Economic Breeding Objectives for Canadian Lamb

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ABSTRACT: New economic breeding objectives were developed for the Canadian Sheep Genetic Evaluation System based on major heavy lamb production systems. Each objective was developed from a profit function that modeled the influence of several traits on revenues and costs within a specified production system. Economic traits included live sale weight, carcass weight, carcass fat and muscle conformation, daily feed intake, number of lambs weaned, and lambing ease and interval. Standard quantitative genetics methodology was used to derive linear breeding objective equations for each system.
Keywords: Sheep; Selection index; Profit function

Introduction

The Canadian meat lamb industry is smaller than some others worldwide, but domestic demand well exceeds production, so it continues to expand. A diverse range of breeds and production systems exist across the country. These present unique opportunities and challenges for genetic improvement. Until recently, the Canadian Sheep Genetic Evaluation System (CSGES) published four selection indexes for lamb breeders. In the most recent versions, a basic Growth index included body weights at birth, 50d (weaning) and 100d. Terminal indexes added ultrasound-measured fat and loin depths. Maternal indexes added numbers of lambs born and weaned per litter. At the time the indexes were developed, very little information was available on economic influences of traits in the Canadian sheep industry. Therefore, index weightings were largely based on other indexes employed worldwide (Tosh and Wilton (2002, 2004)).

Since initial development, several modifications have been made to the indexes and new traits have been added to CSGES. With improving commercial data collection, development of economics-based indexes has become viable. Therefore, new studies were undertaken to develop economic breeding objectives and selection indexes for Canadian lamb breeders.

This paper describes development of the first economic breeding objectives for Canadian lamb production. Six profit functions were designed for terminal, maternal and self-replacing lines. Breeding objective equations were then derived. Methodology is illustrated with the breeding objective designed for self-replacing systems with graded carcass sales and accelerated lambing. Variations for the other five systems are discussed.

Materials and Methods

Production Models. Profit functions were built to describe six major intensive systems (Table 1). For crossbreeding, Terminal sire (T) systems produce rams, and Maternal (M) systems produce prolific ewes; the market lambs are F1 crosses. Self-replacing (SR) systems usually produce purebred ewes and market lambs. Systems were further defined for sales of live lambs or rail-graded carcasses, and annual or accelerated lambing (Table 1). All breeding objectives were designed for year-round sales of heavy lambs at a fixed age. Although farmers often aim to sell lambs at an optimum weight, commercial data revealed a wide range of weight and age endpoints. In an optimal system, selection for traits at a fixed weight endpoint is equivalent to selection at a fixed age endpoint (Wilton and Goddard (1996)).

Table 1. Summary of terminal sire (T), maternal (M) and self-replacing (SR) systems.

System	Mating	Production unit	Market lamb	Lambing freq.
T1	Cross	ram	F1 live	1/yr
T2	Cross	ram	F1 carcass	1/yr
M1	Cross	prolific ewe	F1 live	1/yr
M2	Cross	prolific ewe	F1 live	>1/yr
SR1	Pure	ewe	carcass	1/yr
SR2	Pure	ewe	carcass	>1/yr

For each system, a function was constructed where *Profit (P,* CAD*) per individual per year = Revenues - Costs*. Revenues (*R*) derived from sales of an individual's lambs. Number of lambs sold was the product of number of litters per year, which relates to lambing interval (Int, d), and number weaned per litter (N_w). Post-wean survival is typically very high, and so assumed to be 100%.

Live sale weight was assumed to be weight at 100d of age (Wt_{100}, kg). Lamb live sale price ($/kg) was modeled as a linear regression of market prices (Sept 2011-Aug 2012, OSMA) on live sale weights. Regression parameters were intercept α_l = 6.366 and coefficient β_l = -0.045 (p<0.0001 for all, R^2=0.3172).

For graded carcass sales, lambs were assumed slaughtered at 150d of age, based on commercial data. Meat sold was the product of carcass weight (Wt_C, kg), and yield. Yield was predicted from carcass fat cover at the GR site (F, mm) and muscle conformation (Cf, scored 1-5) as per Jones et al. (1996), with intercept α_y=0.7892, and regression coefficients β_{y1}=-0.0051 and β_{y2}=0.0125. Base carcass price was set at 8.86$/kg (June-Sept 2012 average, FPAMQ).

Price premium/discounts are applied according to heavy lambs grids, where optimum grid prices are achieved at F=7 to 12mm and Cf=5 (FPAMQ (2011)). Slaughter data was used to develop a prediction function to model these grids; regression parameters were intercept α_c=0.629, and coefficients β_{c1}=0.032, β_{c2}=0.103, β_{c3}=-0.001, β_{c4}=-0.008 and β_{c5}=-0.001 (p<0.0001 for all, R^2=0.943).

Costs (*C*) derived from an individual's own costs plus its lambs' costs. Lambing costs were a product of numbers of lambings per year and the cost associated with each. Lambing ease (LE) was defined as a categorical trait with the following probabilities of expression and prices: surgery/replacement p_S=2%, 150$; hard assist p_H=5%, 20$; easy assist p_E=10%, 10$; and unassisted p_U=83%, 0$. Prices for easy assist and hard assist were based on 15$/h labour. Where surgery would be required, price was based on 150$ for ewe replacement. LE was assumed to have an underlying normal distribution of potential for easy lambing with μ=0 and σ=1.

Estimates of daily feed intake and feed prices were based on total digestible nutrients (TDN) requirements (NRC, 1985; C. Wand, OMAF, pers. comm.). Feed price was calculated at 0.30$/kg based on corn at 90% TDN (corn=280$/t; also corresponds with moderate-quality hay=0.077$/kg at 55% TDN).

Ewe feed intake was the sum of intake during maintenance (non-reproductive), gestation, and lactation phases. Maintenance time was calculated as lambing interval – 147d gestation – 50d lactation. Daily Feed Intake of ewe in maintenance (DFI_E, kg) was based on ewe average mature body weight of 79kg. DFI during gestation and lactation were based on ewe weight and average number of lambs born per litter; these were converted to DFI_E scaling factors (δ_{gest}, δ_{lact}, Table 2). Other ewe costs were assumed to be negligible and fixed. Lamb DFI (DFI_L, kg) was defined to 50d of post-weaning. Other lamb costs, including tagging and health treatments, were assumed fixed at 5$/lamb.

Breeding Objectives. For each production model, a linear breeding objective (aggregate genotype) equation was derived. Economic values for each trait were calculated as the partial derivative of the profit function, calculated at commercial population means. Population means and variances (Table 2) were representative of major breeds used in such systems in Canada: Suffolk (terminal sire line flocks), Rideau Arcott (maternal line flocks), and Dorset (self-replacing flocks). Economic values for LE were calculated as per Quinton et al. (2010).

Results and Discussion

Profit function components for the SR2 system are shown below, with all variables as previously defined.

$$P_{ewe/yr} = R_{lambs} - C_{lambing} - C_{ewe\_feed} - C_{lambs}$$

$$R_{lambs} = \left\{ \begin{bmatrix} \frac{365}{Int} \cdot N_w \end{bmatrix} \times \begin{bmatrix} 8.86 Wt_C \left(\alpha_y + \beta_{y1} F + \beta_{y2} Cf \right) \\ \cdot \left(\alpha_c + \beta_{c1} F + \beta_{c2} Cf + \beta_{c3} F^2 + \beta_{c4} Cf^2 + \beta_{c5} F \circ Cf \right) \end{bmatrix} \right\}$$

$$C_{lambing} = \frac{365}{Int} \left[\left(150 p_S\right) + \left(20 p_H\right) + \left(10 p_E\right) + \left(0 p_U\right) \right]$$

$$\begin{aligned} C_{ewe\_feed} &= C_{ewe\_main} + C_{ewe\_gest} + C_{ewe\_lact} \\ &= 0.3 DFI_E \left[\left(Int - 197 \right) + 147 \delta_{gest} + 50 \delta_{lact} \right] \end{aligned}$$

$$C_{lambs} = \frac{365}{Int} N_w \left[0.30 DFI_L (50) + 5 \right]$$

Profit functions for the other five systems (not shown) were constructed in a similar manner, varying some traits and fixing variables as appropriate. For live sale and maternal systems, revenue functions were instead based on Wt_{100}, as previously described. For terminal sire systems, Int, N_w and DFI_E were fixed to population means. For annual lambing systems, Int was fixed to 365d.

The economic breeding objective (*H*) for SR2 was as follows, where v_i are economic values and g_i are genotypes for each trait *i*.

$$\begin{aligned} H_{SR2} &= \left\{ \begin{matrix} v_{Wt_C} g_{Wt_C} + v_F g_F + v_{Cf} g_{Cf} + v_{DFI_E} g_{DFI_E} \\ + v_{LE} g_{LE} + v_{DFI_L} g_{DFI_L} + v_{N_w} g_{N_w} + v_{Int} g_{Int} \end{matrix} \right\} \\ &= \left\{ \begin{matrix} 12.30 g_{Wt_C} - 2.76 g_F + 15.24 g_{Cf} - 127.31 g_{DFI_E} \\ + 11.66 g_{LE} - 26.50 g_{DFI_L} + 225.32 g_{N_w} - 1.02 g_{Int} \end{matrix} \right\} \end{aligned}$$

Table 2. Population means (μ), phenotypic standard deviations (σ_P) and heritabilities (h^2) of traits in terminal (T), maternal (M) and self-replacing (SR) breeding objectives[1].

Trait	μ T	μ M	μ SR	σ_P T	σ_P M	σ_P SR	h^2
Wt_{100}, kg	41.6	41.6		7.4	7.4		0.31
Wt_C, kg	23.1		24.2	2.0		2.0	0.31
DFI_E, kg		0.73	0.73	0.16	0.14	0.14	0.25
δ_{gest}		*1.35*	*1.29*				
δ_{lact}		*2.85*	*2.28*				
DFI_L, kg	1.10	1.10	1.04	0.26	0.26	0.24	0.25
F, mm	12.4		10.6	2.0		2.0	0.27
Cf, score	3.20		3.28	0.40		0.40	0.20
LE[2]	0.0	0.0	0.0	1.0	1.0	1.0	0.15
N_w		1.97	1.54	0.54	0.82	0.58	0.05
Int, d		303	318	68	63	73	0.04

[1] DFI_E scaling factors δ shown in italics below μ
[2] Underlying liability scale; category proportions in text

Table 3. Relative economic values[1] of traits in terminal (T), maternal (M) and self-replacing (SR) breeding objectives.

Trait	T1	T2	M1	M2	SR1	SR2
Wt_{100}	18.0		18.0	21.7		
Wt_C		12.8			11.9	13.7
DFI_E			-10.8	-9.5	-10.0	-9.0
DFI_L	-3.2	-3.2	-3.2	-3.9	-2.8	-3.2
F		-3.3			-2.1	-2.8
Cf		2.4			2.4	2.7
LE	3.9	3.9	3.9	4.7	3.9	4.5
N_w			30.1	36.3	19.2	29.2
Int				-19.0		-14.9

[1]Relative economic value = economic value × $\sigma_{genetic}$

Breeding objective equations for the other five systems (not shown) were constructed similarly. Table 3 presents relative economic values for each objective. As expected, objectives were: increased weights, carcass conformation score, lambing ease and litter size; and decreased feed intake, fat cover and lambing interval. Terminal objectives put primary emphasis on weight traits (50-72% of *H*) and secondary emphasis on DFI_L, F and LE (13-15% per trait). Maternal and SR objectives put primary emphasis on N_w (37-46%) and secondary emphasis on weight, Int and DFI_E (17-23% per trait).

These breeding objectives were built from current knowledge of market prices, population performances and genetic parameters. The economic and biological parameters applied were best estimates for medium-term stability, but some may need to be refined as new knowledge emerges. Further improvement could be made with more performance data recorded. For example, there is currently little information on lambing ease and objectives are based on general assumed values.

Comparison of these economic objectives with other published objectives or indexes worldwide is somewhat difficult due to different industry parameters and trait definitions. Canadian flocks are on average smaller and more intensively managed than in major exporting countries. Wool from meat breeds has little value in Canada and is considered a management cost instead of a revenue source. Resistance to parasites is of major concern in other countries, but economic and biological parameters are not well studied for Canadian conditions. These objectives were designed for breeders of heavy lambs for year-round marketing and may not be suitable for those specializing in small lamb production for seasonal markets.

The main distinction of these objectives compared with others is incorporation of feed intake. The objectives in this study should improve ewe and lamb feed efficiency by simultaneously selecting for faster growth and decreased intake. Feed intake is typically not included in selection indexes because it is difficult and expensive to measure. However, feed costs account for 60-80% of farm expenses (OSMA (2010)) and economic models and breeding objectives should include this trait. Direct multi-trait selection on commonly evaluated indicator traits such as growth and fat should have correlated responses to improve feed efficiency.

CSGES currently calculates multiple-trait BLUP genetic evaluations (EPDs) for thirteen lamb traits, but carcass traits, DFI and LE are not yet evaluated. Therefore, corresponding selection indexes that contain evaluated traits (birth and weaning weights, Wt_{100}, ultrasound fat and loin measures, survival, Int, N_w) are now being developed. Preliminary studies indicate that the new economic carcass indexes put greater relative weighting on fat and less on loin depth, because carcass fat has greater influence on profitability and a stronger relationship with ultrasound measures than conformation score. New traits survival and Int have a large proportion of emphasis in the new maternal and self-replacing indexes. New indexes also tend to put less emphasis on weaning weight and Wt_{100} than previous ones due to positive correlations with feed intake. Sensitivity analyses indicate that new indexes are fairly robust to minor changes in objective economic values.

Conclusion

New economic breeding objectives have been developed for Canadian terminal, maternal and self-replacing lamb systems aimed at year-round heavy lamb production. Corresponding selection indexes are now being developed.

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References

FAMPQ (2011). Agence de vente, agneau lourd, guide du producteur. Ver. 3.0 http://www.agneauduquebec.com

Jones, S. D. M., Robertson, W. M., Price, M. A., et al. (1996). *Can. J. Anim. Sci.* 76:49–53

OSMA (2010). Introduction to Sheep Production Manual. http://www.ontariosheep.org/ Accessed Feb 2014.

OSMA (2012). http://www.ontariosheep.org/ Accessed Sep 2012.

NRC (1985). Nutrient Requirements of Sheep. 6th ed. National Academies Press, Washington, DC.

Quinton, V. M., Wilton, J. W., and Robinson, J. A. (2010). Proc. 9th WCGALP. PP4–177

Tosh, J. J., and Wilton, J. W. (2002). *Can. J. Anim. Sci.* 82:591–593

Tosh, J. J., and Wilton, J. W. (2004). *Can. J. Anim. Sci.* 84:713–715

Wilton, J.W., and Goddard, M. E. (1996). *J. Anim. Sci.* 74:37–45