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Optimising finishing pig delivery weight: participatory decision problem analysis

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Literature review conducted as preparatory activity for monitoring meeting 1

Van Meensel (2010) present a production-economic model for optimizing pig-finishing farms. The optimization depends on the curvature of the production function relating the use of feed and piglets to the production of slaughter pigs, and on prices paid for feed, piglets and slaughter pigs. The production function is established mechanistically through combining growth, feed intake and mortality functions. Mechanistically modeling the production function results in farm-specific curvatures, which is shown to be advantageous over data-driven methods like Data Envelopment Analysis and Stochastic Frontier Analysis (see (Coelli *et al.* 2005) for an introduction to these methods), which assume the same curvature for all farms in the dataset. Farm-specific curvatures result from differences in technical performance between farms.

Animal growth models, which are essential to describe the pig production function have become more complex over time (Black 1995). Some approaches fit serial bodyweight measurements to mathematical growth equations that relate growth to the body weight or age of the animal (Lopez *et al.* 2000; Craig and Schinckel 2001; Schinckel and Craig 2002; Bridges *et al.* 1986). Moreover, mechanistic simulation models with better description and prediction of the fundamental biological processes have been presented (Black 1995). Stochasticity has also been introduced to account for biological variation in populations (Black 1995). Currently, growth simulation models also mechanistically model the allocation of nutrients for growth and maintenance needs. Additionally, growth of different tissues or chemical components that make up life weight is modeled (van Milgen *et al.* 2008; Kyriazakis 1999; De Lange *et al.* 2003; Schinckel *et al.* 2003). Despite the wealth of available growth models, their implementation into commercial practices is hampered because of the need for detailed parametrization and the absence of workable and accurate parameter estimation protocols (De Lange *et al.* 2001; Schinckel and De Lange 1996).

Besides growth, a description of feed intake is needed to construct the economic production function. The combination of a feed intake curve and growth model should allow for an accurate description of the evolution of the feed-to-gain ratio with increasing live weight as a measure of feed efficiency. Mechanistically predicting voluntary feed intake is difficult because of the multitude of influencing factors (Forbes 2007; Nyachoti *et al.* 2004). Schinckel and de Lange (1996) suggest to fit polynomial or non-linear models to feed intake data in order to derive curves that are gender-genotype specific due to the impact of genetic selection and gender on feed intake.

For economic optimization, it is also important to model how input quality affects input prices, the production function and output quality. Prices for piglets can vary depending on uniformity, health status and weight at purchase. Feed incurs the largest variable cost and its price is affected by quality and content (Niemi *et al.* 2010). The compound feed ingredients vary in price. The pig's nutrient requirements change during the growth process and especially the relative need for protein over energy diminishes as pigs grow. Moreover, the pig's feed intake capacity increases with age, thus diets require gradually lower protein and energy content levels. This dynamic adaptation of the feed content to match with growth requirements results in lower feed prices in a later finishing stage (Niemi *et al.* 2010).

In addition to growth and feed intake, mortality affects the pig production efficiency (Whittemore 1998). Few studies have considered mortality in finishing herds. According to Maes *et al.* (2004), mortality is a multifactorial condition and prolonged finishing duration is associated with higher mortality. Mortality risk may not be uniform throughout the finishing period (Maes *et al.* 2001). The relationship between finishing duration or life weight and mortality risk is crucial for determining the economic impact of mortality. Pigs that die represent a considerable economic loss which increases as pigs age.

The link between output quality and age and weight affects output prices and hence affects the optimal delivery weight. The relationship between carcass quality and weight is also gender and genotype-specific. Lean meat percentage, for example, decreases with increasing life weight, due to increased fat deposition at the end of finishing (Correa *et al.* 2006). This decrease is more pronounced for barrows compared to boars (Xue *et al.* 1997). Slaughterhouses commonly use quality incentive payment schemes penalizing and rewarding for (un)desirable carcass characteristics (Hoste *et al.* 2004). Price penalties are given for pigs outside the desired weight range or with a substandard lean meat percentage, while premiums are given for carcasses with better quality (higher lean meat percentage, better conformation). Although the relationship between carcass quality and price premiums or discounts allotted by slaughterhouse is not always transparent, quality is an important issue in the search for an optimal delivery weight.

Dressing percentage reflects the share of saleable carcass weight in pig live weight and therefore influences optimal delivery weight. The carcass mainly consists of muscle tissue and fat, components which mature later than organs and bones. Therefore, the dressing percentage increases with increasing body weight (Latorre *et al.* 2004; Cisneros *et al.* 1996; Albar *et al.* 1990; Gu *et al.* 1992).

The abovementioned factors suffice to establish the production function of an individual pig or a farm that produces only one batch of pigs per year. The production function is then deemed timeless (Winder and Trant 1961). Contemporary intensive pig production, however, consists of a continual sequence of production cycles (rotations), characterized by a certain duration. A current rotation competes for time with a consecutive one. In this case, profit maximization cannot be based on considerations of a single production cycle. Profit maximization per delivered pig or per batch of delivered pigs becomes inadequate. Instead, the opportunity cost for replacement should be considered by maximizing profit per period of time. Ross (1980) calculated the number of rotations as the number of days per year divided by the sum of the finishing duration per rotation and the average idle time between two consecutive production cycles.

Literature review conducted as preparatory activity for focus group 1

The opportunity cost for replacement in pig production has larger implications for delivery weight optimization on farms that work according to the *all in/all out* (AIAO) principle instead of continuous restocking. With continuous restocking, finishing units are continuously occupied with pigs. Batches of marketed pigs are instantaneously replaced by new weaner piglets. Under AIAO, farmers keep groups of pigs, closely matching in age and origin, (and hence also weight and requirements) together in the production process. This management reduces risks for disease transmission, because animals of different age are not mixed and AIAO creates sanitary vacuums during which facilities can be cleaned and disinfected (Scheidt *et al.* 1995). The opportunity cost for replacement becomes crucial because a consecutive rotation can only be initiated from the moment the last finished pig in the current rotation has been marketed and the facilities have been cleansed. Under AIAO profit-maximization per delivered animal is probably sub-optimal to profit-maximization per unit of time.

AIAO also implies that faster growing pigs are kept longer in relation to the slower growers before being marketed, because entire groups of animals enter and leave together. In a heterogeneous finishing herd, this results in suboptimal marketing results because fast and/or slow growing pigs may suffer from price penalties under a quality incentive payment scheme. Applying “Split harvesting”, i.e. marketing consecutive batches of pigs from a finishing unit according to their growth rate, can alleviate this problem (Niemi and Sevón-Aimonen 2009; Boys *et al.* 2007; Huang and Miller 2004; Giesen *et al.* 1988; Kure 1997).

The type of pig farm (farrow-to-finish vs. finishing) also affects the delivery weight optimization. On farrow-to-finish farms adopting AIAO, the supply of weaned piglets at regular intervals urges the farmer to empty a finishing unit in a timely way before restocking it with pigs from the nursery (Toft *et al.* 2005). Extending the finishing duration would disturb the production schedule. The ultimate timing to market finishing pigs is fixed at the operational level and postponement requires strategic or tactical adjustments to the supply of weaner piglets (Kure 1997). The operational flexibility of these farms lies in incidentally advancing the terminal marketing of the current rotation which only extends the idle time between the current and consecutive rotation. This will not change the number of rotations per year. Strategic adjustment of the weaner piglet supply is needed if the farmer wants to increase the rotation coefficient in the finishing facilities.

Finishing farms purchasing feeder piglets may not have this fixed rotation burden at the operational level because feeder piglets can be supplied on short notice by a dealer. However, finishing farms may have commercial relationships with multiplier farms and may therefore have to adapt to their supplier’s production schedule. The operational decision flexibility is than similar for finishing and farrowing-to-finish farms. Only the amount of idle time between production cycles can be changed because the arrival of feeder piglets has been strategically determined. Adapting the rotation coefficient on these farms requires tactical or strategic negotiations with feeder piglet suppliers.

References

Albar J, Latimier P, Granier R (1990) Poids d'abattage: évolution des performances d'engraissement de carcasse de porcs abattus au delà de 100 kg. Journées de la Recherche.Porcine Fr 22, 119-132.

Black JL (1995) The evolution of animal growth models. Modeling growth in the pig. 3-9.

Boys KA, Li N, Preckel PV, Schinckel AP, Foster KA (2007) Economic replacement of a heterogeneous herd. *American Journal of Agricultural Economics* 89, 24-35.

Bridges TC, Turner LW, Smith EM, Stahly TS, Loewer OJ (1986) A mathematical procedure for estimating animal growth and body composition. Transactions of the ASAE-American Society of Agricultural Engineers (USA) 29, 1342-1347.

Cisneros F, Ellis M, McKeith FK, McCaw J, Fernando RL (1996) Influence of slaughter weight on growth and carcass characteristics, commercial cutting and curing yields, and meat quality of barrows and gilts from two genotypes. Journal of animal science 74, 925-933.

Coelli TJ, Rao DSP, O'Donnell CJ, Battese GE (2005) 'An introduction to efficiency and productivity analysis.' Springer Science +Business Media New York

Correa JA, Faucitano L, Laforest JP, Rivest J, Marcoux M, Gariépy C (2006) Effects of slaughter weight on carcass composition and meat quality in pigs of two different growth rates. Meat Science 72, 91-99.

Craig BA, Schinckel AP (2001) Nonlinear mixed effects model for swine growth. The Professional Animal Scientist 17, 256-260.

De Lange CFM, Marty BJ, Birkett S, Morel P, Szkotnicki B (2001) Application of pig growth models in commercial pork production. Canadian Journal of Animal Science 81, 1-8.

De Lange CFM, Morel PCH, Birkett SH (2003) Modeling chemical and physical body composition of the growing pig. Journal of animal science 81, E159-E165.

Forbes JM (2007) 'Voluntary food intake and diet selection in farm animals.' (CABI International)

Giesen GW, Baltussen WHM, Oenema J (1988) Optimalisering van het afleveren van mestvarkens. Landbouw-Economisch Instituut, (Publikatie / Landbouw-Economisch Instituut 3.139), (LEI-Den Haag)

Gu Y, Schinckel AP, Martin TG (1992) Growth, development, and carcass composition in five genotypes of swine. Journal of animal science 70, 1719-1729.

Hoste R, Bondt N, Ingenbeek P. (2004) Visie op de varkenskolom. Landbouw Economisch Instituut LEI, Den Haag

Huang H, Miller GY (2004) Variability in Growth, Pig Weights and Hog Marketing Decisions. Urbana 51, 61802.

Kure, Henrik (1997) Optimal slaughter pig marketing. In ‘Proceedings of the Dutch/Danish symposium on animal health and management economics’.(Ed. R. Kristensen)pp. 39-47. (Royal Veterinary and Agricultural University, Department of Animal Science and Animal Health: Copenhagen)

Kyriazakis I (1999) 'A quantitative biology of the pig.' (CABI International)

Latorre MA, Lázaro R, Valencia DG, Medel P, Mateos GG (2004) The effects of gender and slaughter weight on the growth performance, carcass traits, and meat quality characteristics of heavy pigs. Journal of animal science 82, 526-533.

Lopez S, France J, Gerrits WJ, Dhanoa MS, Humphries DJ, Dijkstra J (2000) A generalized Michaelis-Menten equation for the analysis of growth. Journal of animal science 78, 1816-1828.

Maes D, Larriestra A, Deen J, Morrison R (2001) A retrospective study of mortality in grow-finish pigs in a multi-site production system. Journal of Swine Health and Production 9, 267-274.

Maes DG, Duchateau L, Larriestra A, Deen J, Morrison RB, de Kruif A (2004) Risk factors for mortality in grow-finishing pigs in Belgium. J.Vet.Med.B Infect.Dis.Vet.Public Health 51, 321-326.

Niemi JK, Sevón-Aimonen ML (2009) Economically optimal pig delivery scheduling and the design of meat pricing schemes when pig group is heterogeneous. In: ‘17th International Farm Management Congress’. Peer reviewed papers. IFMA, Cambridge, UK. pp. 531-539

Niemi JK, Sevón-Aimonen ML, Pietola K, Stalder KJ (2010) The value of precision feeding technologies for grow–finish swine. Livestock science 129, 13-23.

Nyachoti CM, Zijlstra RT, De Lange CFM, Patience JF (2004) Voluntary feed intake in growing-finishing pigs: A review of the main determining factors and potential approaches for accurate predictions. Canadian Journal of Animal Science 84, 549-566.

Ross RW (1980) The use of a production function to maximize Profits in a Feeder Hog Enterprise. Canadian Journal of Agricultural Economics/Revue canadienne d'agroeconomie 28, 33-37.

Scheidt AB, Cline TR, Clark LK, Mayrose VB, Van Alstine WG, Diekman MA, Singleton WL (1995) The effect of all-in-all-out growing-finishing on the health of pigs. Swine Health Prod 3, 202-205.

Schinckel AP, Craig BA (2002) Evaluation of alternative nonlinear mixed effects models of swine growth. The Professional Animal Scientist 18, 219-226.

Schinckel AP, De Lange CF (1996) Characterization of growth parameters needed as inputs for pig growth models. Journal of animal science 74, 2021-2036.

Schinckel AP, Li N, Preckel PV, Einstein ME, Miller D (2003) Development of a stochastic pig compositional growth model. The Professional Animal Scientist 19, 255-260.

Toft N, Kristensen AR, Jørgensen E (2005) A framework for decision support related to infectious diseases in slaughter pig fattening units. Agricultural Systems 85, 120-137.

Van Meensel J, Lauwers L, Van Huylenbroeck G, Van Passel S (2010) Comparing frontier methods for economic-environmental trade-off analysis. European Journal of Operational Research 207, 1027-1040.

van Milgen J, Valancogne A, Dubois S, Dourmad JY, Sève B, Noblet J (2008) InraPorc: A model and decision support tool for the nutrition of growing pigs. Animal Feed Science and Technology 143, 387-405.

Whittemore C (1998) 'The science and practice of pig production.' (Blackwell Science Ltd)

Winder JWL, Trant GI (1961) Comments on" Determining the Optimum Replacement Pattern". Journal of Farm Economics 939-951.

Xue J, Dial GD, Pettigrew JE (1997) Performance, carcass, and meat quality advantages of boars over barrows: A literature review. Swine Health Prod 5, 21-28.