ECONOMIC EVALUATION OF NEW TECHNOLOGY : THE CASE OF THE MILK GROWTH HORMONE BOVINE SOMATOTROPIN

J.A. du Plessis
Centre for Farm Management, University of the Free State, Bloemfontein

P.J. Potgieter
Department of Agricultural Economics, University of the Free State, Bloemfontein

The purpose of this paper is to discuss development and use of procedures to evaluate application of Bovine Somatotropin (BST) with respect to profitability at farm level. BST remains a controversial product and uncertainty surrounding its appropriateness as technology is increased by the fact that no local study in connection with its profitability has been conducted previously. On-farm response trials at three representative case study sites and a personal telephonic survey conducted amongst existing users of BST provided a valuable basis to develop and apply a management simulation model. The model and procedures of analysis are flexible and could be applied to other problems of dairy farm management. Results indicated that, given the conditions of research, utilisation of BST proved to be profitable. BST has the capability to improve profitability of certain dairy businesses. The critical factors in determining profitability of BST utilisation, apart from management, are the milk price, response to BST as well as BST and feed cost. Milk production quotas may have a negative effect on profitability of BST.

1. INTRODUCTION

The purpose of this paper is to discuss development and use of procedures to evaluate application of Bovine Somatotropin (BST) with respect to profitability at farm level. Supplemental application of synthetically produced BST has the ability to increase milk production in dairy herds. Although BST has been adopted by some farmers in South Africa and abroad since 1994, it remains a controversial product. Commercial utilisation has not yet been approved in the European Union and in South Africa some milk buyers have publicly voiced strong objections against BST, while others are in favor of it. Also, economic and management implications of BST utilisation have not previously been studied under South African conditions, causing uncertainty regarding its appropriateness as technology to enhance profitability.

Section 2 explains the method of research, followed by results and conclusions in Section 3 and an epilogue in Section 4.

2. METHOD OF RESEARCH

Research consisted of three parts, of which details may be obtained from Du Plessis (1996). *Firstly*, a personal telephonic survey was conducted amongst existing users of BST in order to collect data to be used in economic analysis, as well as to scrutinize management implications of BST utilisation in practice. *Secondly*, on-farm BST response trials were performed at three case study sites, the purpose of which was to determine increase in milk production as a result of BST application under specific farming conditions and also to gather data for economic analysis. *Thirdly*, an economic and management simulation model was developed and used to examine the impact of BST on milk production, feed consumption and profitability of dairy enterprises under conditions of which the research was conducted.

The research was limited to specific conditions. Geographically it was restricted to the Free State province, and then also to farmers who adhere to above average management practices and produce relatively high milk yields[1] (although this category of farmers are in minority, they are responsible for the largest share of the province's milk production (Van Rooyen, 1994)). The research setting was chosen in accordance with stipulations of BST manufacturers, who recommend that BST only be used under conditions of sound management that are conducive to high milk yields. Although care must always be taken when attempting extrapolation beyond limits of research, it is believed that some results, and particularly procedures of analysis, may have wider application.

2.1 Personal survey

The exact amount of farmers that make use of BST in the Free State is unknown, but 15 names were received from the producers of BST. Telephonic interviews were conducted with ten of these farmers. This involved designing of a questionnaire, scheduling of appointments and execution of interviews. Average interview time amounted to 30 minutes and quality were such that results could be based on data of all interviewed.

The questionnaire consisted of two parts, the first dealt with biographic data and background information concerning farming operations (such as herd composition and reproduction parameters), while the second part covered questions related specifically to BST utilisation. In particular, data about the nature of BST application, change in feeding required because of BST, milk yield response of BST, influence on reproduction and animal health as well as advantages and disadvantages of BST perceived by respondents were collected. The questionnaire is contained in Du Plessis (1996, Annex E).

2.2 Case studies

Farming businesses that took part in Free State Master Dairy Farmer competition and in the official milk recording scheme, were considered to serve as case studies. Precondition were that they had accurate data available and conformed to conditions conducive to BST application (above average management with no apparent restrictions on feeding, animal health and milking practices). The three businesses selected were situated in the districts of Bloemfontein (central Free State), Hertzogville (northern Free State) and

Bethlehem (eastern Free State). Two of the farmers farmed with Holstein animals and one with Ayrshires. None of the farmers applied BST previously. Herd size varied between 133 and 56 cows in milk, average milk yield between 7 734 and 8 920 kilograms per cow over 300 days and inter calving period between 396 and 423 days. All three made use of total mixed rations with four different feeding groups, one being cows in first lactation and the others based on yield differences amongst second and later lactating cows. Rations were fed on *ad lib* basis, so that feed intake could increase when milk production increased. Cows were moved to the next feeding group when milk yield increased above a certain level, so that more concentrated rations in terms of energy and protein were available with higher levels of production.

Feeding practices were particularly important determinants in case study selection, because feeding requirements increase when milk production increases as a result of BST application. According to Peel and Bauman (1987), BST treated cows compare to genetically superior animals of similar production levels, while genetic differences are mainly accounted for through feed intake and regulation of nutrients. As a result, a vital part of the case study research comprised analysis of individual feed components, ration composition and intake levels, to confirm that feeding were according to NRC (1988) recommendations. Annex B of Du Plessis (1996) contains details of all three aspects for each case study, where it was shown that feeding practices were in accordance with NRC standards.

BST response trials at each case study site consisted of selecting control and treatment groups, BST treatment of the latter, recording of milk yields and processing of results. The first two aspects receive further attention. In order to select control and treatment groups, pregnant cows in health, going into second or higher lactation with condition scoring at least 2,5 (Wildman et.al, 1982) and no visual deficiencies to udders or legs, were selected. These criteria correspond to recommendations made by manufacturers of BST (Twigge, 1994). There were proceeded to divide selected cows into two groups with comparable age, production potential and days in milk, after which a treatment group were randomly chosen. Treatment groups were treated four times (every 14 days) with *Lactatropin*™ over a period of eight weeks, while detailed records were noted. Apart from BST application, animals of both groups were treated according to normal farming practices.

2.3 Model development and procedures of profitability analysis

Although the model was primarily used to determine the influence of BST on decision variables, it was developed to be flexible and could be used for a wide range of economic analysis. It may be described as a functional, time step dynamic, Monte Carlo simulation model that may either be operated on deterministic or stochastic basis[2]. The model was developed on spreadsheet and stochastic appliance involves risk analysis with aid of @Risk add-in. Input to the model include initial herd composition and herd flow parameters (such as mortality and conception rates), feed ration composition, feed intake, group composition and production level of cows, BST response, calendar (days per month), purchase price and quantity of production inputs, selling price of animals and milk selling price. Output include herd flow (change of herd composition on monthly basis as well as determining of events such as artificial insemination and culling), monthly milk production and feed consumption, monthly enterprise budgets, annual enterprise budget, annual cash flow budget as well as financial ratio and diagnostic analysis. Ratio analysis is based on feed cost, allocable production cost, cash flow and profitability ratios. When risk analysis is required, probability distributions of stochastic input variables and correlation between probability distributions are essential. Output of risk analysis include one and two way sensitivity analysis, break even analysis, graphic and tabular presentation of cumulative probability distributions of decision variables with accompanying descriptive statistical measures (such as expected value, median value, minimum and maximum value, range, standard deviation, coefficient of variation and probability of negative outcomes). A comprehensive description of the model and process of model construction, may be found in Du Plessis (1996, Chapter 3 and Annex A).

In short, procedures of analysis amounted to (I) determining expected values, as well as upper and lower limits, of input variables[3], (ii) using expected values to study deterministic outcomes to develop insight into the structure of the issue at hand, (iii) performing sensitivity analysis through toggling values of input variables between limits and constructing of tornado diagrams (see Clemen, 1991) to develop insight into relationships and relative importance of variables, (iv) identifying critical input variables, (v) obtaining additional information about critical input variables to narrow the range between expected lower and upper limits, (vi) repeating of deterministic analysis and performing of two way sensitivity and break even analysis to gain more insight into influence of critical variables (vii) doing risk analysis (Monte Carlo simulation) after critical input variables had been limited in numbers as far as possible and probability distributions as well as dependency relationships of critical input variables studied extensively. In applying this procedure, the following points of departure were important:

- The process rests primarily on work by Philips (1982 & 1984), Hertz and Thomas (1983 & 1984) and Clemen (1991). Philips (1982 & 1984) contributed the concept of *"requisite modelling"*, which stated that the purpose of modelling aids is to incorporate necessary decision elements until a sound basis for decision making exists. Hertz and Thomas (1983 & 1984) demonstrated the power of practical risk analysis as developed by Hertz (1964). Clemen (1991) described an up to date framework for analysing and solving problems.

- The process is iterative and *stops* once a *requisite* basis exists to address the issue at hand.

- One must avoid the common inclination to neglect the earlier steps (specifically the first one) and to pursue to right away towards stochastic simulation.

- Upper and lower limits of variables should ideally provide a basis for sensitivity analysis. Use of 10 or 20 percent intervals around expected values instead, makes sensitivity analysis worth much less.

- The detrimental effects of risk analysis by *"brute force"* are beyond speculation. In other words selecting too many variables to be stochastic, not paying sufficient attention to probability distributions, haphazard use of normal/triangular/uniform distributions and to ignore dependency between variables, will do more harm than good.

Analysis was extended to study the effect of milk production quotas. Six strategies, reflecting combinations of BST application levels and sale of productive dairy cows, were evaluated under different quota levels (Du Plessis, 1996: 73-78).

3. RESULTS AND CONCLUSIONS

3.1 Most important findings revealed by survey

Nine of the ten respondents farmed with Holsteins, while one farmed with Ayrshires. Herd size varied between 55 and 400 cows in milk (average 186), yield between 6 300 and 11 000 kilogram milk per cow over 300 days (average 8 000) and inter calving period between 372 and 430 days (average 400).

With regard to *feeding*, all the respondents employed total mixed rations as feeding system and they all emphasised quality of roughage and balanced rations as preconditions for successful milk production. Nine respondents had more than one feeding group, while one fed the same ration to all of his cows. All of the respondents said that feeding requirements of BST treated cows were similar as that of untreated cows on the same level of milk production. This is in harmony with findings of Chalupa and Galligan (1989).

With regard to *application* of BST, it was concluded that respondents generally adhered to recommendations of manufacturers of BST.

With regard to *animal health* and *reproduction*, seven respondents indicated that BST had no influence on health. Three indicated that BST treated animals experienced a slight tendency to be more prone to disease, but no more than untreated animals on similar production levels. According to all respondents, inter calving period depends on timing of application - when BST is applied after pregnancy, no influence were experienced apart from the fact that inter calving period of treated cows compared with those of untreated cows on similar production levels. These results corresponds with findings of Bauman (1992) and Phillips (1982).

With regard to *response* in milk production due to BST, average increase in yield per cow as indicated by the respondents amounted to 5,30 kilograms per application period with a standard deviation of 1,00 kilogram. Eight respondents said that a small number of cows (less than five percent) do not react well to treatment in terms of milk response.

The most important *disadvantage* of BST usage, was high cost (including expensiveness of Lactatropin™, increased labour required to treat animals and increased claims on management time) as stated by seven respondents. A further disadvantage noted by three respondents, was that response in yield was unstable from day to day (although it was stable over application and lactation periods). The most important *benefit* of BST is, according to all of the respondents, that it may lead to higher profitability.

3.2 Milk yield response obtained in on-farm trials

Table 1 shows average BST response per cow, standard deviation and 95% confidence intervals per two weekly application period of the respective trial groups.

Average response were calculated through employing the method used by Palmer (1989), which take account of initial differences in milk production between trial and control groups. Results were fairly stable between cases, where average marginal increase in milk production per cow as a result of BST application, varied between 4,29 and 6,05 kilogram milk per application period. In all three cases, application of BST lead to highly significant ($P < 0,01$) increases in milk yield. These results compare favourably with local (Palmer, 1989) and overseas (Hartnell, 1993) research findings.

3.3 Profitability of BST utilisation

Table 2 shows that use of BST enhanced profitability as well as cash flow in all three cases. This was due to improved efficiency of milk production as reflected in lower production cost relative to gross income and, in particular, lower feed cost relative to gross income. Feed cost is the single most important cost item in dairy production. According to Bauman (1992), BST usage should lead to improved feed utilisation, because a smaller proportion of nutrients is employed to support maintenance of cows and relative more nutrients are available for milk production.

Sensitivity analysis revealed that profitability of BST use was most notably influenced by (I) the price of milk, followed by (ii) response in milk yield due to BST treatment, (iii) cost of BST itself and (iv) cost of additional feed needed to support increased milk

Table 1: Average increase in average milk production as a result of BST application*

	Case A	Case B	Case C
Average	4,29	6,05	5,28
Standard deviation	1,57	1,73	1,60
- 95% interval	3,87	5,59	4,85
+ 95% interval	4,71	6,52	5,71

* Average kilogram milk per cow per day over a two weekly application period

Table 2: Financial ratio analysis of BST utilisation

	Case A	Case B	Case C
Feed cost as % of gross income:			
Without BST	67,77%	58,00%	68,89%
With BST	65,40%	56,11%	66,37%
Production cost as % of gross income:			
Without BST	81,82%	79,67%	80,04%
With BST	80,55%	78,39%	78,25%
Profitability ratio:*			
Without BST	21,20%	20,33%	19,96%
With BST	23,95%	21,61%	21,75%
Cash inflow as % of cash outflow:			
Without BST	114%	114%	126%
With BST	117%	117%	129%

* Gross margin as percentage of total capital employed in dairy enterprise

production as a consequence of BST application. It furthermore indicated that within the context of research, chances that use of BST would not be profitable, were insignificant. Break even points for all four of these critical variables were comfortably outside predetermined minimum/maximum limits (break even was defined to be the point where profitability with BST treatment equalled profitability in absence of BST).

Also, even when the price of milk and response milk yield were simultaneously pinned at their minimum values, while cost of BST and feed were set to their maximum values, use of BST still lead to improved profitability. This means that sensitivity analysis indicated that no further risk analysis was needed to investigate profitability of BST under circumstances of research. However, Monte Carlo simulation analysis was performed by Du Plessis (1996) to illustrate capabilities of the model. In doing this, values of the four critical values were derived from probability distributions, while other variables were fixed at expected values.

3.4 Impact of milk production quotas on profitability of BST utilisation

It was found that BST utilisation was profitable in situations where quotas were introduced, albeit less profitable than in situations where no quotas applied. This result corresponds with findings of Giesen, Oskam and Berentsen (1989). Optimum management strategies in view of quotas depended on the specific (especially cash flow) situation of business, time period of quota and choice indicator (for example profitability versus cash flow). In general, the most profitable strategy was to manipulate BST and sale of lactating cows in such a way that milk production approached the upper limits of quota.

4. EPILOGUE

A computer spreadsheet model was developed and used to evaluate profitability of BST use under specific local conditions. On-farm response trials at three representative case study sites and a personal telephonic survey conducted amongst existing users of BST provided a valuable basis to develop and apply the model. The model and procedures of analysis are flexible and could be applied to other problems of dairy farm management. Results indicated that, given the conditions of research, utilisation of BST proved to be profitable. One may conclude that BST has the capability to improve profitability of certain dairy businesses. The critical factors in determining profitability of BST, apart from management, are the milk price, response to BST as well as BST and feed cost. Milk production quotas may have a negative effect on profitability of BST. Results of this study correspond in general with prominent overseas research findings.

NOTES

1. It is recognised that obtaining high yields is not necessarily synonymous to good management.

2. Functional as opposed to and typically less complicated than mechanistic (Ritchie, 1989); dynamic as opposed to static, because effect of time is incorporated (Marsh, 1986), time step as opposed to event step, because occurrences follow a chronological time sequence (Dent & Blackie, 1979); simulation because it emulates behaviour of a system to address problems that are not prone to be solved by direct experimentation (Yonkers, 1989, Law & Kelton, 1990) and finally Monte Carlo simulation because outcomes of variables are derived randomly from probability distributions (Hertz, 1964).

3. The survey and case studies provided valuable input to this process, but there was also drawn from an extensive body of literature that exists about the topic; see Du Plessis (1996, Chapter 2).

REFERENCES

BAUMAN, D.E. (1992). Bovine Somatotropin: Review of an emerging animal technology. Journal of Dairy Science, Vol. 75:3432.

CHALUPA, W. & GALLIGAN, D.T. (1989) . Nutritional implications of somatotropin for lactating cows. Journal of Dairy Science, Vol. 72:2510

CLEMEN, R.T. (1991). Making hard decisions: An introduction to decision analysis. PWS-KENT Publishing Company, 20 Park Plaza, Boston, MA.

DENT, J.B. & BLACKIE, M.J. (1979) . Systems simulation in agriculture. Applied Science Publishers

Ltd, Essex, England.

DU PLESSIS, J.A. (1996). Ekonomiese en bestuursimplikasies op plaasvlak met die gebruik van die groeihormoon Bovine Somatotropin (BST) in die Vrystaat. Unpublished M.Sc.(Agric) dissertation. University of the Orange Free State, Bloemfontein.

GIESEN, G.W.J., OSKAM, A.J. & BERENTSEN, P.B.M. (1989) . Expected economic effects of BST in the Netherlands. Agricultural Economics, Vol. 3:231 - 248.

HARTNELL, G.F., FRANSON, S.E., BAUMAN, D.E., HEAD, H.H., HUBER, J.T., LAMB, R.C., MADSEN, K.S., COLE, W.J., & HINTZ, R.L. (1991). Evaluation of sometribove in a prolonged-release system in lactating dairy cows: production responses. Journal of Dairy Science, Vol. 74:2645.

HERTZ, D.B. (1964). Risk analysis in capital investment. Harvard Business Review. Reprinted in Harvard Business Review, September-October 1979, 169-181.

HERTZ, D.B. & THOMAS, H. (1983). Risk analysis and its applications. New York: Wiley.

LAW, A.M. & KELTON, W.D., (1990). Simulation modeling and analysis. New York: McGraw-Hill.

MARSH, W.E. (1986) . Economic decision making on health and management in livestock herds: Examining complex problems through computer simulation. Ph.D. thesis. University of Minnesota. U.M.I. Dissertation services, Ann Arbor, Michigan.

NRC (1988). Nutrient Requirements of Dairy Cattle. Sixth revised ed. National Research Council, National Acadamy Press, Washington, D.C.

PALMER, C.R. (1989). Trials with bovine somatotropin on comercial dairy herds in South Africa. Congress of S.A.V.A.. September 1989.

PEEL, C.J. & BAUMAN, D.E. (1987) . Somatotropin and lactation. Journal of Dairy Science, Vol. 70:474.

PHILLIPS, L.D. (1982). Requisite decision modelling. Journal of the Operational Research Society Vol. 33:303-312.

PHILLIPS, L.D. (1984). A theory of requisite decision models. Acta Psychologica, Vol. 56:29-48.

RITCHIE, J.T. (1989). Crop models and decision making: scenario for the future. In: Weiss, A. (ed.) Climate and agriculture approaches to decision making. Proceedings of the American Meteorology Society, 5-7 March 1989, Charleston, SC.

TWIGGE, P.R. (1994). Personal communication. Managing Director, Monsanto Animal Sciences, Sandton, tel. 011-7837505

VAN ROOYEN, V. (1994). The dairy industry in the Free State. Proceedings of the conference on value adding to agriculture in the Free State, 22-23 September 1994, UOFS, Bloemfontein.

WILDMAN, E.E., JONES, G.M., WAGNER, P.E., BOMAN, R.L., TROUTT, H.F. & LESCH, T.N. (1982). A dairy cow body condition scoring system and its relationship to selected production characteristics. Journal of Dairy Science, Vol. 65:495-501.

YONKERS, R.D. (1989). Impacts of exogenously-determined variables on dairy farms: A simulation modeling approach. Ph.D. dissertation. Texas A&M University. U.M.I. Dissertation services, Ann Arbor, Michigan.