Selection for piglet mortality and litter size in outdoor organic pig production systems

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Abstract
This study evaluated breeding goals for increasing litter size of sows 11 days after farrowing (LS11) in organic production systems while aiming to reduce piglet mortality (Mort11). Investigated breeding goals included LS11 only, or Mort11 and total number of piglets born (TNB) combined. Response to selection, expressed as LS11, was derived using selection index theory. We found that selection based on breeding goal of LS11 only, or using equal economic weights for TNB and Mort11 would increase LS11, but at the costs of increasing piglet mortality. By defining LS11 as two traits of TNB and Mort11, selection could reduce piglet mortality through possibility of altering economic weights for the traits in breeding goals, and through exploiting heritability differences of TNB and Mort11 in selection. By increasing economic weight for Mort11, breeding program for organic pig production could achieve zero genetic change in Mort11 while still gaining more TNB.

Introduction
In non-organic Danish pig production, litter size of sows has increased almost linearly from 2003 to 2019 (Nielsen *et al.*, 2013; Hansen, 2020). In the same period, mortality rate of piglets decreased steadily until 2016, but showed an increasing trend after 2016 (Hansen, 2020). This increase in piglet mortality could be due to a non-linear effect of litter size on mortality traits. However, trait definition in the breeding goal used in some breeding programs could be a problem as well. For example, using litter size at day 5 after farrowing, commonly known as LS5, for selection (Nielsen *et al.*, 2013) might be suboptimal for reducing the mortality of piglets, because this approach assumes the trait total number born per litter (TNB) and mortality traits have the same genetic background. We hypothesized that by decomposing litter size into TNB and a mortality trait, the number of piglets alive can be improved.

Mortality of piglets reduces animal welfare and generates economic losses. Both are major concerns in organic as well as non-organic production systems. However, the welfare concern of piglet mortality is particularly important for the organic system, because consumers and society have high animal welfare requirements and expectations for organic systems (Font-i-Furnols *et al.*, 2019). The use of a trait such as LS5 in selection might increase the number of piglets alive at day 5 after farrowing, but at the cost of an overall increased number of dead piglets. From a welfare point of view, this is not desirable. The trait LS5 is commonly used in the Danish conventional system. In the organic system, number of piglets alive at 11 days after farrowing (LS11) may be more suitable, because of management practices.

The aim of this study was to evaluate breeding goals for increasing number of piglets alive from sows in outdoor organic pig production systems. The specific objectives were to: (i) estimate genetic parameters for sow traits of TNB, number of piglets dead at 0-11 days of piglet age (Mort11) and LS11; (ii) evaluate effect of different economic weights for TNB and Mort11 in breeding goals; (iii) assess the use of LS11 *versus* TNB and Mort11 in the breeding goals; (iv) develop a breeding goal for increasing LS11 without an increase in Mort11.

Materials and methods

Data were collected from the largest organic nucleus and multiplier pig farm in Denmark. Mort11 and TNB were recorded from 3,977 litters of 1,219 sows. The phenotypes of TNB were total number of piglets born per litter of sows. The phenotypes of Mort11 were number of dead piglets per litter that included stillborn piglets and piglets that died from farrowing to 11 days of age. The phenotypes of LS11 were: LS11 = TNB – Mort11. This study considered records of litter size after 11 days of farrowing only, because piglet mortality during this period accounted for the majority (80%) of pre-weaning piglet mortality in the outdoor organic pig production (Chu *et al.*, 2021). In addition, recording of Mort11 was easier and more accurate compared to mortality records at a later period in the outdoor system. Phenotyping of piglet mortality in the Danish outdoor piglet production system is challenging after removing hut fenders, allowing piglets to move freely throughout the field.

For estimation of variance components, pedigree-based linear BLUP models were used. The statistical model for TNB and Mort11 included three fixed effects (breed of the litter, parity of the sow and herd-year-season), two random effects (direct genetic effects of the sow and permanent environment effects caused by sow), and residual term. Bivariate models for TNB and Mort11 were run using the average information restricted maximum likelihood estimation method (DMUAI) in the DMU package (Madsen and Jensen, 2013). Genetic parameters of LS11 were not estimated, but derived from TNB and Mort11. This is because the genetic parameters derived and estimated are mathematically equivalent. We did not want to introduce estimation problem to the comparison of breeding goals for LS11 *versus* TNB and Mort11. In addition, in our preliminary analysis, the use of genetic parameters of LS11 that were either estimated or derived led to the same conclusions for this study.

Phenotypic variance ($\sigma^2_{p_{LS11}}$) of LS11 was derived from phenotypic variance estimates of TNB ($\sigma^2_{p_{TNB}}$) and Mort11 ($\sigma^2_{p_{Mort11}}$):

$$\sigma^2_{p_{LS11}} = \sigma^2_{p_{TNB}} + \sigma^2_{p_{Mort11}} - 2\sigma_{p_{TNB},p_{Mort11}} \quad (1)$$

Other variances and covariances were derived in similar ways.

Responses to selection expressed as LS11 were derived using selection index theory. Investigated breeding goals (H_1 and H_2) were:

$$H_1 = v_{TNB} * TNB + v_{Mort11} * Mort11 \quad (2)$$

$$H_2 = v_{LS11} * LS11 \quad (3)$$

where v_{TNB}, v_{Mort11} and v_{LS11} are economic weights of trait TNB, Mort11, and LS11, respectively; v_{LS11} =1.

The selection indexes (I_1, I_2) corresponding to H1 and H2 were:

$$I_1 = b_{TNB}\overline{TNB} + b_{Mort11}\overline{Mort11} \quad (4)$$

$$I_2 = b_{LS11}\overline{LS11} \quad (5)$$

where $\overline{TNB}$, $\overline{Mort11}$, and $\overline{LS11}$ are the mean of TNB, Mort11 and LS, respectively with assumption that sows had on average 2 litters (2 repeated records) at the time of selection; b_{TNB}, b_{Mort11} and b_{LS11} are selection indexes.

Expected response to selection and additive genetic change (S_{g_i}) for trait *j* in the breeding goal were calculated using formula as described in Gibson and Dekkers, (2003). For breeding goal H_2, S_{g_i} of TNB and Mort11 were derived from correlated response of LS11.

Desired gain indexes were derived as described by Brascamp (1984), so that that the genetic change of Mort11 was zero. After that, economic weight for H_1 in the case of desired gain were derived.

Results and discussion

The mean of TNB per litter was 15.2 with the standard deviation of 4.0. The mean of Mort11 per litter was 2.3 with the standard deviation of 2.4. Overall piglet mortality rate from pre-farrowing to 11 days of piglet age was 15%. This value was lower than the mortality rate reported in Denmark for organic herds (~27% (Rangstrup-Christensen *et al.*, 2018)) and non-organic herds (~20% (Hansen, 2020)). The lower observed mortality level was likely due to the high level of management on the study farm.

Figure 1 shows the data on dead piglets collected for this study, of which about 62% were stillborn piglets and piglets that died before 1 day of age. It was difficult to distinguish between stillborn and dead at 0 or 1 day of age as herdsman might not be present at the day of birth delivery. About 10 to 11 days of piglet age, hut fenders were removed. At this time, uncounted dead piglets were recorded, thus we could see at slightly higher piglet death compared to day 5 to 8.

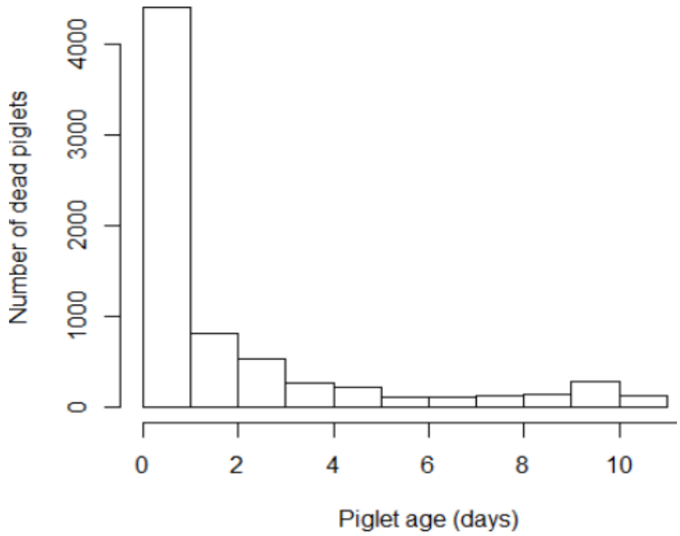

Figure 1: Histogram of piglet mortality from 0 to 11 days of piglet age.

Heritability and genetic variances of TNB were higher than those of Mort11 although these differences were not statistically significant (Table 1). Genetic correlation between TNB and Mort11 was positive. In other words, the larger litter size of sows, the more piglets died. Parameters of LS11 were derived from estimates of bivariate models of TNB and Mort11. Genetic correlation between LS11 and TNB were highly positive. The genetic correlation between LS11 and Mort11 was also positive, but at low level.

Table 1: Genetic parameters for TNB, Mort11 and LS11: heritability (diagonal), genetic correlations (below diagonal) and phenotypic correlation (above diagonal).

Trait	TNB	Mort11	LS11	Phenotypic variance
TNB	0.09	0.45	0.80	13.45
Mort11	0.66	0.06	-0.18	4.99
LS11	0.87	0.20	0.06	11.08

Note: Standard errors of heritability estimates were ~0.02.

Response to selection in units of LS11 was highest when the breeding goal of selection included TNB and Mort11 traits with an equal economic weight (Table 2). However, the potential gain in LS11 for this breeding goal came from increasing additive genetics of TNB, while at the same time piglet mortality increased. These differences in potential genetic changes for TNB and Mort11 could be explained by the difference in genetic variation, and the positive correlation between the two traits (Table 1).

Table 2: Response to selection expressed in LS11 based on different breeding goals.

Breeding goal	v_{TNB}	v_{Mort11}	v_{LS11}	$S_{g_{TNB}}$	$S_{g_{Mort11}}$	LS11
H_1[a]	1	-1	-	0.572	0.149	0.424
H_1[b]	1	0	-	0.624	0.234	0.389
H_1[b]	0	-1	-	-0.507	-0.288	-0.218
H_1[c]	1	-1.76	-	0.363	0.000	0.363
H_2[d]	-	-	1	0.450	0.053	0.397

Note: [a] equal economic indexes for TNB and Mort11; [b] alternative economic weights; [c] desired gain indexes; [d] optimum index using derived parameters from bivariate model of TNB and Mort11.

By altering the breeding goal and focusing on Mort11 only, piglet mortality could decrease (Table 2). However, TNB and as well as LS11 decreased, which might not be acceptable from an economic perspective. Therefore, we used a desired gain breeding goal to achieve zero genetic change in Mort11, which might be more acceptable to society and organic consumers (Font-i-Furnols *et al.*, 2019). With the desired gain indexes, more economic weight was put on Mort11. LS11 increased, although the increase in response to selection was lower compared to the scenario using equal economic weights for Mort11 and TNB.
A breeding goal that only consisted of LS11 led to lower response to selection compared to the scenario that included TNB and Mort11 with equal economic weight in the breeding goal. The two breeding goals were equivalent in economic weights for component traits. However, the higher response to selection of the breeding goal using TNB and Mort11 was due to the possibility of having different selection indexes (b_{TNB} and b_{Mort11}) for the two traits. In other words, differences in heritability of the two traits were taken into account. In contrast, the use of LS11 only would assume equal index for TNB and Mort11 (=b_{LS11}).

Conclusions

Selection based on breeding goal of LS11 only, or using equal economic index weights for TNB and Mort11 would increase number of piglets alive at 11 days after farrowing for sows, but at the costs of increasing the number of dead piglets slightly.
By defining number of piglets alive for sows as two traits of TNB and Mort11, selection could reduce piglet mortality through the flexibility of altering economic index weights for the traits in breeding goals, and through utilizing differences in heritability of TNB and Mort11.
By increasing the economic index weight for Mort11, breeding program for organic pig production could achieve zero genetic change in piglet mortality until day 11 while still gaining more TNB.

References

Brascamp, E. W. (1984) Anim. Breed. Abstr. 52:645–654.
Chu T.T., Zaalberg R.M., Villumsen T.M., Jensen J. (2021) 72nd EEAP, Davos, Switzerland.
Font-i-Furnols M., Skrlep M., Aluwe M. (2019) IOP Conference Series: Earth and Environmental Science.
Gibson J., Dekkers J. (2003) Design and economics of animal breeding strategies.
Hansen C. (2020) Seges Svineproduktion NOTAT NR. 2014.
Madsen P., Jensen J. (2013) DMU: A Package for Analysing Multivariate Mixed Models.
Nielsen B., Su G., Lund M.S., Madsen P. (2013) J. of Anim. Sci. 91, 2575-2582.
Rangstrup-Christensen L., Krogh M.A., Pedersen L.J., Sørensen J.T. (2018). animal 12, 810-818.