$294/feeder)
	Feed proximity sensor (53)	\$6600 (\$125/feeder)	\$3600 (\$68/feeder)	Feed proximity sensor	\$3600 (\$68/feeder)
Other	Computer and interface hardware (1)	\$4000	\$3000	Installation	\$5000
	Software (1)	\$200	\$1000		
Total		\$33,400	\$22,300		\$52,200
Cost per pig place		\$41.75	\$28.00		\$65.25

CONCLUSIONS

A prototype blend feeding system performed reliably and delivered adequately mixed diets (CV<10%) over a wide range of protein contents (13.1 to 19.6%). Designed as a retrofit for existing intermediate sized operations, the estimated cost of the blend feeding system is \$41.75 per pig place. This compares very favourably with an estimated \$65.25 per pig place for commercially-available, turn-key system designed for installation in large, new facilities. A customer can further reduce this cost to \$28.00 per pig place by installing the components.

ACKNOWLEDGMENTS

The financial support of AARI (Alberta Agriculture Research Institute) and APPDC (Alberta Pork Producer's Development Corporation) made this research possible.

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