A stochastic bio-economic pig farm model to assess the impact of innovations on farm performance

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# Supplementary material

Supplementary Material S1 Equations used to calculate costs and returns

This section presents the equations used to calculate the costs and returns of sows and fattening pigs for a typical farrow-to-finish farm.

*Cost of gilts and sows per farm*

*Return from gilts and sows per farm per year*

*Costs of fattening pigs*

*Returns from fattening pigs*

*Private and social profits*

: Refer to Supplementary Table S3 for the calculations.

**Abbreviations**

: average daily feed usage of piglets (kg/d)

: average daily feed usage of replacement gilt (kg/day)

: average daily feed usage of gestating sow (kg/day)

: average daily feed usage of lactating sow (kg/day)

: age of replacement gilt at 1st oestrus (days)

: age of replacement gilt at first mating (days)

: age of replacement gilt at purchase/selection (days)

: final body weight of piglet (kg)

: culling rate of replacement gilts until mating per year in decimal

: culling rate of sows in decimal

: daily replacement gilt non feed cost (labour, energy, transport, veterinary, maintenance and repairs, etc.) (R$/day)

: daily sow non-feed and non-semen costs (labour, energy, transport, veterinary, maintenance and repairs, etc.) (R$/day)

: Greenhouse gas emission factor of finishing pig feed (kg CO2-eq/kg feed)

: Greenhouse gas emission factor of growing pig feed (kg CO2-eq/kg feed)

: Greenhouse gas emission factor of piglet feed (kg CO2-eq/kg feed)

: Greenhouse gas emission factor of sow feed (kg CO2-eq/kg feed)

: cost of energy during fattening per finished pig (R$)

: total cost of energy during fattening per sow per year (R$)

: total feed cost of fattening pigs per farm per year (R$)

: total finishing pig feed cost per sow per year (R$)

: total growing pig feed cost per sow per year (R$)

: total piglet feed cost per sow per year (R$)

: farrowing interval (days)

: number of days between 1st insemination and culling of sows (days)

: interval between purchase/selection of replacement gilt and conception (days)

: number of days between weaning and culling (days)

: interval between weaning and oestrus (days)

: cost of labor during fattening per finished pig (R$)

: total cost of labor during fattening per sow per year (R$)

: live weight of gilt at culling (kg/gilt)

: live weight of sow at culling (kg/sow)

: live weight of finished pig at slaughter (kg/pig)

: mortality rate during finishing period (from 70kg to slaughter) in decimal

: mortality rate during growing period (from weaning to 70 kg) in decimal

: mortality rate of replacement gilts (before conception) in decimal

: mortality rate of sows in decimal

number of piglets born alive per sow per farrowing

: number of piglets born alive per sow per year

: number of finished pigs per sow per year

: number of farrowing per sow per year

: number of growing pigs transferred to finishing phase per sow per year

: number of purchased/selected replacement gilts per farm per year

: number of existing sows per farm (sows with at least one farrowing)

: number of sows per farm including pregnant gilts

: number of piglets weaned per sow per year

: other variable costs (maintenance-repairs, transport, marketing, others) during fattening per finished pig (R$)

: total other variable costs (maintenance-repairs, transport, marketing, & others) during fattening per sow per year (R$)

: purchasing cost of replacement gilt/opportunity cost of selected gilt (R$/gilt)

finishing pig feed price (R$/kg)

growing pig feed price (R$/kg)

: piglet feed price (R$/kg)

: price of sow and gilt feed (R$/kg)

: price of finished pigs (R$/kg live weight)

: price of culled replacement gilt (R$/kg live weight)

: price of culled sow (R$/kg live weight)

: feed conversion ratio (kg feed/kg gain)

: finishing phase

: farrowing rate (proportion of sows farrowed) (decimal)

: gestation length (days)

: growing phase

: lactation length (days)

: marketing cost of culled gilts/sows (R$/sow)

: number of oestrus at first mating

: pre-weaning mortality rate (decimal)

: total revenue from the sale of finished pigs per farm (R$/farm/year)

: total revenue from the sale of finished pigs (R$/sow/year)

: total return from culled gilts (R$/farm)

: total return from culled sows (R$/farm)

: Annual replacement rate of sows (decimal)

: semen cost per dose (R$/dose)

: semen dose per sow per pregnancy (#)

: Shadow price of CO2 emission (US$/kg)

: Service repetition rate (decimal)

: Total cost of production per farm per year (R$)

: total cost of replacement gilts per farm per year (R$)

: total cost of sows per farm per year (R$)

: total fixed cost per farm per year (R$)

: Total feed usage of finishing pigs during the finishing phase (kg/finished pig)

: Total feed usage of growing pigs per finished pig (kg/finished pig)

: Total feed usage of piglets per finished pig (kg/finished pig)

: Total feed usage of sows per finished pig (kg/finished pig)

: total number of piglets born including piglet loss during birth per sow per year

: total variable cost of fattening pigs per farm per year (R$)

: total number of replacement days for gilts (till conception) (days)

: cost of veterinary during fattening per finished pig (R$)

total cost of veterinary during fattening per sow per year (R$)

: extra days open due to anoestrus and failed conception

Supplementary Table S1 *Production indicators, input demands and costs in the piglet production and growing-finishing units*

|  |  |  |  |
| --- | --- | --- | --- |
|  | Piglet production | Growing-finishing | Reference |
| Production indicators |  |  |  |
| Productive sows (#/farm) | 1 500 | - | Embrapa1 |
| Finished pigs (#/sow/year) | - | 24.65 | Embrapa1 |
| Rounds per year | - | 2.85 | Martins *et al*. (2012) |
| Finished pigs per round (#) | - | 4 000 | Martins *et al*. (2012) |
| Main input demands |  |  |  |
| Labour demand | 110 sows/person | 1 500 fattening pigs/person | Martins *et al*. (2012) |
| Energy demand (kwh) | 164 per sow/year | 4.5 kwh/finished pig | Martins *et al*. (2012) |
| Semen dose per pregnancy (#) | 2 | - | Martins *et al*. (2012) |
| Input prices |  |  |  |
| Monthly wage (R$) | 1200 |  |  |
| Cost of electricity (R$/kwh) | 0.27 |  | www.iea.sp.gov.br |
| Cost of semen (R$/dose) | 11.71 |  | Embrapa1 |
| Cost of production per kg live weight of finished pig (R$) | | | |
| Cost veterinary | - | 0.05 | Embrapa1 |
| Other variable costs (e.g. maintenance and repair, transport and marketing) | - | 0.30 | Embrapa1 |
| Fixed cost | - | 0.229 | Embrapa1 |
| Cost of production (calculated) | Per sow per year | Per finished pig |  |
| Labour cost (R$) | 131.04 | 3.37 |  |
| Semen cost (R$/pregnancy/sow) | 23.14 | - |  |
| Energy cost (R$) | 44.28 | 1.22 |  |
| Veterinary cost2 (R$) | 83.30 | 2.14 |  |
| Other variable costs2 (R$) | 532.34 | 13.68 |
| Fixed cost (R$/farm/year) | 1 016 073 |  |  |

R$ = Brazilian Real.

1 Embrapa swine and poultry centre (http://www.cnpsa.embrapa.br/cias/dados/custo.php).

2 Assuming that the distribution of these costs between the piglet production and growing-finishing units is similar with the distribution of labour cost between the two units.

Supplementary Material S2 Parameters and equations to calculate CH4 and indirect N2O emissions from manure

For the growing and finishing phase, the mathematical models of Dourmad *et al*. (2003) and Rigolot *et al*. (2010) were used to calculate the amounts of volatile solids and nutrient excretions using the different diets.

*Volatile solid excretions*

*N, P and K excretions*

. N body weight is computed as (cited in Saintilan *et al*., 2013):

where

: Crude protein content of the diet (g/kg)

: coefficient of degradation of organic matter of manure (decimal, 0.00187: assuming a dry matter of 56g/kg manure and 20 o C storage temperature)

: digestibility coefficient of crude protein of feed (decimal)

: digestibility coefficient of dry matter of feed (decimal)

: digestibility coefficient of organic matter of feed (decimal)

: digestible energy content of feed (MJ/kg)

: dry matter of effluent (kg/pig)

: dry matter content of faeces (kg/pig)

: dry matter content of feed (decimal)

: Empty body weight (kg/pig)

: feed intake (kg/pig)

: growing-finishing pig

: Flushing interval of manure from the storage (days) (manure is stored for 120 days in Brazil)

: K content of diet (g/kg)

: K excretion per pig (kg/pig)

: K intake per pig (kg/pig)

: K retained per pig (kg/pig)

Lipid mass of a pig (kg/pig; obtained from the pig growth model)

Lean meat percentage (%)

: Mineral matter (ash) content of feed (decimal)

: Neutral Detergent Fiber content of feed (decimal)

: N excretion in the faeces (kg/pig)

: Nitrogen content of urine (kg/pig)

: N intake per pig (kg/pig)

N retained (kg/pig)

: Nitrogen volatilization coefficient during manure storage (decimal, 0.48 from Intergovernmental Panel on Climate Change (IPCC; 2006) default value for liquid manure management)

: organic matter of biogas (kg/pig)

: Organic matter of faeces (kg/pig)

: organic matter of feed (decimal)

: organic matter (volatile solid) of effluent (kg/pig)

Protein mass of a pig (kg/pig; obtained from the pig growth model)

: P content of diet (g/kg)

: P intake per pig (kg/pig)

: P excretion per pig (kg/pig)

: P retained per pig (kg/pig)

: total N excretion per pig (kg/pig)

Supplementary Table S2 *Parameters and equations to calculate CH4 and indirect N2O emissions*

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Parameters | Sows | Piglets | Growing-finishing pig | | |
| Ref.  case1 | Macaúba case2 | Co-products case3 |
| Number of animals (#/finished pig) | 0.043a | 1.05a | 1.00 | 1.00 | 1.00 |
| Duration (days) | 142a | 38a | 105 | 105 | 105 |
| Nutrient excretion (kg/finished pig) | |  |  |  |  |
| N | 0.199a | 0.183a | 3.66 | 3.78 | 3.82 |
| P | 0.185b | 0.15b | 0.54 | 0.49 | 0.58 |
| K | 0.074b | 0.06b | 1.35 | 1.48 | 1.74 |
| Manure composition (kg/finished pig) | |  |  |  |  |
| N4 | 0.103 | 0.095 | 1.90 | 1.96 | 1.99 |
| P | 0.185 | 0.15 | 0.54 | 0.49 | 0.58 |
| K | 0.074 | 0.06 | 1.35 | 1.48 | 1.74 |
| Volatile solid (*VS;* kg/finished pig) | 3.315a | 1.653a | 18.47 | 27.41 | 26.33 |
| Potential CH4 production5 (*B0;* M3 CH4/kgVS) | 0.29 | 0.29 | 0.29 | 0.29 | 0.29 |
| CH4 conversion factor5 (*MCF; decimal*) | 0.42 | 0.42 | 0.42 | 0.42 | 0.42 |
| Volatilisation5 (%) | 48 | 48 | 48 | 48 | 48 |
| Emission factor5 (*EF; decimal*) | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| *CH4 emissions =VSB00.67MCF* | | | | | |
| *Indirect N2O emissions =N excretionVolatilisationEF (44/28)* | | | | | |
| Greenhouse gas emission from manure (kg CO2-eq/finished pig)6 | | | 61.62 | 82.30 | 79.92 |

1 A corn-soybean meal based finishing diet was used in the reference case.

2 A macaúba kernel cake based finishing diet was used.

3 A co-product based finishing diet was used. Diets of sows, piglets and growing pigs, which are common to the three cases, were considered.

4 Assuming 48% volatilisation during storage (IPCC, 2006).

5 IPCC (2006).

6 Including sows and piglets emissions.

a Cherubini *et al*. (2014).

b Diesel *et al*. (2002).

Supplementary Table S3 *Net benefit from manure per case*

|  |  |  |  |
| --- | --- | --- | --- |
|  | Reference case1 | Macaúba case2 | Co-products case3 |
| Avoided fertiliser (kg/finished pig) |  |  |  |
| Urea | 3.43 | 3.53 | 3.57 |
| P2O5 | 4.76 | 4.48 | 4.96 |
| K2O | 2.96 | 3.23 | 3.76 |
| Prices of artificial fertilisers (R$/kg)4 |  |  |  |
| Urea | 1.42  0.88 | 1.42  0.88 | 1.42  0.88 |
| P2O5 | 0.88 | 0.88 | 0.88 |
| K2O | 1.40 | 1.40 | 1.40 |
| Values of avoided fertilisers (R$/finished pig) |  |  |  |
| Urea | 4.87 | 5.01 | 5.06 |
| P2O5 | 4.19 | 3.95 | 4.37 |
| K2O | 4.15 | 4.52 | 5.26 |
| GWP of avoided fertiliser production (Kg CO2-eq/ finished pig)5 | | | |
| Urea | 12.10 | 12.45 | 12.59 |
| P2O5 | 2.57 | 2.42 | 2.68 |
| K2O | 1.81 | 1.97 | 2.29 |
| Environmental benefit of avoided fertiliser (R$/finished pig)6 | | | |
| Urea | 1.81 | 1.87 | 1.89 |
| P2O5 | 0.39 | 0.36 | 0.40 |
| K2O | 0.27 | 0.30 | 0.34 |
| GHG emission from manure (kg CO2-eq/finished pig) | 61.62 | 82.30 | 79.92 |
| Environmental cost of manure (R$/finished pig) f | 9.24 | 12.34 | 11.98 |
| Net benefit from manure (R$/finished pig) | 6.44 | 3.67 | 5.34 |

GWP, global warming potential; GHG, greenhouse gas.

1 A corn-soybean meal based finishing diet is used.

2 A macaúba kernel cake based finishing diet is used.

3 A co-product based finishing diet is used. Diets of sows, piglets and growing pigs, which are common to the three cases, are considered.

4 2015 market prices in MG (www.conab.gov.br).

5 Using emission factors of fertiliser production from Kool *et al*. (2012).

6 Using the shadow price of CO2 emission (US$0.045/kg) and the 2015 exchange rate (R$3.33/US$).

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