Genetic gain and economic weights of selection strategies including boar semen traits in a cross-breeding system

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ABSTRACT: Economic weights and genetic gains from alternative selection strategies, excluding or including four boar semen traits, were evaluated. The semen traits were: volume (VOL), semen concentration (CON), progressive motion of spermatozoa (MOT), abnormal spermatozoa (ABN) and an index thereof (DOSES). A three-way cross-breeding scheme (maternal nucleus lines A and B, and paternal nucleus line C) was considered. The economic weights of VOL, CON, MOT, ABN, and DOSES for 7 to 1 semen collections per week ranged from US$0.21 to $1.44/ml, $0.12 to $0.83/x10^3/mm^3, $0.61 to $12.66/%, $-0.53 to $-10.88/%, and 2.01 to 41.43 %/dose, respectively. Genetic gains across strategies were similar for the maternal traits and lower for the growth traits when semen traits were considered. The strategy including the four boar semen traits separately enabled higher genetic gains in these traits relative to DOSES without compromising the genetic gain in the maternal traits.
Keywords: economic weight

Introduction

In swine crossbreeding systems, selection decisions tend to prioritize reproductive traits in maternal lines and growth and carcass traits in for the paternal lines. Although boar semen traits play an important role in the efficiency and productivity of the system, these traits are usually neglected during selection (Rothschild, 1996; Smital et al., 2005; Ruiz-Sanchez et al., 2006; Wolf, 2009).

Conventional evaluation of boar fertility typically includes a measurement of semen volume (VOL, ml), sperm concentration (CON, x10^3/ml^3), and the percentage of sperm that are progressively motile (MOT, %) and morphological abnormal (ABN, %). Heritability estimates for VOL, CON, MOT, and ABN range from 0.14 to 0.25, 0.13 to 0.26, 0.05 to 0.18, and 0.4 to 0.12, respectively (Grandjot et al., 1997; Wolf, 2009, 2010). These estimates suggest that selection practices can improve boar semen traits, leading to higher sperm quality and quantity with equal or lower boar population size, and subsequent higher production efficiency of the swine industry (Robinson and Buhr, 2005; Smital et al., 2005; Oh et al., 2006; Foxcroft et al., 2008).

Despite the genetic parameters estimates available and economic, health and welfare value associated with the improvement for boar semen traits, no systematic study of the impact of these traits in breeding plans has been presented. Therefore, the objectives of this study were to understand the impact of including boar semen traits in pig production systems and to identify the most effective integration of boar semen traits into selection practices. These objectives were supported by two aims: 1) to derive the economic weight for boar semen traits, and 2) to evaluate the genetic gain from alternative selection strategies that differ in the consideration of boar semen traits within a three-tier pig production system.

Materials and Methods

Economic weights. A profit equation adapted from an established economic system was considered (Rutten et al., 2000). The profit was calculated as:

$$P = R - C$$

where
P = profit/boar space/time
R = returns/boar space/time
C = cost/boar space/time
Time = week

The returns depends of the amount of semen doses obtained, the semen sale price, and the semen collection interval (Smital et al., 2005; Rutten et al., 2000):

$$R = ([VOL \times CON/1000] \times [MOT/100 \times (1-(ABN/100))])/DCA \times S \times i$$

where
DCA = expected amount of spermatozoa in one dose (usually 3x10^9 for conventional insemination in US, Safranski et al., 2008), S = sale price ($/semen dose), and i = collection interval (from seven collection to one collection per week).

The cost is given by:

$$C = F + CC \times (t/i) + CD \times (t/i) \times ([VOL \times CON/1000] \times [MOT/100 \times (1-(ABN/100))])/DCA$$

where
F = fixed cost/boar space/time ($/boar/week), CC = cost per collection ($), t = time, and CD = cost /dose ($/dose).

Partial derivatives of the profit function, taken with respect to each trait of interest were used to compute the economic weight for each boar semen trait. Values for the cost variables and estimates of heritability and phenotypic standard deviations for the semen characteristics were obtained from a literature reviews (Rutten et al., 2000; Smital et al., 2005).

Selection strategies. A three-tier, three-way crossbreeding scheme with sixteen genetic groups was considered (González-Peña et al., 2014). Briefly, two nucleus maternal lines (A and B, 500 sows/line) and a nucleus paternal line (C, 500 sows) line were simulated. At the multiplier level, BxA sows are obtained, and the commercial level BxA sows are inseminated with semen from C boars producing market pigs.

Three strategies to select seedstock and the BxA sows were simulated. **Strategy I** (baseline strategy) excluded boar semen traits and encompassed genetic selection for records of traditional traits like number of pigs born alive (NBA), litter birth weight (LBW, kg), adjusted 21-day litter weight (A21, kg), number at 21 days (N21, days), days to 113.5 kg (D113, days), backfat (BF, mm), average daily gain (ADG, g), feed efficiency (FE), and lean carcass % (LEAN). **Strategy II** included Strategy I and selection for a novel boar semen indicator (DOSES) that combines the four boar semen traits (Smital et al., 2005):

DOSES = (VOL*CON/1000)*(MOT/100*(1-(ABN/100))/DCA

Strategy III included Strategy I and simultaneous selection for the four boar semen traits VOL, CON, MOT, and ABN separately.

Seven selection indices (male and female A, B and C and female BxA) that included the semen traits were developed within each strategy. The seven indices were applied to obtain replacement boars and sows in each of the three nucleus groups and to generate multiplier BxA sows inseminated with line C. Phenotypic standard deviations, correlations, and heritability estimates of the boar semen traits included in the selection indices are listed in **Table 1** (Smital et al., 2005; Wolf, 2010).

Table 1. Heritability (h^2), phenotypic standard deviations (σ_p), genetic (above diagonal), and phenotypic (below diagonal) correlations of the boar semen traits.

	Parameter		Correlation				
Traits[1]	h^2	σ_p	VOL	CON	MOT	ABN	DOSES
NBA	0.10	2.50	-0.07	-0.02	0.04	-0.24	-0.10
VOL	0.25	91.86	***1.00***	-0.68	-0.04	-0.09	x
CON	0.18	144.92	-0.5	***1.00***	0.12	0.13	x
MOT	0.12	4.31	0.01	0.04	***1.00***	-0.48	x
ABN	0.10	5.75	-0.01	0.03	-0.20	***1.00***	x
DOSES	0.40	10.70	x	x	x	***x***	***1.00***

[1]NBA = number born alive; VOL = semen volume (ml); CON = semen concentration ($x10^3/mm^3$); MOT = progressive motion of spermatozoa (%); ABN = abnormal spermatozoa (%); DOSES = number of semen doses.

The relative economic weight for each trait in the selection indices obtained for each strategy was the product of the economic value multiplied by the standard discount expression to adjust for interest rate across time, expressed relative to the genetic standard deviation of each trait. The resultant values were calculated as percentage of the total sum, that shows the relative economic importance of each trait within a line (Wünsch et al., 1999). One round of selection (selection solely based on parental and half-sib information) was used and thus the effects of inbreeding, reduced genetic variation due to selection, and return from breeding product sales were assumed negligible (Wünsch et al., 1999; Willam et al., 2008). The economic weights were integrated into the selection strategies and applied to the crossbreeding system that was simulated using the software ZPLAN (Willam et al., 2008). This software supports the assessment of genetic and financial progress in a deterministic framework using selection indexes and gene flow methodology (Willam et al., 2008).

Results and Discussion

The economic weights, based on the traits means and costs proposed for an average boar stud in the US with a range of seven to one collections per week are presented in **Table 2**. The economic values for VOL, CON, MOT, and DOSES increased as the frequency of collection decreased. These changes coincided with a decrease in the economic value of ABN. These results are consistent with reports that more frequent semen collection is associated with fewer spermatozoa being accumulated in the epididymal reserves. The higher economic value of DOSES associated with a lower number of collections per week was probably due to the greater number of usable doses per collection (Rutten et al., 2000).

Table 2. Economic weights (relative economic value = economic weight * genetic standard deviation) from partial derivatives of the profit function by collection schedule.

Traits[1]	Number of collections per week		
	7	2.33	1.00
VOL	0.21 (9.65)	0.62 (28.48)	1.44 (66.14)
CON	0.12 (7.38)	0.35 (21.52)	0.83 (51.03)
MOT	0.61 (0.91)	5.43 (8.11)	12.66 (18.90)
ABN	-0.53 (-0.96)	-4.38 (-7.96)	-10.88 (-19.78)
DOSES	2.01 (13.60)	16.67 (112.81)	41.43 (280.37)

[1]see table 1.

Average genetic gains for the maternal traits (NBA, LBW, A21, N21) were similar across strategies (**Table 3**). However, the genetic gains in Strategies II and III relative to Strategy I were lower by 59.2% and 25.8% (BF), 50% and 50% (FE), and 84.4% and 59.4% (LEAN), respectively. The growth traits that have higher heritability values were particularly sensitive to the inclusion of the boar semen traits, especially when these traits had higher heritability and low genetic correlation estimates, such as with DOSES. The magnitude and sign of the genetic gain resulting from the consideration of boar semen traits depended on the product of the relative value of the economic weight and the genetic and phenotypic variation and covariation among all traits in the index (Sivanadian and Smith, 1997).

The relative economic weights were lower in Strategies II and III relative to Strategy I by 21% and 15% (line A), 18% and 12% (line B) and 32% and 23% (line C), respectively (**Table 4**). These trends were due to the higher number of traits in Strategies II and III relative to Strategy I to accomplish the same selection goal. In Strategy II, DOSES had a weight similar to NBA in the maternal lines and a weight higher than growth traits in the paternal line. This result was driven by the higher economic value estimated. This situation may be undesirable, especially when the correlations of this trait with the growth traits are not completely elucidated. Using the four boar semen traits separately maintained the desirable initial configuration of the selection index.

Table 3. Average genetic gain of the sixteen genetic groups per year by selection strategy.

Traits[1]	Unit	Strategy		
		I	II	III
NBA	pigs/litter	0.013	0.013	0.015
LBW	kg	0.104	0.113	0.107
A21	kg	0.065	0.060	0.063
N21	pigs/litter	0.009	0.009	0.008
D113	days	-0.103	0.153	0.093
BF	mm	-0.287	-0.117	-0.213
FE	kg/kg	0.002	0.001	0.001
ADG	g	0.907	-1.270	0.893
LEAN	%	0.032	0.005	0.013
DOSES	doses		1.229	-
VOL	ml			2.060
CON	$x10^3/mm^3$			-0.477
MOT	%			0.023
ABN	%			0.013

[1]NBA = number born alive; LBW = litter birth weight; A21 = adjusted 21-day litter weight; N21 = number at 21 days; D113 = days for pig to 113.5 kg; BF = backfat; FE = feed efficiency; ADG = average daily gain; LEAN % = lean carcass, VOL = semen volume, CON = semen concentration, MOT = progressive motion of spermatozoa, ABN = abnormal spermatozoa, DOSES = number of semen doses.

In Strategy III, MOT and ABN had a higher relative economic weight than VOL and CON (**Table 4**). This finding was associated with the correlation and the estimated economic weights of these traits (**Tables 1** and **2**). The positive correlation of MOT with NBA, the trait that dominated the index, resulted in the higher relative economic weight of MOT. Although ABN was negatively correlated with NBA and MOT, the absolute values of ABN were the highest compared to the rest of the boar semen traits. This resulted in ABN and MOT having similar relative weights and higher weights than VOL and CON.

Conclusions

The estimated economic weights and relative economic values obtained in this study for the boar semen traits were without precedent. This study demonstrated the impact of including boar semen traits in selection strategies on the potential for genetic gains across maternal, growth and fertility traits. Furthermore, this study uncovered the relative economic weight of all traits under three selection strategies. The integration of four boar semen traits into the selection indices enabled higher genetic gains compared to the novel single indicator of fertility. Our results demonstrate that simultaneous selection for production, sow and boar fertility traits is possible without detrimental effects on the genetic gains for the maternal traits.

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Table 4. Relative economic weights (%) of the traits used in the selection indices of each strategy applied to the maternal (A and B) and paternal (C) nucleus lines with 2.33 semen collections per week.

Traits[1]	2.33 collections per week								
	Strategy I			Strategy II			Strategy III		
	A	B	C	A	B	C	A	B	C
NBA	29.38	36.83	0.46	23.26	30.46	0.31	25.11	32.44	0.35
LBW	0.98	1.23	0.02	0.78	1.02	0.01	0.84	1.08	0.01
A21	1.09	1.36	0.02	0.86	1.13	0.01	0.93	1.20	0.01
N21	13.06	16.37	0.21	10.34	13.54	0.14	11.16	14.42	0.16
D113	0.19	0.15	0.34	0.15	0.12	0.23	0.16	0.13	0.26
BF	23.64	18.83	42.29	18.72	15.57	28.77	20.21	16.58	32.43
FE	20.49	16.32	36.65	16.22	13.49	24.93	17.51	14.37	28.11
ADG	9.45	7.53	16.92	7.49	6.23	11.51	8.08	6.63	12.97
LEAN	1.73	1.38	3.10	1.37	1.14	2.11	1.48	1.22	2.38
DOSES				20.80	17.30	31.97	-	-	-
VOL							0.84	0.69	1.34
CON							0.47	0.39	0.76
MOT							7.31	6.00	11.74
ABN							5.90	4.84	9.47
Total	*100*	*100*	*100*	*100*	*100*	*100*	*100*	*100*	*100*

[1]see table 3.