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Carcass grading for local Vietnamese Ban pigs and its potential for a quality feedback system in a short food supply chain

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Abstract

In-situ conservation of local pig breeds in Southeast Asia requires genetic improvement embedded in viable marketing concepts. Increasing demand offers marketing opportunities for indigenous Vietnamese Ban pork. This study sought to adjust estimation methods for grading light carcasses according to their leanness. Using data from the dissection of 45 carcasses, several models were fitted and evaluated. Although the predictive power of the equations was limited, Ban carcasses could be approximatively classified according to their lean content. Finally, a suggestion of how to include these measurements in a quality feedback system of a short food supply chain is made.

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Keywords: Indigenous pig genetic resource; carcass grading; carcass quality; short food supply chain; northwestern Vietnam

1. Introduction

In-situ conservation of native pig breeds in Southeast Asia requires sustainable approaches of genetic improvement, including an appropriate combination of adaptation traits with production attributes embedded in a viable marketing concept (Valle Zárate and Markemann, 2010). In the mountainous areas of northern Vietnam, a community-based breeding and marketing concept incorporating local breeds was developed, based on more than 10

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years of research by various stakeholders, including local ethnic farmer communities. Currently, increasing demand for specialty meat products - mainly from affluent customers in the urbanized lowlands of northern Vietnam (e.g., see Lapar et al., 2010) - may offer marketing opportunities for indigenous pork. As a result of the increased utilization of exotic breeds by market-oriented pig producers located in proximity to urban markets, the Vietnamese pig population underwent dramatic changes in the last few decades, and indigenous pork is now much less available in urban markets. Uncontrolled admixture with exotic breeds imposes a threat to pig breed diversity in Vietnam (Berthouly-Salazar et al., 2012). Purebred native pig breeds were pushed back to the remote, less accessible highland regions where pig husbandry fulfills multiple functions for agricultural households and is only a secondary activity compared to crop production (Lemke et al., 2006). Under these circumstances, the marketing of pork is only done sporadically. The native Ban pig kept by Black Thai farmers in northwestern Vietnam is a small, black-coated breed with erect ears. It grows slowly and accumulates high amounts of depot fat at the slaughter weight (around 60 kg) commonly applied in rural areas. While not being competitive on the commodity pork market, remote smallholders can deliver a highly appreciated niche product derived from this breed. To avoid excessive fat accumulation, urban high-end or niche retailers (e.g., 'green/natural' food stores) request lightweight pigs and put an emphasis on a high lean meat content. In the case where existing information asymmetries between producers and retailers cannot be minimized and quality considerations are not taken into account on the producer level, stable, trustworthy relationships are not likely to be achieved among actors along the value chain. Therefore, tools to assess the quality of products and regular feedback loops have to be implemented. Because of its applicability in live marketing, an ultrasound measurement of backfat thickness was considered in a first approach. But, because of the low dorsal backfat layer in Ban pigs the use of this non-invasive method was not feasible. Therefore, measurements conducted on carcasses for quality grading were considered. In European slaughterhouses with high slaughter volumes and slaughter rates, optical probe measurements for lean meat content estimation are used to disburse farmers respective to the carcass quality delivered. Processors also use the data generated to allocate carcasses to different product and processing segments. For the emerging short food supply chain for specialty Ban pork, no quality control and feedback system with respect to carcass quality exists so far. However, low cost methods such as the 'two points' method (TP method, 'Zwei Punkte Messverfahren') for the estimation of the lean meat content of carcasses could be suitable to be incorporated in the short food supply chain for specialty Ban pork as it neither requires costly instrumentation nor very skilled labor.

The aim of the present research was thus to calibrate an equation for lean meat percentage estimation in Ban carcass halves qualifying for high-end niche marketing. Several adjusted equations were comparatively evaluated. Furthermore, the applicability for vertical coordination in the frame of a short food supply chain for Vietnamese Ban pigs is discussed.

2. Material and methods

2.1. Animal selection

The study was carried out from October 2013 to February 2014 in Son La city (21° 19′37″ N, 103° 54′51″ E) and its surrounding districts. Son La city is the capital of the mountainous Son La province in northwestern Vietnam. In total, 45 purebred Ban pigs originating from different litters, dams and farms were selected. Slaughter animals were castrated male pigs at an age of 5 to 7 months. The average fasted live weight at slaughter was 16.4 kg (also see Table 1). At this weight, Ban pigs qualify for marketing at a price premium to restaurants and the food retail sector in the northern Vietnamese lowlands.

2.2. Slaughter and measurements

Three small-scale butchers (capacity of 1-2 pigs per day) conducted the slaughter according to common slaughtering practice, i.e. bleeding without prior stunning. A maximum of four pigs per day was slaughtered on 19 slaughter days. Pigs were collected on the day before slaughter and fasted for at least 12 h prior to slaughter. After bleeding, pigs were scalded and manually dehaired. Viscera, head, feet and leaf fat were removed and the hot carcass weight was recorded. Then the carcass was split along the backbone. Within 45 min postmortem, the backfat and muscle thickness on the right carcass half were measured using a metric ruler according to the two points method (TP method). The minimum backfat thickness (mm) was recorded above the *gluteus medius*, and the muscle thickness (mm) as the shortest distance between the cranial end of the *gluteus medius* and the dorsal edge of the *canalis vertebralis*. Afterwards, the carcass half was dissected into the tissue components lean (defined as red striated musculature separable by knife), fat, skin and bone. The total lean of the carcass half was then weighed and the lean yield expressed relative to the weight of the dressed carcass half.

Table 1. Central tendency and distribution for live weight and carcass measurements of Vietnamese Ban pigs dedicated for specialty niche markets.

Trait	Mean ± sd	Min	Q25	Median	Q75	Max
Live weight in kg	16.4 ± 4.7	10.5	13.0	15.5	18.0	29.3
Carcass weight in kg	9.2 ± 3.0	5.1	7.2	8.8	10.0	18.7
Lean meat content in %	42.0 ± 4.9	30.8	38.7	42.0	46.0	53.3
Backfat thickness in mm	6.6 ± 4.2	1.0	2.0	7.0	9.8	16.0
Muscle thickness in mm	24.9 ± 5.5	13.0	20.5	24.0	29.5	42.0

2.3. Statistical analysis

The equations fitted to the data were derived from different sources (see Table 2, references 1 to 8) currently or formerly prescribed for the estimation of lean meat percentage from the TP method in small abattoirs in Europe. For this, the nls function for nonlinear models of the ‘stats’ package of R version 3.1.1 (R Core Team, 2014) was used. Additionally, an own model was developed based on all established scale transformations of the predictors (backfat thickness and muscle thickness). In a backward selection process, terms were removed at $P>0.1$ and a model (Table 2, model 9) was selected based on its relative quality, according to the Akaike information criterion. To evaluate the goodness of fit and the predictive power of different equations, the coefficient of determination (R^2), root mean square error (RMSE) and root mean square error of prediction (RMSEP) were calculated. The RMSEP is based on the prediction sum of squares statistic (PRESS), a leave-one-out refitting prediction method as described in Allen (1971), and implemented in R via the ‘qpcR’ package by Spiess (2014). For selected equations, diagnostic plots were produced to assess their validity.

3. Results and discussion

In Table 1, the descriptive statistics for the data set are shown. For Ban pigs produced for niche and specialty markets, the lean meat percentage averaged 42%, i.e. a substantial proportion of Ban pigs did not exceed a lean meat content of 40%. For the measurement of backfat thickness, a high frequency of values below 2 mm was noted.

At present, the mathematical expression of TP formulas for lean meat percentage estimation in pig carcasses for most European countries does not comprise transformed predictor variables (e.g., root transformation of backfat thickness at *gluteus medius* or of muscle thickness). But, in the case of lightweight Ban pigs, model 1) calibrated from this equation performed worse compared to more complex models with regard to the fit to the data, according to the RMSE (4.23) (Table 2). In contrast, the predictive ability with respect to the PRESS and RMSEP statistics (964 and 4.63, respectively) was superior to most of the other models. Adding carcass weight as a predictor in equation 2) did not substantially improve the fit of this equation, whereas the predictive power was even slightly reduced. A RMSE below 4% was obtained for equations 4), 5) and 9) only, whereas formula 9) yielded the lowest RMSE and the highest coefficient of determination. These equations still varied markedly with respect to their RMSEP. Model 4), calibrated from the equation derived from the Commission Decision 96/4/EC, revealed the lowest PRESS and RMSEP. The linear term for muscle thickness was not significant ($P>0.1$) for model 4), and only the intercept and the linear term for backfat thickness at *gluteus medius* reached statistical significance ($P<0.05$). For model 9), all terms at least tended to be significant by definition ($P<0.1$). Therefore, the equations from model 4) and 9) were regarded as potentially suitable for incorporation into a carcass grading and quality feedback system for Ban pigs.

Table 2. Calibrated equations for the estimation of lean meat percentage according to the two points method and criteria (root mean square error = RMSE, prediction sums of squares = PRESS, root mean squared error of prediction = RMSEP, coefficient of determination = R^2) for statistical evaluation of the obtained formulas.

Ref.	Calibrated equation	RMSE	PRESS	RMSEP	R^2
1)	$Y = 34.62–0.290·x_1+ 0.374·x_2$	4.23	964	4.63	0.242
2)	$Y = 34.36–0.330·x_1+0.336·x_2+0.161·x_3$	4.21	998	4.71	0.249
3)	$Y = 13.74+32.11·(x_1/x_2)+7.64·\sqrt{x_2}+1.53·\log(x_2)+6.66·\sqrt{x_1}$	4.07	1117	4.98	0.300
4)	$Y = 54.26–1.28·x_1 + 0.065·x_1^2–0.983·x_2+0.026·x_2^2$	3.92	915	4.51	0.347
5)	$Y = 23.95+39.76·(x_1/x_2)+0.812·x_2–6.09·\log(x_1)–0.930·x_1+0.300·x_3$	3.90	1099	4.94	0.356
6)	$Y = 51.48+2.10·x_1+0.439·x_2–0.290·(x_2/x_1)–13.33·\sqrt{x_1}$	4.10	1159	4.74	0.289
7)	$Y = 14.45+33.37·(x_1/x_2) +7.14·\sqrt{x_2}–2.02·\log(x_1)–6.82·\sqrt{x_1}+0.282·x_3$	4.01	1269	5.08	0.319
8)	$Y = 37.36–12.63·(x_1/x_2)–5.31·\log(x_1)+5.40·\sqrt{x_1}+0.407·x_3$	4.36	1010	5.31	0.196
9)	$Y = 212.16+1.80·x_1–19.56·x_2–9.93·\sqrt{x_1}+426.45·\sqrt{x_2}–559.80·\log(x_2)$	3.71	1173	5.10	0.416

Y: estimated lean meat percentage; x_1: backfat thickness; x_2: muscle thickness; x_3: hot carcass weight

References: 1) Commission Implementing Decision 2011/258/EU; 2) Commission Decision 2008/364/EC; 3) Commission Decision 89/471/EEC; 4) Commission Decision 96/4/EC; 5) Commission Decision 2005/879/EC; 6) Bahelka et al., 2005; 7) and 8) Kušec et al., 2007; 9) own model

The basic model assumptions were evaluated by visual inspection of the diagnostic plots (Fig. 1). The QQ-plots indicated no violation of the assumption of normality, but the plot of standardized (studentized) residuals vs. predicted values of lean meat percentage pointed toward a reduced variance of residuals with increasing predicted lean meat percentages. This was more strongly expressed for model 9), and could be related to challenges in measuring the marginal thickness of the subcutaneous fat layer above the *gluteus medius* of lightweight pigs. When excluding pigs with a live weight below 12 kg, the distribution of standardized residuals over predicted lean meat percentages improved (not shown).

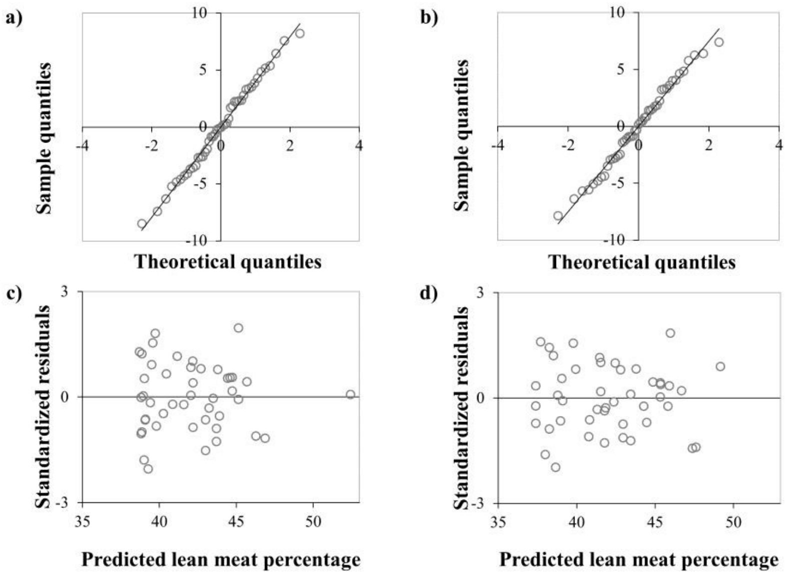

Fig. 1. QQ-plots for model 4 (a) and model 9 (b) and standardized residuals vs. predicted lean meat percentage plots for model 4 (c) and model 9 (d), respectively.

The RMSE and RMSEP of both selected models were still relatively high, which is, in the first place, probably attributable to the small sample size, yet other problems in measurements – as in a backfat layer being too thin, or the determination of the shortest distance between *gluteus medius* and the vertebral canal by the assessor's vision – could have exaggerated errors. The European Commission demands calibrated formulas to yield a RMSE smaller than 2.5%, but this condition was not fulfilled by any of the adjusted models. Gispert and Font i Furnols (2012) achieved a RMSE value of <2% and a coefficient of determination of 78% for the TP method in Spain. Their equation was applied to pigs of a slaughter weight of 60-120 kg, and no carcass exhibited a backfat thickness above the *gluteus medius* of <4 mm. Similar results for the TP method were obtained for pig carcasses in Croatia (Kušec et al., 2007) and Slovakia (Bahelka et al., 2005). In both cases, the referent pig population was much heavier compared to that in the present study. In the Croatian survey, the backfat thickness of 53% of the carcasses fell into the category of between 12 and 20 mm (Kušec et al., 2007). Based on the accumulated data and model diagnostics, model 4) can be used for an approximate assessment of lean meat content in lightweight Ban pigs. It is, however, strongly recommended to re-calibrate the equations for the TP method using i) a larger data set and ii) excluding pigs lighter than 12 kg that did not develop a subcutaneous fat depot below this body weight.

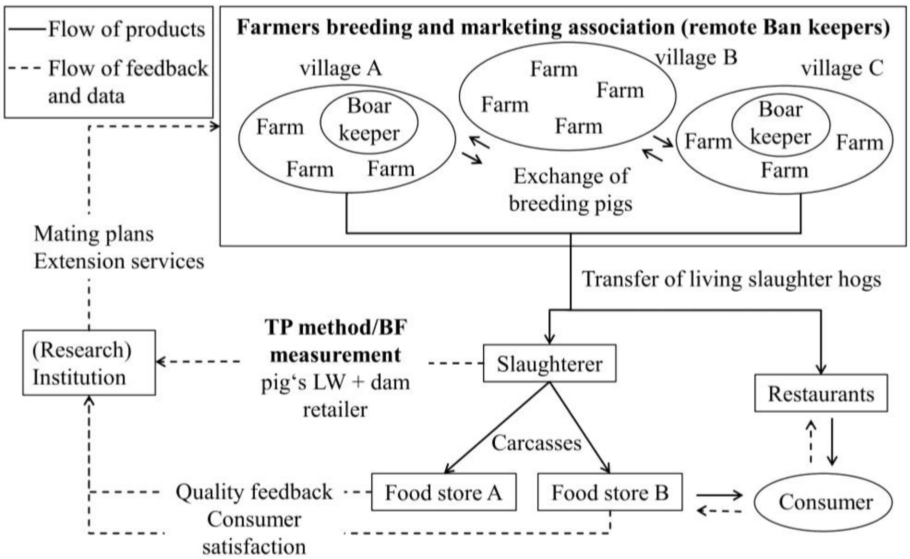

Fig. 2. Potential incorporation of carcass measurements (TP method: two points measurements; and/or BF measurement: backfat thickness at last rib) for a quality control and feedback system in a short food supply chain for specialty Ban pork.

Re-calibrated equations or equation 4) on an interim basis can then be included as a quality control and feedback tool, as is schematically depicted in Fig. 2. Alternatively, measurements of the backfat thickness at the last rib could be recorded to determine the degree of carcass fatness. This short food supply chain is an extract of the more comprehensive set-up developed by Herold et al. (2010) and only focuses on purebred Ban fatteners. Purebred Ban pigs are produced by a farmers' cooperative, comprising of several remote villages. Once an order is taken, pigs are transported to a local slaughterer who has been trained in conducting the measurements, and who records the date, farmer's name, pig live weight and carcass weight, and TP and backfat measurements, as well as the address of the retailer in the lowlands to whom the carcass is to be sent. At this point, an official meat inspection by the veterinary department – which is often not done at present – could also be included. The retailer in turn records his/her satisfaction with the carcass quality and optionally that of his/her customers' satisfaction. If sufficient data is accumulated and linked by a central institution (e.g., a national or provincial research institution and/or authority), sires and dams with high genetic merit with respect to carcass composition could be identified and considered for mating plans. In addition, other valuable feedback for designing production systems optimizing the carcass quality of Ban pigs could be delivered via extension services. Customers, particularly restaurants, that request small (live) pigs with a live weight under 12 kg can, however, not be effectively included in the feedback loop. Due to the cheap and relatively easy and straightforward applicability of the TP method, the inclusion of more than one slaughterer in the feedback system would also be possible. This fits well with the decentralized strategy chosen for the short food supply chain in the outlined model.

4. Conclusions

It seems to be of high relevance to align quality feedback and control systems with the emerging short food supply chain for lightweight Ban pigs to safeguard its long-term stability. In this respect the low-cost estimation of lean meat content by the TP method could be suitable. However, equations calibrated from the actual data set are clearly not adequate for grading individual animals. In the long term, marginalized ethnic smallholders should be linked to remunerative markets by a pork value chain including vertical coordination via feedback loops. It is thereby aimed at firstly, diversifying smallholders' incomes, and secondly, at the *in situ* conservation of a valuable pig genetic resource of the Vietnamese highlands.

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