EFFECTS OF IMPORTING SEMEN OF HOLSTEIN, HOLSTEIN-FRIESIAN AND JERSEY BULLS ON THE FUTURE PROFITABILITY OF AN ARGENTINE DAIRY FARM

EFECTOS DE IMPORTAR SEMEN DE TOROS HOLSTEIN, HOLSTEIN-FRIESIAN Y JERSEY SOBRE LA RENTABILIDAD ECONÓMICA FUTURA DE UNA FINCA LECHERA ARGENTINA

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ADDITIONAL KEYWORDS

Crossbreeding. Genotype-environment interaction. Modelling.

PALABRAS CLAVE ADICIONALES

Cruzamientos. Interacción genotipo-ambiente. Modelización.

SUMMARY

Effects of mating strategies and payment systems on farm profit ($/ha) of an Argentine dairy herd were evaluated. The mating strategies were: upgrading to Holstein, upgrading to Holstein-Friesian, upgrading to Jersey and rotational crossbreeding Holstein-Friesian x Jersey using imported semen. Holstein bulls were selected for milk yield whereas Holstein-Friesian and Jersey bulls were selected on an economic index combining estimated breeding values for lactation yields of milk, fat and protein and mature cow body weight weighted by respective relative economic values.

Payment systems were milk volume, fat yield, protein yield, milk solids (fat plus protein) yield and multiple components based on fat, protein and volume. Phenotypic and economic performances for a period of 20 years were obtained with deterministic modelling. Phenotypic performance was predicted from the genetic merit of bulls and cows, and effects of breed, heterosis, age and genotype x environment interaction. Feed requirements per cow were estimated for maintenance, lactation, pregnancy, and growth of the replacements. Dry matter requirements were supplied by a ration composed of pasture (80 p.100), silage (10 p.100) and concentrate (10 p.100). Stocking rate was calculated by assuming 6000 kg of dry matter utilised annually per hectare. Productivity per hectare was calculated as performance per cow multiplied by stocking rate. Profit was calculated as the difference between income (milk and beef) and costs related to the number of cows and the land area farmed.

Upgrading the herd to Holstein for 20 years resulted in the heaviest cows with the highest per cow production of milk, fat and protein, highest feed requirements per cow, the lowest stocking rate, the lowest production of fat and protein per hectare and the highest production of milk per hectare. Upgrading to Jersey resulted in the lightest cows with the lowest per cow production of milk, fat and protein, lowest feed requirements per cow, consequently, the highest stocking rate, the highest production of fat per hectare, intermediate production of protein per hectare and the lowest production of milk per hectare.

Rotational Holstein-Friesian x Jersey crossbreeding resulted in similar production of fat and protein per hectare to upgrading to Jersey although this was achieved with a lower stocking rate.

Profit in the base year was calculated to be $103/ha. Upgrading to Holstein resulted in the highest profit ($322/ha) in year 20 if milk was paid on milk volume. Upgrading to Jersey resulted in the highest profit ($311/ha) in year 20 if milk was paid on fat yield. Rotational crossbreeding resulted in the highest profit in year 20 for all other payment systems. Results suggest that semen from bulls of foreign populations must be strategically used according to production and economic circumstances if profitability is to be maximised. Interactions between genotype and physical environment and between genotype and economic environment must be carefully considered. Rotational crossbreeding systems could increase profitability of Argentine dairy herds under the market conditions assumed in this analysis.

RESUMEN

Se evaluaron los efectos de diferentes estrategias de apareamiento y sistemas de pago de leche sobre la rentabilidad económica futura de una finca lechera argentina. Las estrategias de apareamiento fueron: cruzamiento absorbente a Holstein, cruzamiento absorbente a Holstein-Friesian, cruzamiento absorbente a Jersey y cruzamiento rotacional entre Holstein-Friesian x Jersey usando semen importado. Los toros Holstein, fueron seleccionados para alta producción de leche por lactancia, mientras que los toros Holstein-Friesian y Jersey, fueron seleccionados mediante un índice económico que combinó los méritos genéticos para producción de leche, grasa y proteína por lactancia y peso vivo de una vaca madura, ponderados por sus respectivos valores económicos. Los sistemas de pago fueron: rendimiento de leche, rendimiento de grasa, rendimiento de proteína, rendimiento de sólidos (grasa más proteína) y componentes múltiples, combinando rendimientos de grasa, proteína y volumen. Los respuestas fenotípicas y económicas por un periodo de 20 años, fueron obtenidas usando simulación determinística. Las respuestas fenotípicas esperadas fueron obtenidas considerando el mérito genético de los toros y vacas, los efectos de raza, heterosis, edad de la vaca e interacción entre genotipo y medio ambiente. Los requerimientos de alimento por vaca fueron estimados para mantenimiento, producción de leche, gestación y para el crecimiento de los reemplazos. Las necesidades de materia seca fueron cubiertas por una ración compuesta de pasto (80 p.100), ensilado (10 p.100) y concentrado (10 p.100). La carga animal fue calculada asumiendo que se disponía de 6000 kg de materia seca de pasto/ha. La producción de leche por hectárea fue calculada multiplicando la producción de leche por vaca por la carga animal. La rentabilidad económica fue calculada como la diferencia entre ingreso (venta de leche y animales) y costos relacionados con el número de vacas y el área de la finca destinada al pastoreo.

El cruzamiento absorbente a Holstein por un periodo de 20 años, dio lugar a las vacas más pesadas, con las más altas producciones de leche, grasa y proteína por lactancia, las más bajas cargas animales, las más bajas producciones de grasa y proteína por hectárea y la más alta producción de leche por hectárea. El cruzamiento absorbente a Jersey resultó en las vacas más livianas, con las más bajas producciones de leche, grasa y proteína por lactancia, los más bajos requerimientos de materia seca por vaca y, como consecuencia, la más alta carga de animales, la más alta producción por hectárea de grasa, una producción intermedia por hectárea de proteína y la más baja producción de leche por hectárea.

El cruzamiento rotacional entre Holstein-Friesian x Jersey, originó una producción de grasa y proteína por hectárea similar a la del cruzamiento absorbente a Jersey, pero con una carga de animales por hectárea más baja.

La rentabilidad económica de la finca en el año base fue de $103/ha. El cruzamiento absorbente a Holstein resultó en la rentabilidad más alta ($322/ha) en el año 20, cuando la leche fue pagada por rendimiento de leche. El cruzamiento absorbente a Jersey resultó en la rentabilidad más alta ($311/ha) en el año 20, cuando la leche fue pagada por rendimiento de grasa. El cruzamiento rotacional resultó en la más alta rentabilidad en el año 20, cuando la leche fue pagada por todos los otros sistemas de pago. Los resultados obtenidos en este estudio sugieren que el semen de toros de otras poblaciones, debe ser usado en una forma estratégica que esté de acuerdo con las condiciones ambientales y económicas, si el objetivo de la finca lechera es maximizar la rentabilidad económica. Las interacciones entre genotipo y medio ambiente climático y entre genotipo y medio ambiente económico, deben ser consideradas adecuadamente. Los sistemas de cruzamiento rotacional pueden incrementar la rentabilidad económica de las fincas argentinas bajo las condiciones analizadas en este estudio.

INTRODUCTION

A common practice in some Latin American countries is to introduce semen from dairy bulls sourced from other countries. The major risks of this strategy are the presence of genotype-environment interaction and ignorance of differences in economic and production circumstances. Interaction of genotype by environment is defined as the differential in the expression of the same animal genotype in different climates or management systems. This interaction can take two forms (Cromie *et al.*, 2000) causing either; (i) a scaling effect across environments with no change in ranking of genotypes, or (ii) a change in the actual ranking of genotypes across environments. The regression coefficient of daughter milk yield (expressed as a deviation from herd mean) on sire producing ability for milk is a measurement of the genotype by environment interaction caused by an scale effect, whereas the correlation between breeding values estimated in two environments measures the change in the ranking of the genotypes across environments. Regression coefficients of daughter milk yield on sire producing ability for milk of North American Holstein bulls have been reported between 0.16 to 0.66 in Mexico, Colombia, and Puerto Rico (Cienfuegos-Rivas *et al.*, 1999; Stanton *et al.*, 1991).

Breed improvement programs have been operated for decades in some countries, resulting in worthwhile genetic gains in milk yield and milk components. The selection schemes have been designed according to home country economic and production circumstances. If semen is used in other countries with different circumstances (e.g., payment system, feed costs and feed supply) there is likely a reduction in the expected economic responses. For example, Holmann *et al.* (1990) reported that average economic returns from investing in semen from American Holstein bulls in Colombia, Mexico and Venezuela were negative for most scenarios considered. The authors concluded that imported semen should be used strategically in situations of high conception rate and good environment for high milk response to sire selection.

Currently, there is world-wide uncertainty about future economic conditions, due to possible changes in systems of production and market needs. Selecting on the basis of present conditions may turn out to be inappropriate for future conditions, or to be less appropriate than expected (Gibson, 1989). For example, reduction in the price for milk, and the change in the payment system based on milk volume to payment based on concentrations of fat and protein, has occurred in the Argentine dairy industry and has resulted in renewed interest in lower cost systems of milk production based on rotational grazing systems with a 365-day calving interval and a concentrated calving pattern.

Changes in production systems and payment systems warrant review of the way that Argentine dairy farmers have produced herd replacements from bulls of high genetic merit for milk production. The objective of this paper was to investigate ways of producing herd replacements that result in the highest profit ($/ha) under different payment systems for milk.

MATERIAL AND METHODS

Farm model

A pastoral farm model developed by Lopez-Villalobos *et al.* (2000a) was used to evaluate the effect of payment systems and selection and crossbreeding strategies on the relative farm profitability ($/ha) of an average Argentine dairy farm. Productive parameters of the Argentine herd simulated were 4760 l milk, 166 kg fat, 150 kg protein, 520 kg body weight, 20 p.100 replacement rate. Average herd production was calculated from genetic yield levels, heterosis and age effects across 9 age classes for lactating cows.

***Table I.** Payment systems[1] ($/kg) devised from average SanCor milk.* (Sistemas de pago ($/kg) derivados a partir de la leche promedio de SanCor).

Single components				FPV		
VO	FO	PO	FPO	F	P	V
0.14	4.04	4.48	2.14	1.4	3.22	–0.0095

[1]F = yield of fat; P= yield of protein; V = volume of milk; VO = volume of milk only; FO = yield of fat only; PO = yield of protein only; FPO = yield of fat plus protein only; FPV = yields of fat and protein with a penalty for volume of milk.

The ration (based on dry matter) was composed of 80, 10 and 10 p.100 of pasture, silage and concentrate, respectively. All pasture was assumed to be produced on the farm with an average production of 8000 kg DM/ha/yr, 75 p.100 of pasture utilisation and 10 MJ of ME/kg DM. Silage and concentrate were brought to the farm with a cost of $0.06 and $0.14/kg DM. Contents of ME were assumed to be 10.5 and 13 MJ/kg DM.

The metabolisable energy requirements were derived using the Agricultural and Food Research Council (1993) guidelines for maintenance, growth, lactation and pregnancy of cows and for growth of the replacements. It was assumed that cows could at all times consume sufficient quantities to meet the specified energy demands.

Farm profitability was calculated as the difference between gross income (milk and beef) and farm production costs. Income from milk was calculated using some alternative payment systems. Payment systems were derived from standard milk containing 3.47 p.100 of fat and 3.13 p.100 of protein with a value of $0.14 per kg **(table I)**. The SanCor milk payment system is based on concentration of fat and protein. Milk with 0.1 p.100 of protein above or below 3.13 p.100 is worth 2.3 p.100 above or below the value of the standard milk. Similarly, milk with 0.1 p.100 of fat above or below 3.47 p.100 is worth 1 p.100 above or below the value of the standard milk. An equivalent multiple component payment system expressed as kg of fat, kg of protein and kg of milk (FPV) was derived from multiple regression. Values for fat (F), protein (P) and volume (V) were derived from the regression of the value of 100 kg milk, valued with the SanCor payment system, on kg of fat, kg of protein and litres of milk.

Average farm production costs per year were representative of the SanCor company (Departamento de Producción Primaria de SanCor Cooperativas Unidas Ltda.,1999). Direct expenses per cow were $193 and included: labour, animal health, breeding and

Table II. *Input variables and annual rates of genetic gains for the simulated foreign populations.* (Variables usadas y tasas anuales de ganancia genética de las poblaciones simuladas proveedoras del semen importado).

	Holstein	Holstein-Friesian	Jersey
Number of milking cows	10,000,000	1,746,778	490,324
Potential bull mothers	900,000	149,251	112,816
Percentage of milk cows in lactation 1 through 9	20.1; 17.5; 15.1; 12.6; 10.5; 8.6; 6.9; 5.2; 3.5		
Number of progeny-tested bulls per yr	1,106	157	44
Size of progeny group	85	85	75
Age of bulls at the end of progeny test	5	5	5
Maximum age of active sires, yr	8	8	8
Number of contract matings to produce a young bull	10	10	10
Number of bull fathers	10	3	3
Relative economic values of traits included in the selection objective			
Lactation yield of milk	1	–0.052	–0.052
Lactation yield of fat		0.540	0.540
Lactation yield of protein		4.040	4.040
cow mature body weight		–0.450	–0.450
Rates of genetic gain			
Milk, l/yr	136	28	23
Fat, kg/yr	2.1	1.4	1.3
Protein, kg/yr	2.3	1.9	1.6
Cow mature body weight, kg	1.8	0.3	0.3

Table III. *Breed and heterosis[1] effects.* (Efectos de raza y heterosis).

	Lactation yield			Body
	Milk (l)	Fat (k)	Protein (kg)	weight (kg)
Breed effects				
H	7500	270	240	620
HF	3940	178	140	494
J	3099	168	123	407
First cross heterosis (p.100)				
HF x J	3.9	4.5	4.0	1.7

[1]Heterosis effects are expressed as percentage of the average of the two parental breeds.
H= Holstein; HF= Holstein-Friesian; J= Jersey.

herd testing, farm dairy expenses, electricity and freight. Direct expenses and overheads per hectare were $408 and included: pasture renovation, fertiliser, weed and pest control, repairs and maintenance, vehicle expenses, administration, standing charges and depreciation. Additional costs (concentrates, labour, animal health and breeding) for rising 1-yr and 2-yr olds were $84 and $74 per animal, respectively.

Genetic Gain Model

Effect of continuous use of semen from foreign bulls in an Argentine herd on farm profitability was evaluated over 20 years using the models developed by Lopez-Villalobos *et al.* (2000b). Four mating strategies were simulated: upgrading to Holstein; upgrading to Holstein-Friesian; upgrading to Jersey; and two-breed rotational Holstein-Friesian x Jersey.

Daughter productive performance was predicted based on 1) the average estimated breeding value of sires and dams, 2) interaction between genotype and environment, 3) breed and heterosis effects, and 4) age effects.

Semen from elite bulls was imported to sire replacements. The imports were made every year with each new batch of foreign proven sire semen higher in genetic merit than the previous batch because of genetic gain achieved in the foreign population.

Rates of genetic gains for the three foreign populations are shown in **table II**. These rates were calculated using selection index theory from input variables shown in **table II** and acknowledge a higher rate of genetic gain achieved in the Holstein population.

Genetic parameters (heritabilities, and genetic and phenotypic correlations) were taken from Spelman and

Table IV. *Regression coefficients of productive performance of the replacements on the estimated transmitting abilities of Holstein-Friesian, Jersey and Holstein bulls when used in the Argentine herd.* (Coeficientes de regresión del comportamiento productivo de los reemplazos sobre los valores de cría de los toros Holstein-Friesian, Jersey y Holstein usados en el hato argentino).

	Bulls	
Trait	H-F and J	H
Cow mature body weight	1.00	0.90
Lactation milk yield	1.05	0.70
Lactation fat yield	1.05	0.70
Lactation protein yield	1.05	0.70

H= Holstein; HF= Holstein-Friesian; J= Jersey.

Table V. *Body weights, energy requirements, stocking rates, and production of milk and milk components per cow and per hectare for herd in the base year and year 20 after different mating strategies*[1]. (Peso vivo corporal, requerimientos de energía, cargas animales y producción de componentes de leche por vaca y por hectárea para el hato en el año base y año 20 después de seguir diferentes estrategias de apareamiento).

		Mating strategy for 20 years			
	Base	UPGHF	UPGJ	Rot_HFxJ	UPGH
Body weight, kg	520	488	417	464	573
Production per cow					
Milk, l/yr	4760	4494	3720	4319	6809
Fat, kg/yr	166	200	192	205	203
Protein, kg/yr	150	178	159	176	187
ME requirements per cow, MJ/yr	58,772	59,573	52,900	58,172	69,188
DM from pasture, kg/yr	4702	4766	4232	4654	5535
DM from silage, kg/yr	560	567	504	554	659
DM from concentrate, kg/yr	452	458	407	447	532
Stocking rate, cows/ha	1.28	1.26	1.42	1.29	1.08
Production per hectare					
Milk, L/yr	6075	5657	5274	5568	7381
Fat, kg/yr	212	252	273	265	220
Protein, kg/yr	191	224	226	227	203

[1]Mating strategies were: UPGHF = upgrading to Holstein-Friesian, UPGJ = upgrading to Jersey, Rot_HFxJ = Rotational crossbreeding using straightbred Holstein and Jersey bulls, and UPGH = upgrading to Holstein.

Garrick (1997) for the Holstein-Friesian and Jersey populations and from Dommerholt and Wilmink (1986) for the Holstein population. Phenotypic standard deviations were calculated assuming equal coefficients of variation for the populations exporting the bulls (13.2 p.100 for milk yield, 12.7 p.100 for fat yield, 11.9 p.100 for protein and 7.0 p.100 for cow mature body weight).

Breed and heterosis effects are shown in **table III**. Breed and heterosis effects for the Holstein-Friesian and Jersey populations were derived from results of genetic evaluation in New Zealand (as shown in Lopez-Villalobos *et al.,* 2000a). Breed effects for the Holstein population were 7500 l milk, 270 kg fat (3.6 p.100) and 178 kg protein (3.2 p.100).

Regression coefficients of productive performance of the replacements on estimated transmitting ability of bulls are shown in **table IV**. It was assumed that Holstein-Friesian and Jersey sires had been evaluated based on the productive performance of their daughters under grazing conditions with no use of concentrates. Therefore, productive performance of the daughters of Holstein-Friesian and Jersey

***Table VI.** Incomes and costs per cow and per hectare for the herd in the base year and year 20 after different mating strategies[1] using different payment systems[2].* (Ingresos y costos por vaca y por hectárea para el hato en el año base y año 20 después de seguir diferentes estrategias de apareamiento y usando diferentes sistemas de pago por leche).

		Mating strategy for 20 years			
	Base	UPGHF	UPGJ	Rot_HFxJ	UPGH
Incomes and costs per cow					
Beef income, $/yr	56	53	45	50	62
Total costs, $/yr	646	650	602	640	718
VO payment					
Milk income, $/yr	666	629	521	605	953
Net income, $/yr	77	32	–37	15	29
FO payment					
Milk income, $/yr	670	808	777	828	818
Net income, $/yr	81	211	220	239	16
PO payment					
Milk income, $/yr	669	796	713	789	836
Net income, $/yr	80	198	156	199	180
FPO payment					
Milk income, $/yr	670	802	747	809	827
Net income, $/yr	80	205	189	220	170
FPV payment					
Milk income, $/yr	670	811	748	815	822
Net income, $/yr	80	214	191	225	166
Incomes and costs per hectare					
Beef income, $/yr	72	67	64	65	67
Total costs, $/yr	824	818	854	823	779
VO payment					
Milk income, $/yr	850	792	739	780	1034
Net income, $/yr	98	40	-52	20	322
FO payment					
Milk income, $/yr	855	1018	1101	1068	887
Net income, $/yr	103	266	311	308	176
PO payment					
Milk income, $/yr	854	1001	1011	1017	906
Net income, $/yr	102	250	221	257	195
FPO payment					
Milk income, $/yr	855	1010	1058	1043	896
Net income, $/yr	103	258	269	284	185
FPV payment					
Milk income, $/yr	855	1021	1061	1050	891
Net income, $/yr	103	269	271	290	180

[1]Mating strategies were: UPGHF = upgrading to Holstein-Friesian, UPGJ = upgrading to Jersey, Rot_HFxJ = Rotational crossbreeding using straightbred Holstein and Jersey bulls, and UPGH = upgrading to Holstein.
[2]Payment systems were VO = volume of milk only, FO = yield of fat only, PO = yield of protein only, FPO = yield of fat plus protein only, and FPV = yields of fat and protein with a penalty for volume of milk.

bulls may be higher (5 p.100 for milk, fat and protein) when exploited in the Argentine herd because 20 p.100 of the dry matter was supplied from concentrates and silage.

Merits of Holstein bulls were estimated based on the productive performance of their progeny under indoor conditions using higher amounts of concentrate than the Argentine herd. Therefore, regression of performances of the daughters of Holstein bulls in the Argentine herd were assumed to be 70 p.100 of the expected performance for milk traits and 90 p.100 for mature cow body weight. Studies show that cows sired by New Zealand Holstein-Friesian bulls and born, reared and milked in Canada produced between 70 and 100 p.100 more milk, fat and protein than their half sisters born, reared and milked in New Zealand (Holmes, 1995). Several studies (Cienfuegos-Rivas *et al.,* 1999; Mpofu *et al.*, 1993; Stanton *et al.*, 1991) report that cows sired by American Holstein bulls and born, reared and milked in poor environments for milk production produced between 16 to 66 p.100 less that their half sisters born, reared and milked under American conditions.

The magnitude of the genotype-environment interaction of Holstein, Holstein-Friesian and Jersey under Argentine conditions has not been reported. Further studies are required.

RESULTS

Table V shows the effects of mating strategies on body weights, energy requirements, stocking rates and production of milk per cow and per hectare for the Argentine herd. Upgrading the herd to Holstein resulted in the heaviest cows with the highest production of milk, fat and protein and feed requirements per cow. This strategy resulted in the lowest stocking rate, the lowest production of fat and protein per hectare and the highest production of milk per hectare.

Divergent effects to upgrading to Holstein were caused by upgrading to Jersey. Upgrading to Jersey resulted in the lightest cows with the lowest production of milk, fat and protein and feed requirements per cow, consequently, the highest stocking rate, the highest production of fat per hectare and the lowest production of milk per hectare.

Rotational Holstein-Friesian x Jersey crossbreeding resulted in similar productions of fat and protein per hectare to upgrading to Jersey, but with lower stocking rate because of heavier body weight of cows.

Table VI shows the effects of mating strategies on incomes and costs per cow and per hectare. Upgrading to Jersey reduced the beef income per cow whereas upgrading to Holstein increased this income.

Upgrading to Jersey resulted in the lowest costs per cow and the highest costs per hectare. On the contrary, upgrading to Holstein resulted in the highest costs per cow and the lowest costs per hectare.

Payment systems for milk had a large influence on milk income and net income per cow and per hectare. Upgrading the herd towards Holstein resulted in the highest net income per cow and per hectare when payment for milk was entirely based on milk volume. Upgrading to Jersey was the mating strategy that resulted in the highest net income per hectare for the payment based on fat yield. For all other payments systems, Holstein-Friesian x Jersey crossbreeding resulted in the highest net income per hectare.

DISCUSSION

Studies (Holmann *et al.*, 1990; Montaldo *et al.*, 1994; Mpofu *et al.*, 1993) have evaluated the economic returns from investing in semen from American Holstein bulls for use in other countries. These studies concluded that imported semen should be used strategically in situations of high conception rate and good environment (feeding and management) for high milk response to sire selection and low price of imported semen. However, none of these studies have evaluated the economic effects when there are differences in the payment for milk and differences in selection objectives. Results from this study suggest that use of semen from foreign bulls should be carefully planned to meet future payment systems determined by the market situations.

In many countries milk production has been based on straightbred cows mainly from the Holstein breed. For several decades the selection objective was basically the increase of milk yield as the payment system for milk was primarily based on milk volume. Continuous (or sometimes abrupt) reduction in the price of milk and changes in the payment system cause changes in the selection objective and the breed of the cows. In New Zealand, Jersey was the dominant breed group in the 1960s and currently Holstein-Friesian is the dominant breed group with a significant proportion (18 p.100) of crossbred Holstein-Friesian x Jersey cows. Results from the present study show that Argentine dairy farmers have the opportunity to choose breed sources and mating strategies that result in increased farm profit according to the present and future production and economic circumstances. If payment for milk is based on milk solids in future, then it is unlikely that continued use of Holstein semen will result in maximum profit for Argentine dairy farmers.

Lopez-Villalobos *et al.* (2000a) showed that for New Zealand conditions crossbreeding strategies can be used to increase the profitability of dairy farmers. Results from this study confirm that crossbreeding systems using semen from bulls of high genetic merit for farm profit (not only milk volume) are strategies that can increase the profitability of Argentine dairy farmers for present and future payment systems.

Possible effects of selection for milk production on reproductive performance and disease incidence were not considered in the present study. There is evidence for declining survival and reproductive performance of Holstein cattle in New Zealand (Burton *et al.*, 1999), The United States (Butler and Smith, 1989), Scotland (Pryce *et al.*, 1999) and Ireland (Dillon and Buckley, 1998) as milk production per cow increases. If these effects were accounted for, the benefits of upgrading to Holstein might be eroded relative to the calculated values in this study.

On the other hand effects of heterosis for fertility and survival on farm profit were not considered. Values of first-cross Holstein-Friesian x Jersey heterosis for longevity are about 222 days (B. L. Harris, Livestock Improvement, personal communication). This means that crossbred cows have better abilities (production, health and fertility) to avoid culling. Accounting for these effects would increase the profitability calculated for the rotational Holstein-Friesian x Jersey strategy.

The present study evaluated the profitability of introducing semen of bulls from other populations differing in selection objectives to the importing herd. It was shown that payment systems have a large effect on the economic responses of the mating strategies.

This is a form of genotype-economic environment interaction. The genotypes do not rank the same across all payment systems. Upgrading to Holstein might be the best strategy if milk were paid on volume and upgrading to Jersey might be the best strategy if milk were paid on fat yield.

Some countries have sophisticated breeding designs to produce replacements for future market conditions. A further study is required to evaluate the economic consequences of a local breeding scheme for the Argentine dairy industry that incorporates the use of customised selection indexes.

CONCLUSIONS

Results from this study show that semen of bulls from other populations and breeds must be used strategically according to the production and economic circumstances of the importing country. Rotational crossbreeding using semen from bulls of high genetic merit for farm profit might be used to produce cows suitable for payment systems based on milk solids or multiple components. This mating strategy would allow future changes in the production system and market conditions to be covered more efficiently than by a strategy with only one breed.

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REFERENCES

Agricultural and Food Research Council. 1993. Energy and Protein Requirements of Ruminants. An Advisory Manual Prepared by the AFRC Technical Committee on Response to Nutrients. CAB International, Wallingford, United Kingdom.

Butler, W.R. and R.D. Smith. 1989. Interrelationships between energy balance and postpartum reproductive function in dairy cattle. *J. Dairy Sci.,* 72: 767-783.

Burton, L.J., B.L. Harris, A.M. Winkelman and Z.Z. Xu. 1999. Reproductive performance and genetic improvement of fertility in dairy cattle. *Dairy farming Annual, Massey University,* 51: 59-67.

Cienfuegos-Rivas, E.G., P.A. Oltenacu, R.W. Blake, S.J. Schwager, H. Castillo-Juarez and F.J. Ruiz. 1999. Interaction between milk yield of Holstein cows in Mexico and the United States. *J. Dairy Sci.,* 82: 2218-2223.

Cromie, A. R., D. L. Kelleher and F. J. Gordon. 2000. The impact of dairying environment on the response to increase in genetic merit in dairy herds. In: 72nd Annual Report 1998-1999. pp: 49-56. Agricultural Research Institute of Northern Ireland.

Departamento de Producción Primaria de SanCor Cooperativas Unidas Ltda. 1999. Monitoreo del desempeño productivo, económico, financiero y patrimonial de las empresas agropecuarias del sistema SanCor, año 1998. SanCor Cooperativas Unidas Ltda., Sunchales, Santa Fe, Argentina.

Dillon, P. and F. Buckley. 1998. Effects of genetic merit and feeding on spring calving dairy cows. *Proc. Ruakura Farmers' Conference,* 50: 50-56.

Dommerholt, J. and J.B.M. Wilmink. 1986. Optimal selection responses under varying milk prices and margins for milk production. *Livest. Prod. Sci.,* 14: 109-121.

Gibson, J.P. 1989. The effect of pricing systems, economic weight, and population parameters on economic response to selection on milk components. *J. Dairy Sci.,* 72: 3314-3326.

Holmann, F.J., R.W. Blake, R. Milligan, R. Barker, P.A. Oltenacu and M.V. Hann. 1990. Economic returns from United States artificial insemination sires in Holstein herds in Colombia, Mexico and Venezuela. *J. Dairy Sc.,* 73: 2179-2189.

Holmes, C.W. 1995. Genotype x environment interactions in dairy cattle: a New Zealand perspective. In: T.L.J. Lawrence, F.J. Gordon, F.J. and A. Carson (Eds.) Breeding and feeding the high genetic merit dairy cow pp: 51-58. Occasional Publication Nº 19 of the British Society of Animal Science.

Lopez-Villalobos, N., D.J. Garrick, C.W. Holmes, H.T. Blair and R.J. Spelman. 2000a. Profitabilities of some mating systems for dairy herds in New Zealand. *J. Dairy Sci.,* 83: 144-153.

Lopez-Villalobos, N., D.J. Garrick, H.T. Blair and C.W. Holmes. 2000b. Possible effects of 25 years of selection and crossbreeding on the genetic merit and productivity of New Zealand dairy cattle. *J. Dairy Sci.,* 83: 154-163.

Montaldo, H., B. Mendoza, H. Castro and J.M. Berruecos. 1994. Economic and genetic evaluation of breeding strategies for the Mexican Holstein population. *Proc. 5th World Cong. Genet. Appl. Livest. Prod. Guelph, Ontario, Canada,* 17: 54-56.

Mpofu, N., C. Smith, W. Van Vuuren and E.B. Burnside. 1993. Breeding strategies for genetic improvement of dairy cattle in Zimbabwe. 2. Economic evaluation. *J. Dairy Sci.,* 76: 1173-1181.

Pryce, J.E., B.L. Nielsen, R.F. Veerkamp and G. Simm. 1999. Genotype and feeding system effects and interactions for health and fertility traits in dairy cattle. *Livest. Prod. Sci.,* 57: 193-201.

Spelman, R.J. and D.J. Garrick. 1997. Effect of live weight and differing economic values on responses to selection for milk fat, protein, volume, and live weight. *J. Dairy Sci.,* 80: 2557-2562.

Stanton, T.L., R.W. Blake, R.L. Quaas and L.D. Van Vleck. 1991. Response to selection of United States Holstein sires in Latin America. *J. Dairy Sci.,* 74: 651-664.

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