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Growth curve analysis to determine profit optimization and pig flow

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This paper is an attempt to put into practice some of the growth curve data we have collected in the previous two years. With the growth and feed budget data we have been able to calculate the weight distribution, carcass value, growth rate, and feed efficiency for each day in the finishing barn. Therefore, we are able to determine the net revenue for a barn on any given day of marketing. We then perform a sensitivity analysis to examine the influence of various factors on profit maximization. Subsequently, we have developed a method to describe the probability—when given the constraints of entry weight and days on feed—to determine the probability of achieving the profit maximizing weight.

Profit optimization

The ultimate goal in most production systems is profit. In addition, the total system profit is usually a relatively easy number to obtain in most production systems. The challenge becomes determining what the important factors are to improve profitability when profitability is sub-optimal. The proliferation of low cost computing technology has led to the accumulation of large amounts of data, especially group close-out data. These close-outs are then studied to make a diagnosis of the cause of sub-optimal profitability. However, maximum profit of a group may not result in maximum total profit of the production system.

> For example, in a system with 10 finishing barns, the maximum profit per group may be obtained when the barns are turned 2.7 times per year. Thus, if $10,000 in profit is obtained per group the total profit will be $270,000. However if the barns can be turned 3.0 times per year with a slightly lower profit of $9,500 the total system profit will be $285,000.

This example illustrates that maximizing profit on individual group close-outs may not result in the greatest overall system profit.

Traditionally, the basis of experimentation is to isolate a factor in the system and determine a response function. These functions are usually very accurate for the conditions of the experiment and specific segment of the production system. The function is then translated into economic terms to obtain an idea of the magnitude of the return. This is the basis for the law of diminishing returns. We acknowledge that maximizing profits of certain segments of the chain will be at the expense of profits in other segments possibly resulting in a decrease in total system or chain profit.[1] However, we believe the development of these functions is useful for categorizing and prioritizing factors affecting production system profit. Close-out data provides little information for determining response functions. Measurement of growth curves and feed budget curves have been instrumental for understanding profit maximization strategies.

We use growth curves and close-out data for determining profit optimization strategies. However, we keep in mind that maximizing any one segment of production or factor may not be the optimum for overall system profitability.

Another important tool for maximizing production system profit is to provide capacity buffers in the production system. Buffers between segments in the chains of production are useful for minimizing the negative effects of variability on profits. Carrying costs of the buffer capacity must be balanced against the lost opportunity cost of maximizing profitability for that segment.

> For example, consider two production systems consisting of 30 barns with a carrying cost of $40,000 per barn per year. After developing growth curves, it is determined that both systems have similar shaped profit maximization curves. Adding another barn will increase days on feed by 5 in both systems. However, the days on feed is increased from 110 to 115 in the first system and 120 to 125 in the second. Profitability per barn will be increased by $7,000/barn in the first system and $1,000 per barn in the second. In the case of the first system, profitability will increase by $177,000 per year ($7,000(31 barns=$217,000; $217,000($40,000 cost of extra barn=$177,000). In the second system, profitability will decrease by $9,000 per year ($1,000(31 barns=$31,000; $31,000($40,000=($9,000).

While we recognize the importance of providing buffers in capacity, we believe that the biologic data available to calculate the size of the buffer is not available or is simply not accurate. Therefore, we have chosen to convert biologic growth curves within the finishing phase of production into various economic scenarios and use them as crude indictors of when buffers should be placed in the system.

The optimum target will vary depending on feed cost, packer buying matrix, growth and feed budget curves, and other factors. Thus, profit-maximizing optimums will be production system specific.

Pig flow and production system design

How do we apply these principles for optimum production system design or for practical day-to-day management of existing production systems? We have basically chosen to divide production systems into three different categories.

The first is what we classify as fixed-time systems. An example is producers that have shares in a cooperatively owned sow unit and receive pigs on a fixed time schedule. There is little flexibility in their pig flow and scheduling. These producers have invested a fixed amount in finishing buildings and, thus, their objective is to maximize profit on a per barn basis. Increasing the profitability per barn maximizes the economic return on the fixed assets (finishing barns).

The next category is multiple-site operations that either own all of the production or operate the finishing barn contracts on a per pig space basis. Again, the finisher barn is basically the unit of production. In our experience, these systems fluctuate back and forth between maximizing the profit per group or barn. The fluctuations are based on pig flow and stage of production expansion. As the sow herds are expanded, finishing barns oscillate between being in excess or in short supply. Typically construction schedules are difficult to predict. Therefore, the timing of completion of construction rarely matches pig flow. The system also may have excess or a shortage of finishing space depending on pig flow throughout the year. Consequently, the objective will fluctuate between maximizing profit per barn and maximizing profit per group.

In these production system there are actually two profit maximizing points. The first is the market weight that is the long-range system target. The long-range target will be the system optimum. This weight (**Figure 1**) or day (**Figure 2**) is basically the point at which a group of pigs can be replaced with another group that will accumulate more profit per day. Thus the system optimum is the weight or day that profit is maximized per barn. For the simulation provided in Figures 1 and 2, the optimum profit per barn occurs at approximately 255 lb or 125 days on feed.

The second optimum target coincides with the point at which margin over cost becomes negative. This is the point at which profit is maximized for that group. If there are no pigs available to replace them, losses are minimized by leaving the space empty. For the simulation provided in Figures 1 and 2, the optimum profit per barn occurs at approximately 280 lb or 140 days on feed.

Therefore, the short-term market strategy is to remove pigs from the group when the margin over cost becomes negative for that group (approximately 280 lb in this system; Figure 1). This practice is commonly referred to as topping the barn or first cuts. The number of pigs sold and timing or barn topping depends on the availability of the next group of pigs. Therefore, on a practical basis, the next group of pigs grown in the barn basically dictates the marketing strategy. The strategy is to maximize the profit on each sort group sold out of the barn until the barn is refilled. A production system that has extra finishing space will increase profit by making several

Figure 1. Market Weight Affects Profit Per Group and Barn

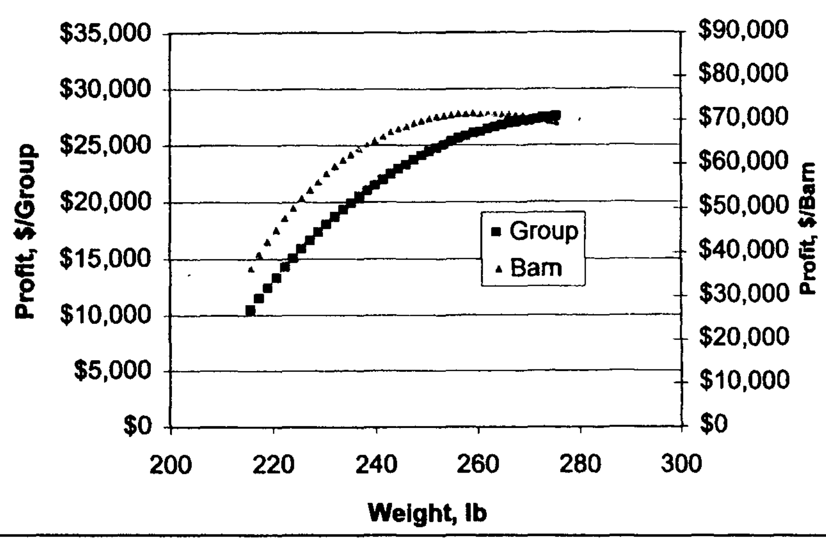
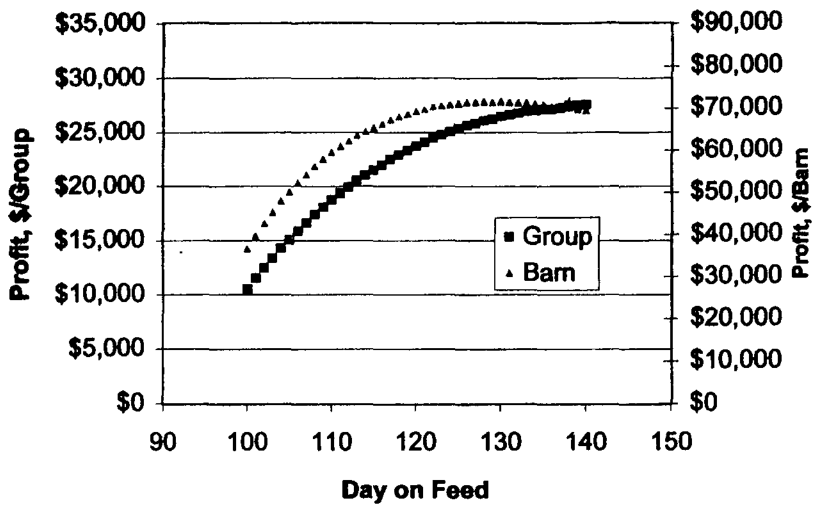


Figure 2. Days on Feed Affects Profit Per Group and Barn



marketing sorts. In contrast, a system that has extra pigs and limited finishing space will make fewer sorts from the group and may be forced to decrease market weight or days to make room for the next group of pigs. Knowledge of how far to the left of the profit maximizing point the actual market weight or days occurs will provide an indication of the opportunity cost lost by lowering market weight.

The third production system is based on a fixed payment per pound of gain. Pig producers that utilize these systems will have the objective of maximizing the profit per group. Since the contract cost is fixed per pound of gain, profit will be optimized at a point at which margin over cost of the group is equal to zero. These producers will generally utilize several sorts since having empty space incurs little expense. These producers will also try to ensure a larger buffer capacity of barns available since they will not incur expense if space is empty. In the long run, these systems will have difficulty maintaining their strategy due to poor facility utilization. Because payments to the barn owners are lower with a fixed payment per pound of gain, barn owners and lenders will demand payment on a fixed space allocation. These systems are economically inefficient and will have difficulty maintaining long term competitiveness.

Effect of variation on profit maximization

We recognize that optimization of a single phase of a chain of production is not the optimum for total system profitability. However, growth curve analysis has provided an understanding of the major factors that affect profitability in the finishing phase. For example, to build on the importance of litter weaning weight as presented elsewhere in these proceedings[2], we have studied the influence of weight into the finisher.

The effects of various entry weights on profitability in the finishing barn are depicted in **Figures 3–5**. The profit per barn was simulated using growth and feed budget curves for a 1,200-head finishing barn. The same growth and feed budget curves were used to generate the three figures. Normal weight distributions were used to simulate the range in initial pig weights around the means of 40, 50, and 60 lb. All costs were kept equal among the different scenarios except for feeder pig cost, which was varied by $3.50 per 10 lb. The profit per group was calculated as if the total barn was marketed on a single day. The profit per year was then calculated by multiplying the days on feed/365 times the profit per group.

These figures correspond to different effects of entry weight in the three different production systems discussed above. The importance of entry weight variance for producers on a fixed time system is illustrated in Figure 3. We can see from the figure that the shorter the fixed time period, the greater the influence that entry weight has on the variability in profitability.

> For example, producers that are fixed on a 110 days on feed system will improve profitability by almost $7,000 per year if entry weight is increased from 50 to 60 lb. However, producers with a fixed 120-day system will only improve profitability approximately $1,000 per year.

This is an example of how the effect of variability can be managed. The 120-day production system can tolerate more variability in entry weight than the 110-day system. Thus, the value of added weight out of the nursery is different between the two production systems.

The entry weight has no effect on the shape of the profit curve per barn based on weight (Figure 4). These curves

Figure 3. Entry Weight Influences Profit per Barn by Day on Feed

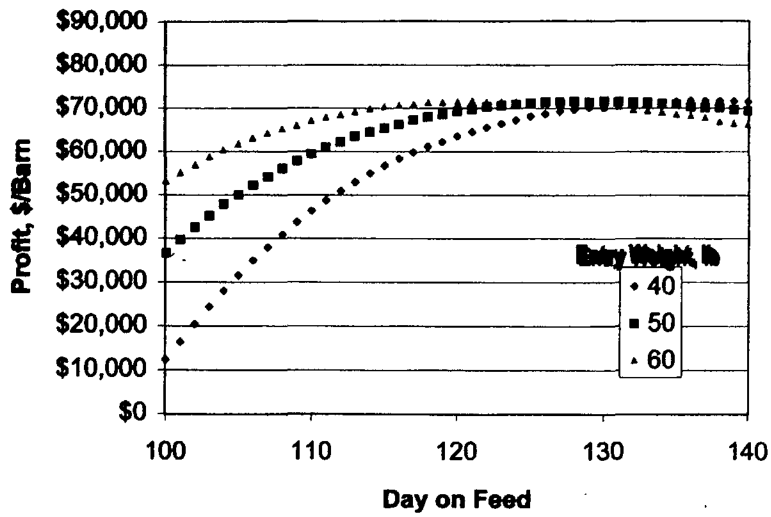


Figure 4. Entry Weight at Similar Market Weights Has Little Impact on Profit per Barn

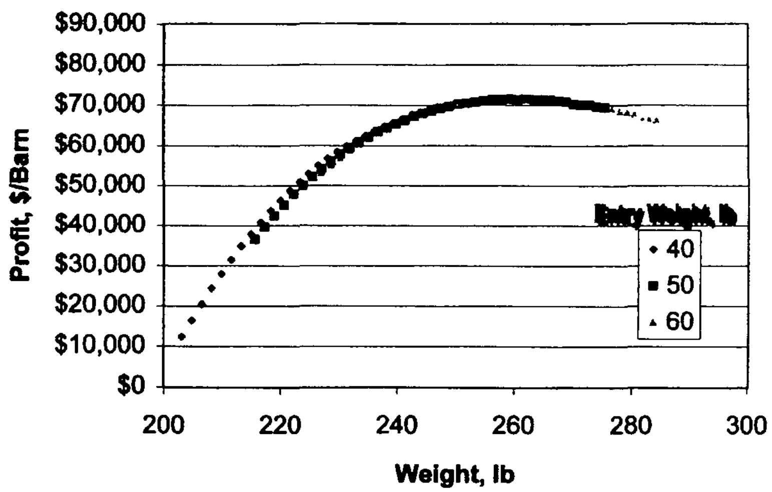
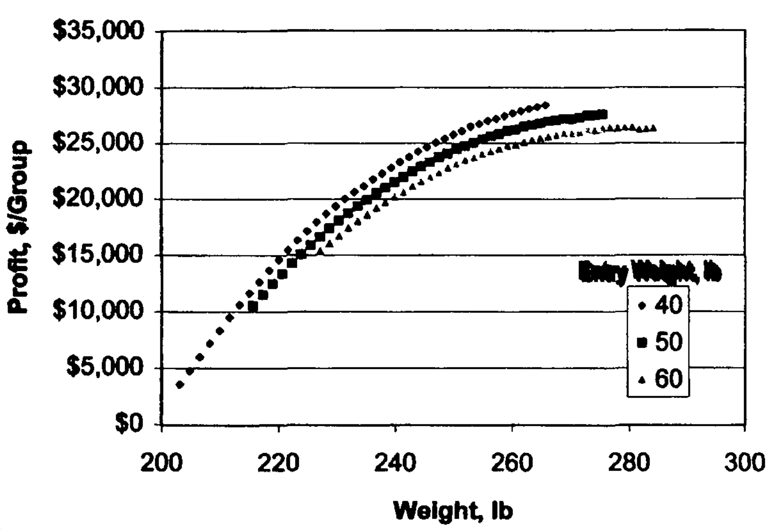


Figure 5. Lower Entry Weights Result in Higher Profit per Group



best represent the profit curves for the second category of production system. The profit maximizing market weight is independent of entry weight. While the curves are similar depending on entry weight more days on feed are required to reach similar market weights. Since the curves are similar for this category, entry weight is less of a concern than in the fixed time system.

The nonlinear curve in Figure 4 also indicates that marginal increases in market weight will improve profitability at a different rate. The farther the current market weight is from optimum the greater that increasing or decreasing market weight affects profitability per barn. Interestingly, the relatively flat portion of the curve between 250 and 270 lb provides for an inherent built-in buffer in finishing capacity. Fortunately, in this production system some fluctuations in market weight has relatively little impact on profitability when market weight falls in this range. Note the large increases in profitability per barn from increasing market weight from 230 to 240 lb compared to the increase from 240 to 250 lb (approximately $10,000 and $5,000, respectively). Therefore, depending on the current production system design increasing market weight by 10 lb has a different economic value depending on the current location of the profit curve.

The profit curves per group depending on entry weight are listed in Figure 5. At a similar market weight, lowering entry weight will increase profitability of the group. However, as indicated in Figure 4, the profitability per barn will be unaffected. We believe this may be a driving force in many production systems for lighter weights into the finisher. When examining profit per group the profit per pig is over $2 higher for the group with an entry weight of 40 lb compared to the group with an entry weight of 60 lb. Consequently, production systems that closely examine individual close-out profitability will tend to utilize shorter nursery production cycles with lower finishing barn entry weight. Production systems with the objective of maximizing profit per barn will increase nursery exit weights in order to decrease the negative effects on profitability of failing to meet the optimum market weight in a set number of days.

The second category of production system producers that fluctuates back and forth between an excess and shortage of finishing space and producers paying a fixed amount per lb of gain will use the information in Figure 5. However, the second category producers will only be trying to maximize profit per group in the case of excess finishing space. The fixed per lb of gain producers will always be evaluating strategies from a profit per group perspective.

Probability of attaining market weight

Once the profit maximizing market weight of a given group is determined, the next problem becomes how we deal with the inevitable group-to-group variation in growth performance. This will be another source of variation and a subsequent reduction in total system profitability. Total production system profitability will be lower than the average market weight of the groups times the expected profit of a group at the mean weight.

> As an example, consider a production system with a profit maximizing market weight of 255 lb. Take three groups of pigs with market weights of 245, 255, and 265 lb and profit of $8,000, 10,000, and 9,500, respectively. As depicted in Figures 3 and 4, average weight below or above the profit maximizing point decrease profitability. Therefore, production system profit ($27,500) does not equal three times the profit of the profit-maximizing group ($30,000) even though the average market weight is similar to the profit maximizing weight.

Production systems with similar market weights but different variability between groups will have different total system profits.

We have begun to study the effects of group variation by examining the probability that optimum market weight will be achieved given the constraints of entry weight and days on feed. At the present time, we assume that the entry weight and growth performance in the finisher is normally distributed as well as independent of nursery growth performance. Evidence indicates that in at least one production system these assumptions seem to hold true.[3] The percentages of groups attaining a desired market weight of 255 lb are listed in **Table 1**. The percentages are based on a mean ADG of 1.65 lb/d with a standard deviation of

Table 1

	Entry Weight, lb		
Day on Feed	40	50	60
100	0.6%	2.3%	6.7%
105	2.3%	6.5%	15.0%
110	6.4%	14.3%	27.0%
115	13.6%	25.4%	41.0%
120	23.9%	38.5%	55.0%
125	36.3%	52.0%	67.4%
130	49.2%	64.3%	77.3%
135	61.3%	74.5%	84.8%
140	71.6%	82.3%	90.1%

0.2 lb/d. For example based on these data 38.5% of groups with an entry weight of 50 lb and 120 days on feed will have an average market weight greater than 255 lb. Approximately, 61.5% of groups will have an average market weight of less than 255 lb.

In conclusion, these examples clearly indicate that profit optimization and pig flow strategies will vary among production systems and factors, such as entry weight.

Implications

- Optimum profit may be reflected by the profit per pig space or pig depending on the production system.
- Optimum marketing strategies will fluctuate depending on the availability of finishing space.
- Variability decreases total system profit below that predicted by the average per pig space or pig.

References

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