Breeding and supply chain systems incorporating local pig breeds for small-scale pig producers in Northwest Vietnam

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A B S T R A C T

In Vietnam, pig production and pork demand are developing rapidly. Still, 80% of the national pig herd is kept on smallholder farms while policy mainly focuses on intensification of pig production. The aim of this study is to evaluate possibilities to organize pig breeding and marketing channels in remote areas in the uplands of Northern Vietnam. The study compiles three parts: (1) Evaluation of farmers breeding management and breed and trait preferences for pigs; (2) Evaluation of different crossbreeding schemes for leaner meat production; and (3) Design of appropriate organizational settings for pig breeding and marketing.

Ban pigs are the second most predominant breed next to the Mong Cai. Ban pigs are valued by farmers for their feed intake spectrum, feed intake capacity, disease tolerance, health/strength, growth rate and carcass quality. For all modelled crossbreeding schemes, genetic gain is low; the Yorkshire×Ban crossbreeding scheme shows the highest overall genetic gain. The traditional production and fattening of Exotic boar×Local dam F 1 crosses does not require particular organizational setups. This system already exists in an improvised way. The advantage of an organized scheme would be the controlled maintenance of the local breed. For the latter, a stratified pig breeding system seems promising, requiring innovative organizational setups. A short food supply chain is proposed. This system builds links between remote and close-to-market villages and populations. Critical organizational aspects like poorly developed infrastructure, poor access to input and output markets and information can be overcome.

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1. Introduction

In Vietnam, pig production is developing rapidly with a strong influence from the government on all elements of the pork production chain but there are also trends to privatisation and commercialisation. This policy mainly focuses on intensification of pig farms in the Red River Delta and areas surrounding large cities (Decision 166/2001/QD-TTg, 2001; MARD, 2000). On the other hand, FAO (2005) estimates that 80% of the national pig herd is kept on smallholder farms. Most of these smallholder farms are not yet participating in the growing pork market. They rely mainly on local breeds or crossbreds with exotic boars to produce for home consumption or local markets (Lemke, 2006). Poor infrastructure and long distances to markets restrict possibilities of pork marketing and exchange of breeding animals. Village breeding programs together with marketing and distribution networks may be promising for linking smallholder farmers to the growing pork market. The aim of this study is to evaluate possibilities to organize breeding and marketing channels in remote areas in the uplands of Northern Vietnam.

2. Material and methods

Basic data were collected in the frame of a long term cooperative project between the National Institute of Animal Husbandry in Vietnam and the University of Hohenheim in...
Germany aiming at the development of village breeding programs. A pig performance testing scheme has been implemented at 328 household farms in nine villages in the Northwest mountainous province Son La in Vietnam. Data and information from this scheme were used. For detailed information on the on-farm performance testing scheme (OPTS) see Lemke et al. (2006) and Roessler et al. (2009).

2.1. Farmers’ breeding management and breed and trait preferences for pigs

A survey was conducted in eight project villages. The farmers in six villages practice market-oriented pig production and in two villages subsistence-oriented production. In total, 188 smallholders with 262 sows were approached in single person interviews (Table 1). A structured questionnaire was used to obtain data on smallholders’ breeding management, smallholders’ breed and trait preferences, and selection criteria. Farmers were asked to identify traits they prefer in a certain sow and boar genotype. Then they were asked to state if they consider a number of predefined traits to be good, average or poor for the specific breed or if they do not consider the trait to be important for this breed. The FREQ procedure of the statistical package SAS 9.1 (SAS Institute, Cary, NC) was used to analyze smallholders’ breeding management, trait preferences and selection criteria for pigs. Village and breed differences were evaluated by chi-square test or Fisher’s exact test if the first test was not valid due to low numbers.

Breeding management, selection criteria for female breeding stock as well as farmers’ trait preferences for local Mong Cai sows and exotic boars have been documented in Roessler et al. (2009). The present study focuses on farmers’ trait preferences for local Ban sows.

2.2. Crossbreeding for lean meat production

Alternative breeding systems were modelled and evaluated with ZPLAN software, version Z10 (Willam et al., 2008) for genetic and economic success parameters. ZPLAN is designed to optimize selection strategies in livestock breeding. It is the only evaluation program that allows comparing genetic and economic success parameters. ZPLAN is designed to optimize selection strategies in livestock breeding. It is the only evaluation program that allows comparing genetic and economic success parameters. It follows a deterministic approach and is based on the gene flow method and selection index procedures. For the calculation of economic parameters, ZPLAN only considers net breeding costs, meaning only those costs in livestock production that can clearly be assigned to the particular breeding system. It does not consider management dependent costs or returns, e.g. from external sales of breeding products in a competitive market. Evaluation criteria calculated by ZPLAN are the annual genetic gain for the breeding objective, genetic gain for single traits and the return of investment adjusted for costs (profit) for the considered period of the breeding system.

The ZPLAN program has two main steps that were followed in the present study: First the currently existing breeding schemes and a stratified breeding scheme (basic breeding schemes) were defined and evaluated. In a second step sensitivity tests were performed, adjusting the breeding schemes with regard to variations of pig performances and number of breeding objective traits as well as restrictions on breeding objective traits in order to explore whether these parameters would have an effect on the economic and genetic merit of the breeding schemes.

The following three breeding systems were modelled in the present study: (1) Crossbreeding of exotic Yorkshire boars with local improved Mong Cai sows as practiced in the more market-oriented production system. This breeding scheme was described and evaluated by Roessler et al. (2009). (2) A breeding scheme reflecting an option for more remote villages, both with market- and subsistence-oriented production with crossing of Yorkshire boars with Ban sows. (3) A more sophisticated breeding system linking the different production systems (market-oriented close to town and far from town and subsistence-oriented far from town) in a stratified crossbreeding system combining terminal crossing of Yorkshire boars on crossbred Mong Cai×Ban sows (Fig. 1).

System 2 is based on the results of the data obtained from questionnaires and information from the OPTS. Currently, 83% of smallholder pig farmers in the remote villages keep Ban sows (Table 1). The Ban population amounts to 340 sows with 110 under the OPTS system (recorded) and 230 unrecorded sows. Six Yorkshire, six Mong Cai and five Ban sires are available. It was assumed that 18% of recorded Ban dams and 15% of unrecorded dams are used for crossbreeding and mated with Yorkshire sires. Thus, 82% of recorded and 85% of unrecorded dams are mated with Ban sires, maintaining the local genetic resource. Genetic gain generated in the group of recorded sows is transferred to the group of untested sows by transferring live animals; 30% of replacement stock in the group of untested sows is originating from the group of recorded dams. The

Table 1
Sow breeds at smallholder farms.

<table>
<thead>
<tr>
<th>Village</th>
<th>Bo</th>
<th>Buon</th>
<th>Co</th>
<th>NH</th>
<th>BD</th>
<th>OtL</th>
<th>TT</th>
<th>PD</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>interviewed hh</td>
<td>N</td>
<td>29</td>
<td>23</td>
<td>23</td>
<td>27</td>
<td>18</td>
<td>22</td>
<td>21</td>
<td>25</td>
</tr>
<tr>
<td>Sows kept by interviewed hh (total)</td>
<td>N</td>
<td>36</td>
<td>38</td>
<td>24</td>
<td>44</td>
<td>27</td>
<td>26</td>
<td>31</td>
<td>36</td>
</tr>
<tr>
<td>Sows kept by interviewed hh (per farm)</td>
<td>N</td>
<td>1.24⁠&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.65⁠&lt;sup&gt;bc&lt;/sup&gt;</td>
<td>1.04⁠&lt;sup&gt;c&lt;/sup&gt;</td>
<td>1.63⁠&lt;sup&gt;bd&lt;/sup&gt;</td>
<td>1.50⁠&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>1.18⁠&lt;sup&gt;ac&lt;/sup&gt;</td>
<td>1.48⁠&lt;sup&gt;ad&lt;/sup&gt;</td>
<td>1.44⁠&lt;sup&gt;ad&lt;/sup&gt;</td>
</tr>
<tr>
<td>Breed composition</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mong Cai</td>
<td>%</td>
<td>77.8</td>
<td>71.1</td>
<td>16.7</td>
<td>40.9</td>
<td>55.6</td>
<td>53.9</td>
<td>16.1</td>
<td>8.3</td>
</tr>
<tr>
<td>Ban</td>
<td>%</td>
<td>13.9</td>
<td>7.9</td>
<td>12.5</td>
<td>9.1</td>
<td>7.4</td>
<td>38.5</td>
<td>74.2</td>
<td>91.7</td>
</tr>
<tr>
<td>Exotic (pure and cross)</td>
<td>%</td>
<td>8.3</td>
<td>7.9</td>
<td>37.5</td>
<td>38.6</td>
<td>29.6</td>
<td>7.7</td>
<td>3.2</td>
<td>–</td>
</tr>
<tr>
<td>Others/breed unknown</td>
<td>%</td>
<td>–</td>
<td>13.2</td>
<td>33.3</td>
<td>11.4</td>
<td>7.4</td>
<td>–</td>
<td>6.5</td>
<td>–</td>
</tr>
</tbody>
</table>

LSM in the rows with different superscripts differ significantly at <sup>P</sup> < 0.05.

1 Market-oriented production, close to town.
2 Market-oriented production, far from town.
3 Subsistence-oriented production, far from town; NH = Na Huong; BD = Bo Duoi; OtL = Ot Luong; TT = Tong Tai A; PD = Pa Dong; hh = household.
average litter size in Ban is seven piglets, mortality until weaning is 20% and sows have two litters per year (Hau, 2008; project’s breeding plan).

The total population within the more sophisticated, stratified crossbreeding scheme was assumed to be 1370 sows with 8% recorded Ban dams, 10% recorded Mong Cai dams and 40% of Mong Cai×Ban F₁ dams. In this system, 70% of recorded Ban dams (77) and 30% of unrecorded Ban dams (70) are mated in purebred mating in remote villages. Respectively, 30% of recorded Ban dams (33) and 70% (163) of unrecorded Ban dams are mated to Mong Cai sires. Crossbreeding between Mong Cai (MC) sires and Ban (B) sows only takes place in remote villages with market-oriented production. In this production system, Mong Cai sows are kept for purebreeding and production of sires. The F₁ (MC×B) dams (548) are then mated to Yorkshire sires in villages with market-oriented production close to the market. The offspring is used for fattening and slaughter. In the Mong Cai population, sows have two litters per year with an average litter size of 9.4 piglets and a mortality of 15% (Hau, 2008).

Further input parameters and genetic parameters are shown in Tables 2 and 3. Traits in the selection index were farrowing interval (FARROW), number of piglets born alive (NBA), average daily gain (ADG) and backfat thickness (BF). Body weight (BW) is monitored, assuming that it is changing due to the correlation with backfat thickness.

Genetic parameters are not yet available for the populations under investigation. Therefore, estimates have been derived from literature (Ducos and Bidanel, 1996; Hermesch et al., 2000; Holm et al., 2004; Peskovicova et al., 2002; Serenius et al., 2004a; Serenius et al., 2004b; Serenius and Stalder 2005; Tholen et al., 1996) and, where possible, from studies with Mong Cai pigs (Duc 1999; Van and Duc 1999) since no genetic parameters for Ban pigs are available in the literature. Genetic parameters were chosen corresponding with Roessler et al. (2009) to facilitate comparison of results.

The economic weight for NBA was defined based on results of Roessler et al. (2008) and economic weights for all other traits were chosen according to Roessler et al. (2009). The number of traits (respectively four and two traits) and economic

Fig. 1. Stratified breeding scheme for Yorkshire x (Mong Cai x Ban).

Table 2
Selected variables used in the modelled crossbreeding schemes. Source: Roessler et al. (2009); modified.

<table>
<thead>
<tr>
<th>Biological-technical parameters</th>
<th>Occurrence</th>
<th>Y x B</th>
<th>Y x (MC x B)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average productive lifetime of Ban sows (years)</td>
<td>3.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average productive lifetime of Ban boars (years)</td>
<td>2.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average age at birth of first offspring (years)</td>
<td>1.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average number of piglets born alive (piglets)</td>
<td>7.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Farrowing interval (years)</td>
<td>0.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weaning rate (per litter)</td>
<td>0.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Genetic superiority of Y sires in ADG</td>
<td>0.30 σa</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Genetic superiority of Y sires in BF</td>
<td>−0.36 σa</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Genetic superiority of MC sires in ADG</td>
<td>0.15 σa</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Genetic superiority of MC sires in BF</td>
<td>−0.17 σa</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Fixed breeding costs (per year) (€)

| Staff salary (data entry) | 2400 | |
| PigChamp software license | 450 | |
| Rent rooms | 1800 | |

Variable costs

| Average costs of recording (per sow) (30% of salaries)* | 1.0 | 11.77 | 5.78 |
| Average costs for weighing (per piglet) (70% of salaries)* | 0.2 | 6.20 | 2.44 |
| Purchase costs of boars (per boar) | 0.6 | 100 | 100 |
| Costs per artificial insemination | 0.6 | 1.53 | 1.53 |
| Costs per natural mating service | 0.6 | 2.05 | 2.05 |

Y = Yorkshire; MC = Mong Cai; B = Ban; ADG = average daily gain; BF = backfat thickness; σa = genetic standard deviation.

* Calculation basis: Staff salaries for measurements and recording data in the field plus farmers’ compensation (totalising 475 Euro month⁻¹); 90 recorded sows and 1006 tested offspring per year.
weights of traits in the index were varied and effects compared. The aim to simulate the breeding schemes with four and with two traits in the selection index was to explore influences on the genetic gain and profit if the number of traits that is selected for is changed. The breeding schemes were compared on basis of genetic gain per trait, monetary genetic gain (in €), breeding costs and breeding profit.

2.3. Organizational requirements

In addition to the evaluation of genetic and economic gain, organizational requirements for the different breeding and corresponding supply chain systems were investigated. A desk study on the organizational requirements was performed to find suitable organizational structures for the modelled breeding schemes. The first modelling of corresponding supply chain structures is based on the theory of short food supply chains (SFSC) as described by Marsden et al. (2000). The basic assumption for SFSC is that the food is defined by the location and/or farm where it is produced. Also, approaches of Murdoch (2000) and Murdoch et al. (2000) on networks in rural development based on commodity-chain- and actor-network-theory were considered. The present study complements another study on provincial level on the organizational feasibility of village breeding programs in the investigated area (Roessler et al., submitted for publication).

3. Results

3.1. Distribution of and farmers’ trait preferences for the local Ban

Ban pigs are the second dominant pig breed in the study area (31.7%) after Mong Cai (43.5%) (Table 1). Ban pigs play a major role in the two villages with subsistence-oriented production (> 70% respectively > 90% of all sows). The survey on farmers’ trait preferences showed that feed intake spectrum and feed intake capacity are the most important traits (nearly 90% of respondents) and also the one perceived as being very well developed (> 80% of respondents) in Ban pigs (Fig. 2). Other important traits for the choice of the Ban breed are disease tolerance (nearly 50%), health/strength (nearly 40%), growth rate and carcass quality (both > 30%). However, only for disease tolerance the trait expression is perceived to be satisfactory (> 30%), while for the other traits, it is not perceived to be good (30% or lower). Prolificacy was mentioned by nearly 20% of respondents as being important but less than 10% perceived it as being good in the actual population.

Table 3

<table>
<thead>
<tr>
<th>Trait</th>
<th>Unit</th>
<th>( \sigma_{g} )</th>
<th>( w \cdot \sigma_{g} )</th>
<th>( h^2 )</th>
<th>FARROW</th>
<th>NBA</th>
<th>ADG</th>
<th>BF</th>
</tr>
</thead>
<tbody>
<tr>
<td>FARROW</td>
<td>day</td>
<td>7.2</td>
<td>-0.14</td>
<td>0.10</td>
<td>0.10</td>
<td>-0.00</td>
<td>-0.00</td>
<td>-0.00</td>
</tr>
<tr>
<td>NBA</td>
<td>piglet</td>
<td>0.4</td>
<td>0.20</td>
<td>0.10</td>
<td>0.00</td>
<td>0.00</td>
<td>0.02</td>
<td></td>
</tr>
<tr>
<td>ADG</td>
<td>( \text{g day}^{-1} )</td>
<td>25.5</td>
<td>0.50</td>
<td>0.50</td>
<td>0.00</td>
<td>-0.05</td>
<td>0.40</td>
<td></td>
</tr>
<tr>
<td>BF</td>
<td>mm</td>
<td>2.1</td>
<td>-0.11</td>
<td>0.45</td>
<td>-0.10</td>
<td>0.05</td>
<td>-0.20</td>
<td></td>
</tr>
<tr>
<td>BW</td>
<td>kg</td>
<td>2.5</td>
<td>0.00</td>
<td>0.30</td>
<td>0.00</td>
<td>0.00</td>
<td>0.10</td>
<td></td>
</tr>
</tbody>
</table>

For trait abbreviations see text. Bold figures: values for Mong Cai populations. No genetic values for Ban population available.

3.2. Crossbreeding for lean meat production

The evaluation of the Yorkshire × Mong Cai breeding scheme was published by Roessler et al. (2009). The results for the Yorkshire × Ban crossbreeding scheme can be seen in Table 4. Genetic parameters are only presented for the Ban breed as Yorkshire sires are bought in without information about their genetic potential; yet it can be assumed that Yorkshire sires are superior in carcass traits for lean meat production compared to the local Ban population (Table 2). The mean generation interval in this breeding scheme is 4.7 years, selection intensity ranges from 0.4 (recorded Ban dams to produce F1 offspring) to 2.5 (Ban sires to produce Ban sires). The monetary genetic gain per year in this system is 0.08 €, variable costs are 11 € per sow. This leads to a negative profit of -34 €. While the genetic gains for meat traits are heading in the wanted direction (positive for ADG and negative for BF), fertility traits show a genetically unfavourable development (FARROW: +1.5 and NBA: 1.5).

Besides the basic breeding scheme, a scheme with restriction on body weight was evaluated (Table 4). The reason for putting this restriction was the predominant use of Ban pigs in the subsistence-oriented system that relies on low input feeding. Increases in average daily gain would lead to a higher nutritional demand of pigs not compatible with the sustainability of the system. This scheme shows only minor changes in success parameters compared to the basic scheme. But contrary to the basic scheme, the genetically unfavourable trend for farrowing interval could be reverted (−3.2).

The results for the stratified crossbreeding scheme are shown in Table 5. The breeding scheme was tested with four traits in the selection index (FARROW, NBA, ADG, and BF) and with two traits in the selection index (FARROW, respectively NBA and ADG). The genetic gain in both systems is low for all traits (monetary genetic gain of 0.003 to 0.008 € per sow and year) and variable costs are high with 12 € per sow. This leads to a negative profit of about -26 € per sow. Only a crossbreeding scheme with two traits in the selection index and with a major focus on the farrowing interval (\( w = 0.8 \)) and a minor focus on average daily gain (\( w = 0.2 \) in Mong Cai and \( w = 0.1 \) in Ban) (BS 2 in Table 5) would lead to a slight reduction and thus a favourable genetic trend in the farrowing interval (−0.3 in Mong Cai and −0.1 in Ban). This goes along with the lowest reduction in number of piglets born alive compared to the other tested schemes (−0.1 and −0.7 respectively) (BS 1 and BS 3 in Table 5). Average daily gain and backfat thickness are changing in the desired direction, however only slightly (1.7 and −0.7 for Mong Cai and 0.5 and −0.2 for Ban respectively) (BS 2 in Table 5). The mean generation interval in this breeding scheme...
is 4.7 years for Ban pigs and 5.0 years for Mong Cai pigs. The selection intensity is zero or close to zero for all selection classes, due to the high number of animals needed for pure and crossbreeding.

Table 6 compares the genetic gain for four different traits for the three different breeding systems. For comparison, all three systems have the same four traits in the selection index, weighted by the same economic coefficients. For all schemes, genetic gain is low and genetic trends for fertility traits are negative. Overall, genetic gain in the Ban population is highest in a crossbreeding scheme with Yorkshire (Y×Ban).

Table 4
Genetic and economic merit for a basic Yorkshire×Ban crossbreeding scheme and a scheme with restriction on body weight.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Basic scheme</th>
<th>Restriction on BW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Genetic gain per year⁻¹ (σₐ⁎100)</td>
<td>1.5</td>
<td>3.2</td>
</tr>
<tr>
<td>Farrowing interval</td>
<td>1.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Number of piglets born alive</td>
<td>−1.5</td>
<td>1.1</td>
</tr>
<tr>
<td>Average daily gain</td>
<td>35.1</td>
<td>27.9</td>
</tr>
<tr>
<td>Backfat thickness</td>
<td>−30.6</td>
<td>−0.03</td>
</tr>
<tr>
<td>Monetary genetic gain per year⁻¹ (€)</td>
<td>0.08</td>
<td>0.08</td>
</tr>
<tr>
<td>Total returns per sow⁻¹ (€)</td>
<td>0.52</td>
<td>0.54</td>
</tr>
<tr>
<td>Fixed costs per sow⁻¹ (€)</td>
<td>23.46</td>
<td>23.46</td>
</tr>
<tr>
<td>Variable costs per sow⁻¹ (€)</td>
<td>10.81</td>
<td>10.81</td>
</tr>
<tr>
<td>Profit per sow⁻¹ (€)</td>
<td>−33.76</td>
<td>−33.73</td>
</tr>
</tbody>
</table>

"a Four traits in the selection index: FARROW with \( w = -0.14 \), NBA with \( w = 0.20 \), ADG with \( w = 0.13 \), BF with \( w = -0.11 \).

"b Two traits in the selection index: FARROW with \( w = -0.8 \), ADG with \( w = 0.2 \), restriction on body weight. \( w \) = economic weight.

3.3. Organizational requirements

The traditional production and fattening of Exotic boar×Local sow \( F_1 \) crosses do not require particular organizational setups. Animals of the Mong Cai and Ban breed are available in all villages of the project (Table 1). Only a few Mong Cai boars and all Yorkshire boars have to be bought in from state farms or private enterprises (Roessler et al., submitted for publication). Also, breeding pigs can be bought from traders at the local pig markets of Son La town (2 traders) or Yen Chau district (1 trader) (Veterinary Department Son La town, 2006 (personal communication)). Fattening pigs are either bought by middlemen who sell the animals for slaughter or are directly sold by farmers for slaughter (Roessler et al., submitted for publication). In Son La province, there exist no large slaughter houses, but pigs are slaughtered by traders (Huong, 2007). At the moment, around 250 traders have the...
Table 6 Evaluation of different breeding systems for smallholder pig producers in Northern Vietnam.

<table>
<thead>
<tr>
<th>Breeding system a</th>
<th>Trait</th>
<th>FI</th>
<th>NBA</th>
<th>ADG</th>
<th>BF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Y × MC</td>
<td>GG MC (σw⁎ 100)</td>
<td>0.4</td>
<td>−0.4</td>
<td>11.8</td>
<td>−10.2</td>
</tr>
<tr>
<td>Y × Ban</td>
<td>GG Ban (σw⁎ 100)</td>
<td>1.5</td>
<td>−1.5</td>
<td>35.1</td>
<td>−30.6</td>
</tr>
<tr>
<td>Y × (MC × Ban)</td>
<td>GG MC (σw⁎ 100)</td>
<td>0.1</td>
<td>−0.1</td>
<td>2.3</td>
<td>−2.0</td>
</tr>
<tr>
<td>Y × (MC × Ban)</td>
<td>GG Ban (σw⁎ 100)</td>
<td>0.0</td>
<td>−0.7</td>
<td>0.8</td>
<td>−0.8</td>
</tr>
</tbody>
</table>

GG = Genetic gain; w = economic weight.

a All breeding systems with same traits and economic weights (w) in the selection index: farrowing interval w = −0.14, number of piglets born alive w = 0.20, average daily gain w = 0.13, backfat thickness w = −0.11.

official license to slaughter pigs (Veterinary Department Son La town, 2006 (personal communication)).

By contrast, stratified pig breeding in the upland regions of Northern Vietnam would require new and innovative organizational setups. One possibility is to combine stratified breeding schemes with the construction of a short food supply chain. Small food supply chains combine the attributes of certified supply chains with the aim of rural development. Certified supply chains ensure a special quality and safety of the food to the consumer (Ifft et al., 2009). Small food supply chains add additional value to the product because the product is linked to a special region or even farm where it is produced with a defined quality and safety standard. This additional, embedded information helps the consumer to link up to the food producer (Marsden et al., 2000). A possible structure for the short food supply chain in Northern Vietnam is depicted in Fig. 3. In the first step of the chain, Ban breeding sows are brought from the remote villages with subsistence-oriented pig production to the remote but more market-oriented villages (according to the present breeding scheme: 13 sows per year). In the remote, subsistence-oriented villages boars and sows are self-replacing. In the remote yet market-oriented villages, Mong Cai×Ban crossbred sows are produced. Mong Cai sows are self-replacing in these villages, while breeding boars are bought from state farms as it is already the common practice (Roessler et al., submitted for publication). Crossbred sows then have to be brought to the villages close to the market (according to the present breeding scheme: 23 sows per year). In the villages close to the market, fattening pigs are produced by crossing Yorkshire sires with the F₁ sows and fattened till slaughter on the same farm. Exotic boars (Yorkshire) have to be bought from external sources which is already the common practice (Roessler et al., submitted for publication). According to the modelled breeding scheme, there will be about 550 F₁ sows. Assuming an average size of 8 piglets per sow and litter, 2 litters per year and a weaning rate of 80% then nearly 9000 fattening piglets will be born and reared per year, yielding about 7200 pigs for slaughter (assuming a survival rate of 80%). These pigs then have to be transported to the slaughterers, facilitated by relatively better infrastructure in villages close to the market. At the moment, there are no large slaughterhouses with large capacities in Son La province that meet national sanitary standards. To ensure product quality and safety issues, it would be important to cooperate only with a few of the 95 existing slaughterers in Son La town and Mai Son district that would do exclusively slaughtering for the short food supply chain. The slaughterhouses are a decisive chain link concerning the quality and food safety of the meat. A small food supply chain would ensure this quality by standards for slaughtering and meat processing. The meat would be mainly marketed within Son La province (by direct marketing, specialist butchers or restaurants) but also outside Son La province by wholesalers or restaurants. In such short food supply chains, value must be added, not only through making the chain links transparent for the consumers but also through propagating the use of local, adapted breeds as well as the regional organization. Within the Northern region of Vietnam two different pork markets exist and could be served by a SFSC: Rural households still prefer pork with higher amounts of fat (Cuong, 2004). On the other hand, Huong (2007) showed that there is an existing market for lean meat in urban households in Son La town. At present, only a small amount of pork is leaving the region.

4. Discussion

4.1. Farmers’ breed and trait preferences for local Ban pigs

Ban pigs in remote villages in Northwest Vietnam are mostly kept dependent on scavenging or very extensive feeding and husbandry conditions (Huyen, 2004; Roessler, 2005). This is reflected by the breeding goals of Ban keepers who value the broad feed intake spectrum and high feed intake capacity of this breed as well as traits connected to disease tolerance and health. Performance and carcass quality traits are also important for the choice of Ban pigs. By contrast to the feed intake spectrum and capacity, actual values of performance and carcass quality traits are perceived not to be at an optimum level and should be improved in future breeding programs. The same has been reported for the performance levels of productive and reproductive traits of Mong Cai pig populations in the same villages (Roessler et al., 2009). The actual growth rate of Ban pigs in the investigated...
villages is 119 g/d (169 g/d in Mong Cai pigs), the backfat thickness is 30.4 mm (28.5 mm in Mong Cai pigs) and 6.1 piglets are born alive (9.3 piglets born alive for Mong Cai sows) (Hau, 2008). Yet, it is assumed that these pigs do not express their full genetic potential and higher performances are expected under improved management conditions (Hau, 2008; Lemke et al., 2006).

4.2. Development of breeding schemes

In the modelled breeding schemes, productive performance (growth rate and body weight), carcass quality (backfat) and reproductive performance traits (number of piglets born alive and farrowing interval) were included as breeding objective traits. The growth rate and body composition as well as the maintenance requirements of pigs influence the absolute amount and pattern of feed intake. Thus, the growth rate, backfat thickness and body weight were used to indirectly measure the ability of the animals to cope with the available foodstuff. Fertility traits were taken as information traits for the health of the animals as only animals with good health will show good fertility. To date, there are no specific genetic parameters for the populations under investigation available. Also, the breeding populations are small and this restricts the achievable genetic gains especially in fertility traits with low heritabilities. This is obvious in the stratified crossbreeding system when also selection intensity is low because nearly all animals have to be used for further breeding. Here, genetic gains in fertility traits are heading towards zero. Comparing the three systems, genetic gains were highest in the Yorkshire × Ban crossbreeding system. This might be biased by the fact that ZPLAN is not calculating increasing rates of inbreeding. With the small number of breeding animals selected per year the program therefore models a high selection intensity not taking into account that this increases inbreeding and might lead to negative effects throughout the population. It might be an adapted solution to focus on fertility traits in the selection index. This will lead to genetic gains even if only low in the local pig populations. Besides, it can be expected that a focus on fertility traits in the local population will lead to high crossbreeding effects, also maternal effects, when crossing with the meat-oriented Yorkshire breed. Altogether, in all evaluated breeding schemes the genetic gains are low and breeding costs are high, leading to a negative profit of > –20 € per sow in all evaluated breeding systems. Costs used in the modelling approach are however not the real costs within a breeding program. For example, the costs calculated for carrying out the OPTS scheme so far reflect the costs of staff employed by the project. These costs are certainly higher than those that might arise when carrying out the proposed breeding system. Ifft et al. (2009) carried out a pilot study for establishing a certified supply chain for poultry in Vietnam. They state that cost effectiveness for building up a supply chain would depend on local market conditions, feed costs, distances to markets and other factors. To their opinion it is not appropriate to evaluate cost effectiveness from project costs alone.

Further it has to be considered that ZPLAN only uses net breeding costs for the calculations. This means, that several cost components of carrying out a breeding program are neglected: For example costs for consulting, marketing and advertising. Or in our case, it is the costs for transferring breeding animals from one breeding step to the other. The idea of a stratified breeding program combined with a small food supply chain represents a concept that goes beyond the capacity of this breeding system evaluation program. Process value analysis or transaction cost approaches might be suitable to value such a combined approach. For example, Grandke (2002) showed that process value analysis can be used to evaluate economic efficiency of a breeding organization.

The core result of the investigation was the modelling of the breeding schemes, thus now having a tool to compare alternative breeding schemes and identifying weak points. The figures out of the modelling should not be interpreted as absolute profit but as relative values having fit the breeding schemes to a comparable level. The “mapping” of the breeding schemes shows that planned breeding in the Son La region is possible and gives all involved stakeholders transparency about animal flows. For a subsequent study, further sensitivity tests will be performed with regard to the population size, test capacity, improved fodder efficiency and different levels of breeding costs.

4.3. Organizational requirements

The studied two-breed crossbreeding schemes Yorkshire × Mong Cai or Ban represent the predominant breeding methods in the investigation area. Such breeding schemes lead to increased growth and lean meat percentage in the carcass and therefore help to adjust carcass quality to the demands of the market. Purebreeding systems were neglected in this study because farmers with more market-oriented pig production in the region have been constantly moving to improvised crossbreeding by themselves. This means that farmers use predominantly exotic boars for crossing; only if Mong Cai or Ban replacements get scarce a purebred boar is used for mating (Roessler et al., 2009). Attempts to return to a purebreeding system in this type of production system do not seem promising while organized crossbreeding with maintaining the local breeds as crossing-resource appears to be an option.

There exist two different pork markets in Vietnam: In urban areas there is a high demand (40% of meat consumed) of lean pork whereas in rural areas demand for lean pork is still low (18% of meat consumed) (Tung, 2001). Rural households mainly consume meat with a higher fat content (Cuong, 2004). Also, in urban areas exists at least a niche market for local (fatter) livestock products (Cuong, 2004). In Son La province, the production is mainly taking place in remote areas. There exists a vertical market for local Ban pigs (Huong, 2007) and farmers use the opportunity to market their Ban pigs (Roessler et al., submitted for publication). These findings are promising for the establishment of a stratified breeding system combined with a short food supply chain. Within a stratified breeding system local genetic resources would be conserved in rural areas and therefore would also supply rural areas with meat with higher fat content. In addition, crossbred animals would be bred and fattened in the areas close to markets and would supply leaner meat to urban households. Still open questions are how big the demand of the special meat qualities is, how many animals in a comparable quality can be supplied, where they are collected, slaughtered and how they will be transported.
Yet, organization of the pork supply chain in Son La province is unsystematic and quality control systems have not been established so far. The market for local Ban pigs only serves a group of customers mainly in the region. Only a small number of Ban pigs are marketed to specialty restaurants in the lowlands. Gross margins realised by Ban producers are higher than those realised by F1 (Exotic × Mong Cai) producers (Huong, 2007). This could be interpreted that consumers of Ban meat appreciate the special quality of this meat and that they are willing to pay a better price for this added value. In the case of a pilot project on development of a certified supply chain of poultry meat in Vietnam, Ifft et al. (2009) report that consumers appreciated the quality of local breeds and also the security of purchasing a traceable product.

For both types of studied breeding schemes (two-breed and three-breed crossbreeding schemes) it is therefore decisive to establish functioning market channels and supply chains. Only if a sufficient market for breeding and slaughter animals exists, the farmers will be motivated to participate in organized breeding schemes. Also, it is important to know who has a decision power within the supply chain. General possibilities to establish supply chains are through contract farming (e.g. Key and McBride, 2003), vertical integration (e.g. Buhr, 2004; Reimer, 2006), trust management (e.g. Spiller and Schulze, 2007; Schulze et al., 2007) or farmer-cooperatives/horizontal integration (e.g. Buhr, 2004). A typical production contract for slaughter pigs comprises that the contractor provides feed, piglets, veterinary care, managerial assistance, marketing service and the contracted farmer is paid a fee for raising the animals (Key and McBride, 2003). Decision power is then with the contractor, the farmer is acting according to the orders of the contractor. In return, the risk for the farmer is low. According to Key and McBride (2003) important factors for farmers to join in a contract-system are the reduced price risk and an easier possibility to obtain financing for setting up or expanding pig production. Reimer (2006) defines integration as pig production carried out on company-owned farms by hired managers. Buhr (2004) defines vertical integration as investment of pig farmers in pork slaughter and further processing facilities and vertical cooperation as business arrangements to maintain ownership of the pork product through the production chain to the final consumer. Therefore, vertical integration/cooperation can either be looked at from a top-down-approach (company as farm owner, hired labour) but also from a bottom-up-approach (farmers as owners of following production steps). So far, all investigations on pork supply chains focus on producers of pigs for slaughter and follow the chain links upwards. Breeding has not played a role in this discussion yet. In Vietnam, different types of market linkages and contract arrangements for the production of pork exist. Although formal contract agreements mostly exist between large integrator firms and large-scale pig producers some of the contract agreements also create opportunities for small-scale farmers to engage in contract arrangements (Costales et al., 2006). However, contracting and vertical integration have not yet become the common practice in pig production in Vietnam. In a case from the Philippines a reason that small-scale pig producers are not widely involved in contract raising was identified as the required high minimum number of piglets to be grown by the contractors (Tiongco et al., 2008). This might also be a reason for a low involvement of small-scale pig producers in contract farming in Vietnam. In Vietnam, horizontal networks have been described for pig production. Farmer cooperatives or associations provide feed, breeding stock and technical as well as animal health and other livestock services to their members. Besides, members obtain information on market prices and outlets. Members are both large-scale and small-scale pig producers (Binh et al., 2007; Costales et al., 2005). In this case, decision power and also the full risk is with the farmers.

In the present study, the establishment of a short food supply chain is suggested. As a first step, the pork producers and breeders in the participating villages would need to organize themselves in local producer associations (horizontal networks). These producer associations would need to agree on joint standards for breeding, feeding, husbandry and veterinary treatments of their pigs to guarantee a certain standard of production (e.g. Wiskerke and Roep, 2007). With horizontal integration, farmers with similar production goals are linked and are able to bundle their products and market them together. Vertical networks are flexible and despite the similar production goals still quite diverse and they build on common interest and trust between the involved partners (Murdoch, 2000), Binh et al. (2007) report about a quality pork supply chain in the Red River Delta region in Vietnam. Here, ten pork producer cooperatives and one veterinary cooperative were set up. These cooperatives made economies of scale exploitable for the pork producers, not only for selling their products, but also for purchasing exotic boars and supplemental feed and for veterinary care.

A well functioning example for a horizontal network on breeding and pork production with a local pig breed is the Erzeugergemeinschaft Schwaebisch-Hall (BESH) in Southern Germany. In case of the BESH, additionally the step of vertical integration was undertaken by building a slaughter house where only animals of the BESH are slaughtered, own shops and a restaurant. Also, BESH is marketing part of their pork on the basis of contracts with different wholesalers or commercial customers like Unilever or Edeka supermarket chain (Zimmer, personal communication). Another part is marketed on regional markets or in special butcher shops with added value by relating the product to the special breed of the association, the local Schwaebisch-Haelilische pig. The bottom-up approach of the BESH could be taken as a model for building up a small food supply chain in Northwest Vietnam. When all members of the chain up to its end can profit from the added value created, the food supply chain will also make its contribution to rural and regional development as shown in other cases like for example the pork supply chain of the De Hoeve company in the Netherlands (Wiskerke and Roep, 2007).

Hoste (2006) states that for competitiveness of the pork supply chain, production costs of slaughter and processing, transport and import levies are decisive. Other important factors are comparability of farms (similar production goals, similar farm structure and size), existence or absence of infrastructure and communication within the chain but also with society. Osinga and Hofstede (2005) point out that a major decision point in building up a food supply chain is the societal context. They define societal context in terms of history and economical, social and cultural factors. In the case of Vietnam, as shown by Roessler et al. (submitted for publication), the societal context is leading to an openness of the farmers to organize in cooperatives and value local resources. A strong
interlinkage with governmental institutions is common although not always free of conflict.

Simultaneously with the development of breeding programs and marketing channels, systems of testing animals for performance and recording data would need to be organized in a sustainable way. This service is at the moment carried out by the project. When developing a horizontal network within the region it would be an option to also organize the recording and performance testing within these farmers groups. The involvement of project employees could then be replaced by more involvement of the farmers themselves and also representatives of breeding organizations or governmental breeding institutions. Animal identification and recording are increasingly getting a matter of market access due to animal health and food safety concerns (Schmitt, 2009). With Vietnam taking increasingly part in international competition, performance control associations would be an adapted solution.

Pig breeding in the investigated area is mostly limited to the region and to small pig populations (compare Roessler et al., 2009, submitted for publication). A stratified breeding scheme might build up links between regions and populations. On the one hand, the establishment of a stratified crossbreeding scheme is more complicated than a simple crossbreeding scheme, since more chain links have to be coordinated. On the other hand, however, a stratified crossbreeding scheme overcomes some critical points like poorly developed infrastructure, poor access to input and output markets and information like in remote villages in Son La province (Lemke et al., 2006; Schad et al., 2007). A stratified system has to be built up carefully step by step. Additionally, crossbreeding between local and exotic breeds helps small-scale farmers to rely on their own breeds and helps to conserve the local breeds by maintaining them in purebreeding for supply of the crossbreeding scheme with purebred sows. This additionally opens options for marketing of breeding stock from the local breeds, actually highly demanded in the northern provinces of Vietnam.

The stratification of a part of the UK sheep industry is one example how a stratified and market-oriented breeding system is able to conserve adapted local breeds. In this system, the adaptation of local breeds to specific environments is exploited for the benefit of these environments and their inhabitants. Adapted hill sheep are used for pasture conservation in the hilly areas and reproduction. Mature animals are then moved to the middle uplands area and crossed with longwool breeds. Crossbred ewes are sold to the lowlands and crossed with special meat type sires (Croston, 1995; UK agriculture, 2009). This system of stratified crossing helped to conserve a variety of 60 different sheep breeds in the UK (Croston, 1995).

Subsequently, building on the results of the modelling of breeding programs and organizational analysis as presented in this paper, a full economic analysis of the suggested system has to be carried out. Also on the breeding level, sensitivity analyses targeting success determining factors like population size and performance testing systems have to be performed. Inbreeding needs to be taken into account and the genetic progress imported to the system with buying in Exotic boars has to be evaluated. Finally, feasibility and transaction costs for establishing and maintaining the system in the frame of infrastructural limitations have to be evaluated and additional options for marketing including breeding stock have to be approached.

References


