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Research Paper

System dynamics modelling of an integrated pig production supply chain

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The supply chain for pigs is a long chain that is not resilient to environmental changes. The most vulnerable point in the chain occurs at the pig production level, which consists of breeding units, great grandparents, grandparents, parents and fattening units. Similar to other agricultural chains, the pig chain is susceptible to disruptions, such as disease outbreaks. The reaction to any disruptions in supply or demand can take several months or even years. A manager might be unable to anticipate changes in the production units and, thus, be unable to effectively manage the chain. In this study, we develop a system dynamics model as a tool for managers to visualise the movement of the entire production chain. This tool enables the integration of important factors at each breeding level that will affect the number of fattening pigs. Scenarios were applied to explore the mechanism of the model, and case studies were developed to represent an integrated pig company.

1. Introduction

In the past, pigs were produced in fragmented, loosely coordinated units. Now, specialisation and vertical integration have led to farms and companies organised into a 'pork chain' (Pérez, De Castro, & Furnols, 2009; Roríguez-Sánchex, Plà-Aragonés, & Albornoz, 2012; Rodríguez, Plà-Aragonés, & Flaulin, 2014; Sosnicki & Newman, 2010). This closely aligned chain often includes vertically and horizontally linked partners, such as geneticists and genetic improvement programmes, farmers, processors, distributors, and retailers (Rodríguez et al., 2014; Sosnicki & Newman, 2010). Collaboration is required among these units to deliver specific meat quality parameters (e.g., tenderness and juiciness) to customers in a timely manner (Roríguez-Sánchex et al., 2012; Sosnicki & Newman, 2010). To meet market demand, pigs, under a batch management scheme, must be delivered within

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Nomenclature

Rates variables

$FCrate_i$	the 'failure to conceive' rate in parity i (expressed as a percentage per week).
$Arate_i$	the abortion rate in parity i (expressed as a percentage per week).
$Nrate_i$	the 'not-in-pig' rate in parity i (expressed as a percentage per week).
$Srate_i$	the service rate in parity i (expressed as a percentage per week).
$Crate_i$	the culling rate in parity i (sows per week).
ABA_i	the 'live births per farrowing' rate in parity i (piglets per farrowing).
$PDrate_i$	the pre-weaning mortality rate in parity i (expressed as a percentage per week).
$WDrate$	the weaner mortality rate (expressed as a percentage per week).
SBR	the ratio of sows to boars.
$CGrate$	the culling and death rate in gilts (expressed as a percentage per week).
$PGrate1$	the rate of gilts passing first replacement score (expressed as a percentage per week).
$PGrate2$	the rate of gilts passing second replacement score (expressed as a percentage per week).
$Rrate$	the replacement rate (expressed as a percentage per week).

Flow variables

FCS_i	the flow of mated sows that fail to conceive in parity i (sows per week).
A_i	the flow of 'aborted pregnancy' sows in parity i (sows per week).
NIP_i	the flow of sows not in pig or sows that go full-term (presumed pregnant and do not farrow) in parity i (sows per week).
MS_i	the flow of mated sows in parity i (sows per week).
TRS	the flow of gilts that pass the assessment test, are in a replacement herd, and are ready to be mated (sows per week).
TOS_i	the flow of dry sows transited to the next parity (sows per week).
$TGW4_i$	the flow of sows in parity i transiting from gestation week 3 to week 4 (sows per week).
$TGW16_i$	the flow of sows in parity i transiting from gestation week 15 to week 16 (sows per week).
Far_i	the flow of gestation sows in parity i entering the farrowing stage at the end of week 16 (sows per week).
AL_i	the flow of sows in parity i after the lactation period transiting to dry sows (sows per week).
CS_i	the flow of culled sows in parity i (sows per week).
NBA_i	the flow of live-born piglets in parity i (piglets per week).
PWD_i	the flow of piglets in parity i that died before weaning (piglets per week).
PWS_i	the flow of piglets in parity i entering the weaned state (piglets per week).
$WDead$	the flow of dead weaners (weaners per week).
TWG	the flow of weaners entering the gilt state (weaners per week).
TWB	the flow of weaners entering the boar state (weaners per week).
$CGilt$	the flow of culled and dead gilts (gilts per week).
$PGilt$	the flow of gilts with a passing replacement score (gilts per week).
$Ext1$	the first flow of gilts sold to external customers for the first time (gilts per week).
$FGilt1$	the flow of gilts with a failing replacement score for the first assessment transferring to fatting units (gilts per week).
$FGilt2$	the flow of gilts with a failing replacement score for the second assessment transferring to fatting units (gilts per week).
Oth	the flow of gilts transferred to other herds within the company (gilts per week).
$Ext2$	the second flow of gilts sold to external customers (gilts per week).

Stock variables

$GW1\_3_i$	the number of gestation sows in weeks 1 through 3 in parity i (sows).
$GW4\_15_i$	the number of gestation sows in weeks 4 through 15 in parity i (sows).
$GW16_i$	the number of gestation sows in week 16 in parity i (sows).
$OSow_i$	the number of open sows in parity i that are available to mate (sows).
$LSow_i$	the number of sows in parity i that are in the lactating period (sows).
$DSow_i$	the number of dry sows in parity i waiting to be mated after the lactation period (sows).
PW_i	the number of piglets in parity i yet to be weaned (piglets).
$Wean$	the number of weaners (weaners).
$Gilt$	the number of gilts in the gilt pool (gilts).
R	the number of replacement sows (sows).

Other variables

$TSow$	total number of sows in the herd (sows).
$MSow$	the desirable herd size (sows).

a specific time window at a specific quantity and quality (Jalvingh, Dijkhuizen, & van Arendonk, 1992; Oliveira, Yus, & Guitián, 2009; Singh, 1986). For this reason and for sanitation, the chain is characterised by an "all-in-all-out" batch system (Lurette et al., 2008). The production from the first stage of the chain must be delivered to downstream units. In this context, disruption to the operations of an upstream sow farm affects the operations of the downstream fattening units, slaughtering house, pork processor and retailers. The effect of an upstream disruption on the downstream chain is a problematic characteristic of the pork chain as well as other food supply chains in the sense that their physical flow cannot