An overview over pig production of fattening pigs with a focus on possible decisions in the production chain

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Chapter 1

Introduction

In Denmark approximately 27 mill piglets are produced each year(2007) (Christensen, 2010). A significant number of these piglets are exported to another countries (around 9 mill) and just a fraction of them (approx. 20 mill) are sent to the fattening units in Denmark. Moreover, pork constitute for about 5% of the Danish export, representing a value of about DKK 28 thousand million in 2009 (Christensen, 2010).

According to Christensen (2010) the number of farms in Denmark are approximately 6500 where 50% are finishing farms, 45% are integrated farms (both sow and finishing pigs) and the remaining 5% are sow farms. It is expected that the number farms will decrease during the next years and become larger, e.g. is the average production of 4400 finishing pigs per farm (2007) expected to increase to between 15000 and 20000 finishing pigs in 2020.

The project PigIT[1] focuses on integrating *information and communication technology* (*ICT*) in the entire production process at herd level through improved methods for automatic monitoring and advanced operations research methods for decision support in growing pigs. The objective is to contribute significantly to the competitiveness of the Danish slaughter pig industry while still ensuring a satisfactory level of animal welfare. The sub-project OMSPE focuses on developing decision models which integrate information from farm data and sensors in the decision process and try to solve the important methodological challenges related to simultaneously taking welfare and productivity into account while still addressing the stochastic nature of the pig production system.

Different production processes within pig production can be classified as mating, gestation, farrowing, weaning and finishing (Christensen, 2010). In the PigIT project the focus is on fattening pigs, i.e. the production process from weaning (3-4 weeks old with a weight of approximately 7 kg) to marketing (20-23 weeks old with at weight of approximately 100-110 kg). That is, we should concentrate on operational decisions in the weaner and finishing units (weekly or daily). However, also strategic decisions related to a time scale with several years and tactical

[1] http://www.pigit.net/

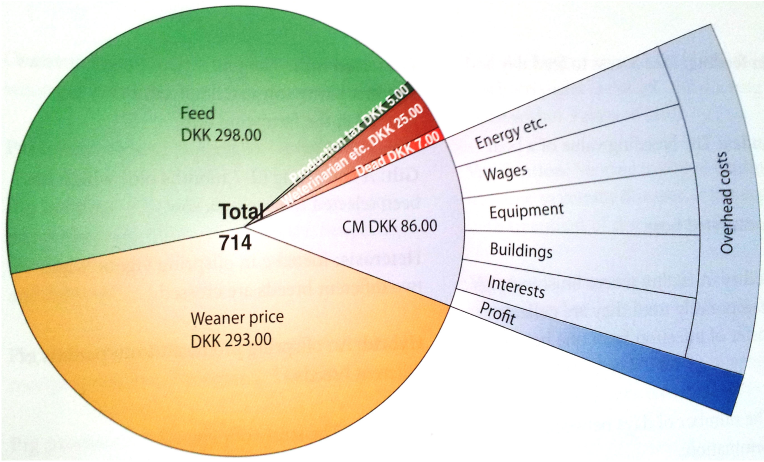


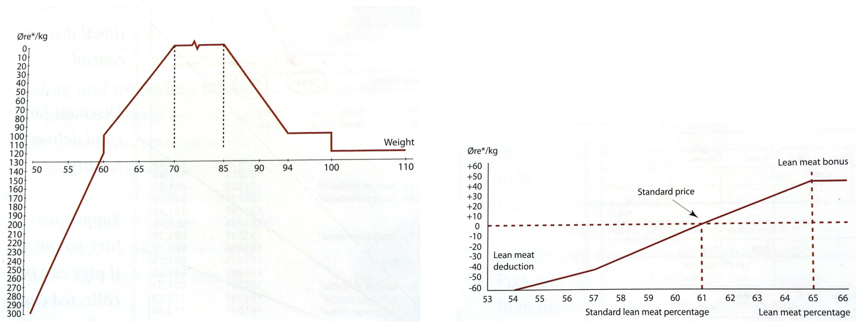
Figure 1.1: Overview over the average cost distribution per finisher pig (Christensen, 2010).

decisions within a production cycle may be taken into account. For instance decisions at the strategic level may be the breeding strategy, weaner supply (flexible or constant), farm layout (e.g. penning method), housing conditions, herd infection and disease strategy (e.g. if tail docked pigs should be bought on finishing farms), choice of technology, batch operation strategy (all in - all out or continuous operation) etc. On the tactical level decisions may concern if tail docking should be applied to the current batch on integrated farms (2-4 days after birth), vaccination of the pen, method of cleaning and disinfection, use of antibiotics etc.

Decisions should be taken such that the profit is maximized while still taking welfare and other objectives into account. An overview over the average cost distribution of a finisher pig in given in Figure 1.1. Overhead costs may be changed at the strategic level. The cost of weaners may be reduced by buying weaners on the spot market[2] when prices are low. However, in general this is not possible, e.g. if a contract with a supplier is used. At the operational level only the feed and costs for treating diseases may be considered as variable. It is evident that since the feed cost contribution is high, decisions related to feeding regimen has vital significance on economic performance. Moreover, decisions related to early prevention or treatment of diseases may help improve welfare and economics.

On the income side the price of a finishing pig is settled on the basis of slaughter weight, lean meat percentage and diseases (see Figure 1.2). Moreover the price may also be affected by e.g. production levy, quantity discount, time of collection, cleaning of vehicle etc. As a result the decisions related to the time of marketing can significantly affect income of the farm. How the manager determines which pigs to market differ among farms. In general the decision is based on observations

[2] `http://www.notering.dk/WebFrontend/SmaagriseNotering_Udvikling.aspx`



(a) Deduction in weight (2009)

(b) Lean meat bonus/deduction. (2009)

Figure 1.2: Deduction and bouns from/to the price of finishing pigs (Christensen, 2010).

and rules of thumb such as marketing the heaviest 20% in the section or at least 80% of the pigs should be within a given weight range Kure (1997).

Economic optimisation of feeding and marketing decisions requires simultaneous analysis of both decisions since feeding decisions affect both carcass value and daily growth rates. It is optimal to market a pig when the marginal net revenue from fattening an additional day is equal to the opportunity cost of replacement Niemi (2006).

In general the optimal decisions at the tactical and operational level is found under a large set operational constraints or fixed conditions such as the penning method and limit on the number of pigs in each pen, type of piglet supply, the pricing system and number of packers. For instance, for fattening pigs there are two main types of penning used at weaning: *weaner pens* and *weaning to finishing* (*WTF*) pens. In weaner pens, the weaners are transferred to finishing units when they reach approximately 30 kg. But in WTF systems, weaners are kept in the same pen until slaughter (single WTF) or half of them are delivered to a finishing unit due to space problems (double WTF) Christensen (2010). The penning method may be changed at the strategic level; however, may be considered as fixed within the OMSPE project. In the following we take a closer look at possible tactical and operational decisions in the weaner and finishing unit.

Chapter 2

The weaner unit

When piglets are 3 or 4 weeks old, they are weaned and transferred to the weaner unit. They should always weigh more than 7 kg when transferred to the weaner unit and they will be in the weaner unit till their weight is approximately 30 kg.

Figure 2.1 illustrates an example on decisions taken in the weaner unit. Tactical decisions are taken in the growing cycle period which is about 7 to 9 weeks Christensen (2010). These decisions can be regarded to the subjects like vaccination of piglets and having various feed mixes which full fill some diet restrictions in the period of growing. Here finding a min-cost feed mix (the diet formulation problem) can be interpreted as a mathematical model Whittemore et al. (2006) and optimization methods can be applied to determine the optimal feed-mix. In the diet formulation problem, considering uncertainty in the input parameters and using the stochastic optimization methods can be a new contribution in our project.

Operational decisions (daily or weekly) are usually affected from strategic and tactical decisions. For example treatment for diseases like diarrhoea and respiratory illnesses can be considered as daily decisions. Moreover, the optimization of feed supply can be considered daily which is adjusted according to the condition of the pigs. Feed supply optimization can be considered as a sequential decision making

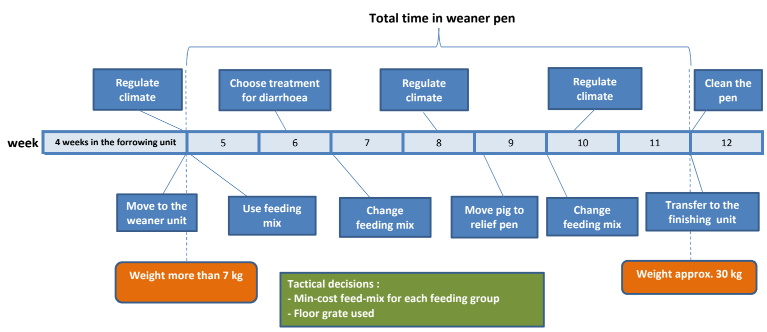


Figure 2.1: An example of decisions in the weaner unit. Operational decisions are shown in blue.

process in which the pigs can be allocated to the different feeding levels and feed-mixes based on their conditions. Allocation of pigs to the different feeding levels can be done according to traits like live weight, back fat thickness and also some latent variables Whittemore et al. (2006). A possible contribution from OMSPE could be to study methods for solving this problem.

For solving the allocation of pigs to different feeding levels a production function (relation between the feed intake and daily gain) should be determined. If the mechanistic models are used, then we can probably employ mathematical programming methods to optimise the production function parameters Parsons et al. (2007) which could be a new contribution. Another approach could be to consider statistical models for modelling deviations from a herd specific production function.

The most predominant disease problem in the weaner unit is diarrhoea which occurs after weaning Christensen (2010). As mentioned in the PigIT project, there are different interventions to deal with this disease. Stochastic programming methods may be used for selecting the best intervention. As a contribution the problem may be modelled by a sequential decision making process. However, it is still unclear how welfare should be quantified.

Chapter 3

The finishing unit

When the piglets weigh approximately 30 kg (11-12 weeks old), they are transferred to the finishing unit and are kept here until they reach their slaughter weight Christensen (2010).

Similar to the weaner unit Figure 3.1 illustrates possible decisions which may be taken in the finishing pen at a tactical and operational level. The decisions relate to areas such as feeding, diseases, marketing, climate, weaner supply etc. In the following sections we will have a further look at some of focus areas

3.1 Decisions related to feeding

Decisions related to feeding can be divided into two groups. On the tactical min-cost feed-mixes have to be found given the feedstuffs on the farm. On the operational level we must allocate the growing pigs to the different feed-mixes such that they gain the best weight and composition Whittemore et al. (2006). The required solution for this problem may be modelled as s sequential decision problem, since there are different stages in the growing period (a stage may be based on e.g.

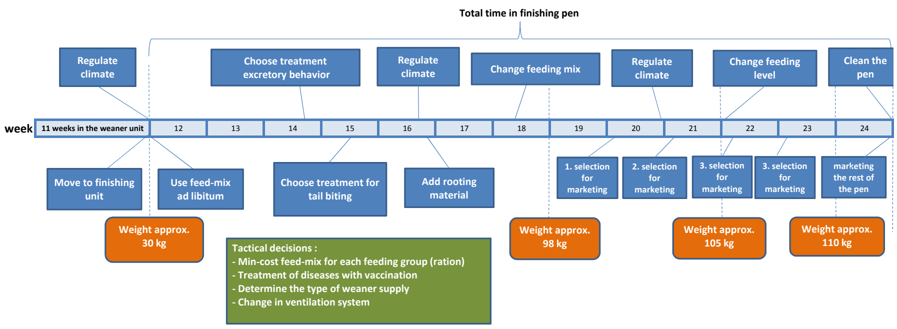


Figure 3.1: An example of decisions in the finishing unit. Operational decisions are shown in blue.

age, live weight and back fat thickness). In each stage we must determine the best feeding ration. Note different farm levels are considered. In general only a limited number of feed-mixes can be used on the farm, i.e. in all pens. Hence, the feed supply in a specific pen is limited to using the same feed-mix is the whole section. This may prose a problem from a modelling point of view since simultaneous decision in different levels adds more complexity to the problem. Probably approximation methods must be used to solve the problem.

3.2 Decisions related to marketing

The most important operation in the finishing unit is marketing of the pigs for slaughter. In each week, the manager must decide which pigs should be delivered to the slaughter house and when the pen should be emptied Kure (1997). This decision is on the operational level. The problem can be considered on different levels, e.g. animal Glen (1983) or pen Kristensen et al. (2012); Kure (1997). This project will focus on the pen level. Like in the weaner unit a production function must be estimated and used in a sequential model for marketing. The complexity of the model will depend on how many levels are taking into account simultaneously and how decisions at the different are linked together. Properly, approximation methods must be used to avoid the curse of dimensionality problem.

Based on the literature Christensen (2010),Kristensen et al. (2012),Kure (1997),Ohlmann and Jones (2008) we can suggest the following contributions within OMSPE:

- In the related literature Kristensen et al. (2012),Kure (1997),Ohlmann and Jones (2008),Parsons et al. (2007),Toft et al. (2005) the death of the pigs in the different stages of the problem has not been considered and therefore it can be added to the models.

- Since economic optimisation of feeding and marketing decisions requires simultaneous analysis there is a need to develop a sequential decision model which consider both feed supply and marketing decisions during the finisher growth period.

- In general a possible delivery day in each week is given from the packer. Models taking into account specific delivery agreements with the packer may be considered.

- In the related literature Kristensen et al. (2012),Kure (1997) usually Kalman filter and DLM are used to estimate the transition probabilities. In this project, other methods (like neural networks) may be used to estimate the probability distribution of the state variables. Because we have on-line data (during the growing period) and by using a general distribution, we may estimate the parameters of this distribution and use it to determine the transition probabilities.

- Properly, new methods like approximate dynamic programming can be useful and will be a new contribution to the herd management problems.

3.3 Decisions related to Diseases

The most important diseases considered in the PigIT project are diarrhoea, undesired excretory behaviour and tail biting. Here the welfare of the animals is important and should be considered. Decisions concerning these diseases can be considered at both tactical and operational level. For example vaccination during the growing cycle is a tactical decision and using medication in the pen can be seen as an operational decision. Furthermore, a strategic decision about using tail docking are also relevant. Finally, also decisions about the method and length of the cleaning period after the pen is emptied are relevant for disease spread.

Relevant decisions under early detection of diarrhoea are medication at pen level, under early detection of undesired excretory behaviour relevant decisions could be reduced stocking rate, cooling approaches, change in temperature strategy or on the tactical level a more lasting change in the ventilation system. Early detection of tail biting may result in decisions such as increased straw from e.g. 10 g to 100 g per pig per day, reduced stocking rate with 2 pigs per pen or reduced temperature (Petersen et al., 2012).

To select the best intervention strategy for each disease, it is possible to use mathematical models. Specially for considering simultaneously welfare and economic issues, we may apply multi-objective optimization models and employ solution procedures like goal programming. Also decisions related to diseases can be combined with marketing decisions Toft et al. (2005) using a sequential decision approach, e.g. to select the best strategy for marketing under certain disease conditions. It may also be possible to extend the model and consider the diseases in a larger state space of the model. In all cases we some challenges in estimating the economic consequences of welfare conditions and the different interventions.

3.4 Decisions related to weaner supply

When all the pigs of a pen are marketed and pen is emptied, new weaners (under weaner pens systems) or piglets with weight around 30 kg (under WTF systems) are inserted into the emptied pen. Usually there are two scenarios for weaner supply. One considers a constant supply in which the piglets are inserted to the pen in predefined defined interval times. Another scenario is a flexible supply in which the piglets are inserted to the emptied pen as soon as possible Kristensen et al. (2012).

Here other scenarios can also be considered. For example the interval length under a constant supply agreement may not be totally constant but can be assumed to be stochastic. Different models for providing the piglets (for example supply by weaner market or supply by farrowing unit or a combination of these methods) can also be considered. This subject may be a new contribution to the project.

Chapter 4

A supply chain approach within the farm

The pig supply chain (SC) can be considered as an integrated structure of procurement (pharmaceutical firms, feed mills), production (sow, weaner and finishing units) and processing (slaughterhouse) units (Rodriguez, 2010). In the literature, researchers have focused on the different parts of the chain and decisions on the strategic, tactical and operational levels. For example, on the strategic level (Bloemhof et al., 2005) studied on the network planning for the pig supply chain in a facility location context, on the tactical level (Khamjan et al., 2013; Balogh et al., 2009) considered the SC between the farm units and slaughterhouse facilities to find the best flow among these agents, on the operational level the decisions at a daily or on weekly periods can correspond to marketing (Boland et al., 1993; Glen, 1983; Kristensen et al., 2012), sow replacement (Kristensen and Søllested, 2004; Rodríguez et al., 2009) and transportation problems (Gribkovskaia et al., 2006). Moreover, often simulation methods are used when consider the SC to analyse the effect of decisions at the different levels of the SC (van der Gaag et al., 2004; Krieter, 2002; Den Ouden et al., 1997).

Most papers consider the chain between the finishing and slaughterhouse facilities. However, there seems to be no study taking a SC approach when model the connection between the weaner and finishing units. In this regard, we can consider the problem as finding the best flow between weaner and finishing entities: how many weaners should be inserted in the weaner unit, how should the pig from the weaner unit be allocated to the finishing unit etc. The goal is to maximize e.g. the yearly net income. In this problem methods such as production planing or simulation can be applied.

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