AN ECONOMIC EVALUATION OF REVERSE OSMOSIS FOR INTERREGIONAL MILK TRANSPORTATION IN AUSTRALIA

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This project was funded by CSIRO Dairy Research Laboratory, Highett, Victoria.

Paper presented at the 34th Annual Conference of the Australian Agricultural Economic Society, University of Queensland, Brisbane, 13-15 February 1990.

ABSTRACT

Costs and benefits associated with the introduction of reverse osmosis in a regulated and deregulated (free interstate trade) dairy industry are evaluated. Reverse osmosis is a filtration technique for the concentration of liquids. During filtration the milk is separated into two phases: permeate and retentate.

The study identifies the costs and benefits of reverse osmosis at factory and farm level. Capital and operating costs for a reverse osmosis plant at a regional depot or factory, processing 10,000L/hr, is estimated at $750,000 and 0.49c/L respectively. Reconstitution costs for concentrated milk are estimated between 0.10 and 0.20c/L.

Economics of size prevent the use of reverse osmosis to concentrate milk on the farm. Capital and operating costs for an on-farm reverse osmosis plant concentrating 2,400L/day are estimated at $30,700 and 1.92c/L respectively. The high cost of on-farm concentration eliminates reverse osmosis as a technology to reduce farm to factory transport costs.

The Australian Bureau of Agricultural and Resource Economics dairy programming model was used to identify the volumes of milk concentrated in a regulated and deregulated dairy industry with current and reverse osmosis transport costs.

Data obtained indicates that in a regulated industry reverse osmosis has only a limited capacity to reduce transport costs. Generally, transport distances and milk volumes transported are too small to economically transport milk as a concentrate.

With current transport costs, 41mL of milk would be transported from Northern Victoria to Sydney in a deregulated industry. This trade would be increased to 110mL when reverse osmosis transport costs were substituted into the deregulated model. An insignificant volume of milk is traded between Northern New South Wales and Brisbane with current and reverse osmosis transport costs (Buningh, in press).

INTRODUCTION

Several years ago it was realised that reverse osmosis could reduce transport costs in the Australian dairy industry. Reverse osmosis is a filtration technique for the concentration of liquids. During filtration the milk flows under high pressures (20-100 Bar) through tubular membranes where the milk is separated into two phases: permeate and retentate. The permeate is that fraction which passes through the filter. Because it is low in solids, it is often discarded as effluent water. The retentate, or concentrate, is high in protein, fat, lactose and dissolved salts, and is used in the manufacture of a wide range of dairy products.

During the past years it has been realised that there are several good reasons to investigate the potential costs and benefits associated with the use of reverse osmosis to reduce milk transport costs (Snow, 1985). The production of milk in Australia is located in areas which are considerable distances from the major population centres. Market milk consumed in the capital cities has often been transported over several hundred kilometres. In Victoria and New South Wales the estimated inter-factory market milk transport cost was $8.2 million and $12 million respectively.

THE MODEL

Reverse osmosis has the potential to enhance regional rationalisation in production and processing due to reduced transport costs. The quantitative evaluation of the effects of reverse osmosis in the dairy industry requires information on the supply relationship for the dairy industry. An additional requirement was for the model to evaluate reverse osmosis in a regulated and deregulated dairy industry.

The methodologies reviewed, for a quantitative evaluation of a shift in the dairy industry supply function included: the normative approaches of mathematical programming and budgeting, and the positive approaches of econometrics, including two-stage procedure, direct estimation approach, and directly estimated single commodity models.

The representative farm linear programming approach has the advantage that the technique takes account of the effects upon supply of all input prices, output prices and all relevant institutional, technological and physical restrictions for the model. The shortcomings of linear programming are the static nature of the theory, the assumption of maximising profits which will lead to an overestimation of supply response functions, and aggregation bias.

Variations in physical characteristics such as location (soils and climate), herd size, historical development, capital resources and managerial skills leads to aggregation bias. Aggregation bias can be minimised if representative farms are classified into groups or regions which are defined according to rigid theoretical requirements of homogeneity.

The two-stage procedure in econometrics derives the output relationship by algebraic manipulation (in the second stage) by imposing profit maximising conditions on the econometric estimations obtained in the first stage of the procedure. Disadvantages of the two-stage procedure are its static nature, inputs are treated as exogenous determinants of output and it relies upon a maintained hypothesis of profit maximisation to derive market level supply and input demand functions from the production, cost, profit or input demand functions estimated in the first-stage' (Colman, 1983 p208).

In the directly estimated single commodity supply models the various parameters are obtained directly from statistical analysis of historical time-series data instead of the technical parameters underlying them. The two requirements for the analytical framework preclude use of the directly estimated supply function approach. This approach neither has the ability to forecast the effect of a policy change which diverges from historical trends, nor provides the level of disaggregation required in this study.

Although both the linear programming and the so-called two-stage econometric procedure allow for the level of aggregation required, both techniques assume profit maximising behaviour. The degree of output and input disaggregation is a major disadvantage of the two-stage procedure. The mathematical programming technique was therefore the approach chosen.

REVERSE OSMOSIS SIMULATION MODEL

To estimate the economic benefits of concentrating milk prior to transportation in Eastern Australia information on the cost of concentrating milk with reverse osmosis was required.

A computer-based financial model developed by Cox and Langdon (1985) and amended by Buningh et.al. (1989) provided the basis for the analysis. Capital and operating costs for a reverse osmosis pilot plant were obtained from a dairy processing plant in Camperdown, Victoria. Data collected were extrapolated to represent a full scale (up to 35 million litres per annum) reverse osmosis concentration plant. Disaggregated capital and operating costs were entered into the spreadsheet model to obtain estimates of the total capital and operating costs, internal rate of return and net present value under various scenarios (sensitivity tests).

The Reverse Osmosis Concentration Transport Cost Model (ROCTM) basically incorporates the activities related to reverse osmosis concentration, reconstitution of concentrate, and transportation by road, air and sea. A list of the capital and operating costs in the model is presented in Table 1.

SIMULATION MODEL RUN

Cost estimates of a new reverse osmosis plant revealed that the cost of imported modules and membranes represent 70-80 per cent of the investment costs. A reverse osmosis plant with a capacity of 10,000L/hr and a flux rate of $30L/m^2/hr$ requires $333m^2$ of membranes. With the cost of imported modules and membranes estimated at $1,150 per square metre of membrane, and the replacement cost of membranes at $486.29/m² (Roach, 1989), the capital cost of a reverse osmosis plant processing 10,000L/hr is estimated at $750,000.

A simulation run was undertaken to estimate the operating costs of a plant processing 10,000L/hr and 35 million litres per year. The plant was assumed to operate for 300 days per year, requiring 12 operating hours per day. Operating costs for a reverse osmosis plant of the prescribed size was estimated at 0.49 cents per litre of milk input.

Transport costs in the model were estimated to be 3.00c/L with transport cost savings from reverse osmosis being 50 per cent. The results of this analysis were an internal rate of return of 33.1 per cent after tax and 46.2 per cent (extrapolated) before tax. Net present value over a 10 year period was $531,033 after tax and $1,028,577 before tax.

Variables with a large impact on the economic feasibility of the process included; percentage of concentration, annual milk throughput, and membrane life-time.

Variables with a low impact on the projected rate of return were electricity and labour. The analysis referred to a reverse osmosis plant which is fully automated requiring labour input when commencing the process and at cleaning and shut-down.

ON-FARM MILK CONCENTRATION

For several years the economics of on-farm reverse osmosis and ultrafiltration have been studied in the United States and Europe (Hiddink, 1979; Novakovic and Alexander, 1987; and Zall, 1987). Ultrafiltration is a separation technique similar to reverse osmosis. However, it is operated under lower pressures. During ultrafiltration water, as well as, lactose, soluble salt amino acids, and small polypeptides cross the membrane.

Advantages of on-farm milk concentration are reduced transport costs, the ability to manufacture more cheese with existing equipment, the disposal of less whey, and a potentially greater cheese yield (Zall, 1987).

With lower capital requirements, the on-farm concentration of milk in the United States was found to be economical with herd sizes exceeding 100 (Slack et.al. 1982). The larger capital requirement of reverse osmosis has prevented its introduction on the farm. Higher operating pressures require larger pumps and a stronger construction.

The capital cost of an on-farm reverse osmosis plant was estimated to be $30,700 (Table 2). In the analysis undertaken it was assumed that the herd size would be 180 cows producing 2,400L/day. Operating capacity of the reverse osmosis plant was 120L/hr requiring 20 operating hours per day.

The analysis indicated that the annual operating cost for this size plant was $13,795. Concentrating milk on-farm using reverse osmosis was estimated at 1.92 cents per litre of milk input. With a net present value of -$63,799 over a ten year period reverse osmosis is not an economical technique to concentrate milk on the farm.

Other important aspects of on-farm milk concentration include the ability of producers to operate such a plant, and the legal problem recognised by Zall (1987) that producers have to be issued with processing licences. With extensive training programs and regular farm visits required by experts it is uncertain whether producers would be able to adapt to on-farm concentration processes.

REVERSE OSMOSIS IN A REGULATED INDUSTRY

The programming model employed to estimate the effects of reverse osmosis for transport cost reductions in the Australian dairy industry was a subregional dairy programming model developed by the Australian Bureau of Agricultural and Resource Economics, Canberra. A detailed description of the model is presented by Williamson, Topp and Lembit (1988), and Topp, Williamson and Lembit (1989).

A study undertaken by the ABARE in 1988 indicated that the total cost per litre of transporting milk in Australia can be represented by the equation

$$TC = 1.23c/L + 0.006\ c/L/km.$$

where the one-way fixed cost of bulk milk transportation is 1.23c/L and the variable cost 0.006c/L/km. Reverse osmosis reduces the volume of milk transport by 50 per cent, and subsequently reduces the variable cost by 50 per cent.

A conservative estimate of the combined cost of concentration and reconstitution of market milk is 0.7c/L, resulting in a one-way reverse osmosis concentration -transport regression equation:

$$TC = 1.23c/L + 0.003c/L/km + 0.7c/L$$
$$\text{Therefore:- } TC = 1.93c/L + 0.003c/L/km.$$

Using the with and without reverse osmosis regression equations it was calculated that the one-way break-even transport distance for concentrated milk was 250km.

With a range of combined concentration - reconstitution costs of between 0.4 and 0.7c/L, the net economic gain from transporting milk over 200km ranged from $610,000 to -$307,000. An increase in the transport distance to 250km changed the net economic gain to between $1,074,500 and $153,000.

If reverse osmosis was to reduce market milk transport costs by up to $1,074,500 annually, this cost reduction would be equal to 0.35c/L on all Victorian market milk produced.

In New South Wales, transport distances are far greater than in Victoria. Market milk in New South Wales is transported over distances up to 700 kilometres. Production quotas in New South Wales allows for milk to be sourced only according to the quota allocations. The output data in Table 3 indicates that at a reverse osmosis concentration-reconstitution cost of 0.7c/L, reverse osmosis would not be economically feasible in the Sydney and South-east regions, in these regions reverse osmosis transport costs exceed the conventional transport costs because of short transport distances. Reverse osmosis would therefore only be operational in the North coast and Riverina regions resulting in a net economic gain of $1.09 million annually (0.28c/L on all market milk consumed in Sydney)(Buningh, in press).

With the cost of concentration and reconstitution reduced to 0.6c/L and 0.5c/L, annual net economic gain would increase to $1.32 million and $1.95 million respectively. Regional transport costs at the combined operating costs of 0.5c/L and 0.6c/L are presented in Table 4. An annual transport cost reduction of $1.32 million and $1.95 million would be equal to 0.55c/L and 0.82c/L on all market milk produced in regions one, three and four, to be consumed in Sydney.

Transport distances and statutory industry arrangements in the other States of Australia prevent reverse osmosis from reducing transport costs significantly.

REVERSE OSMOSIS IN A DEREGULATED INDUSTRY

Increasing pressure on interstate trade liberalization by supermarket chains, and the Closer Economic Relations (CER) agreement with New Zealand, can be expected to alter the current restrictions on interstate trade. The increase in interstate trade could have major effects on the New South Wales and Queensland dairy industries.

The flow of milk in a deregulated market environment with and without reverse osmosis was estimated using the deregulated dairy industry programming model of ABARE. In the model a range of manufacturing milk prices was used, and milk was produced in any region in Eastern Australia. The transportation of milk across State borders was unlimited and the reverse osmosis concentration-reconstitution cost was assumed to be 0.7c/L.

In a free interstate trade environment with current transport costs the interstate trade of milk would be limited. With a manufacturing milk price of 18.7c/L interstate trade in milk from Northern Victoria to Sydney would be 41.17mL. This trade in milk would mainly be undertaken between April and September. At a milk price of 18.7c/L, 27.57mL and 13.60mL of milk would be traded into Sydney in the second and third quarter of the year respectively. With decreasing blended milk prices the interstate trade in milk from Northern Victoria to Sydney would increase (Table 5). With current transport costs the trade of milk between Northern New South Wales and Brisbane is very limited. Only 0.13mL and 1.24mL of concentrated milk is transported to Brisbane (Buningh, 1990).

Reverse osmosis transport costs were introduced in the free-trade model to estimate the volume of interstate trade with reverse osmosis. Interstate trade between Northern Victoria and Sydney is increased considerably with reverse osmosis. With a manufacturing milk price of 18.7c/L trade is increased from 41.17ml (current transport cost) to 110.22mL. At the Victorian manufacturing milk price of 21.7c/L it is estimated that 52.82mL of Northern Victorian milk is traded in Sydney (Table 6). Interstate trade of milk from Northern Victoria to Sydney is predominant during the winter months of April to September when New South Wales faces a higher cost of production due to the higher supplementary feed requirements (Table 7) (Buningh, in press).

At a state level, regional distribution of milk production is not significantly affected in the free-trade model for Victoria and Queensland. However, distributional changes by region are significant in New South Wales as a result of transferable quotas and interstate trade.

In a deregulated market environment the market milk production in New South Wales is reduced significant with the interstate trade of concentrated milk from Victoria. Regional changes are most apparent in the Sydney and South-coast region of New South Wales. Market milk production in Sydney at a manufacturing milk price of 23.5c/L will be reduced from 293.39mL to 152.68mL. Subsequent market milk production in the South-east of the state will be increased from 134.70mL to 222.83mL. At the manufacturing milk price of 23.5c/L no market milk would be produced in the Northern and Riverina regions.

Manufacturing milk production with the introduction of reverse osmosis in a free-trade New South Wales model would remain unaltered in the Northern and Riverina regions. At a manufacturing milk price of 23.5c/L, 103.13ml and 137.13ml of manufacturing milk would be produced in the Northern and Riverina region respectively. The introduction of reverse osmosis would increase manufacturing milk production in the Sydney region from 11.81mL to 152.54mL. Production of manufacturing milk in the South-east of the State would be reduced from 122.46mL to zero with the introduction of reverse osmosis.

CONCLUSIONS

The aim of this paper was to identify the economic benefits from transporting concentrated milk in a regulated and deregulated dairy industry. In undertaking this task use was made of a regional programming model. It was concluded that the application of reverse osmosis would be very limited in a regulated industry. Transportation of concentrated milk would be more extensive in a deregulated market with significant volumes of milk traded between Northern Victoria and the Sydney market.

Table 1. Capital and operating costs in the ROCTM

Capital Costs in the Model.

Reverse Osmosis.

- o RO Plant
- o Installation and Commissioning
  (include electrical, plumbing, pumps, etc)
- o Storage - Milk
  - Concentrate
  - Chemicals
- o Cooling
- o Heating
- o Separating
- o Land
- o Buildings

Reuse of Concentrate

- o Modified Storage
- o Water Purification Plant
- o Water Addition Equipment
- o Blending Equipment
- o Modified Transport Tanker

Operating Costs in the Model

Reverse Osmosis

- o Membrane - Life Guarantee
  - Membrane Area
  - Replacement Cost
- o Cleaning - Acid
  - Alkali
  - Other
  - CIP Water
- o Energy - Electrical
  - Motors
  - Heating
  - Cooling
- o Labour

Reuse of Concentrate

- o Energy - Litres Concentrate P.A.
  - Plant capacity
  - Operating Days P.A.
  - Motors
- o Cleaning - CIP Water
- o Water
- o Labour

Table 2. Capital cost for an on-farm reverse osmosis plant.

Modules and membranes (3 sets)	$ 9,000
Recirculation pump	$ 7,000
Feed pump	$ 4,000
Pressure gauge	$ 400
Permeate storage vat	$ 5,000
Permeate flow meter	$ 300
Pressure release valve (permeate vat)	$ 1,000
Stop alarm	$ 1,000
Installation and commission	$ 3,000
Total	$30,700

Table 3. Aggregate regional market milk transport costs in New South Wales with and without reverse osmosis ($m).

Region	Transport cost without RO	Transport cost with RO (0.7c/L)
1 North Coast	$ 4.23m (4.25c/L)	$ 3.42m (3.44c/L)
2 Sydney	$ 3.09m (2.00c/L)	$ 3.56m (2.31c/L)
3 Riverina	$ 1.18m (5.10c/L)	$ 0.89m (3.86c/L)
4 South east	$ 3.02m (2.60c/L)	$ 3.03m (2.61c/L)
	$11.51m	$10.91m

Table 4. Aggregate regional reverse osmosis market milk transport costs to Sydney ($m).

Region	Aggregate regional reverse osmosis market milk transport cost	
	0.6c/L	0.5c/L
1 North Coast	$3.32m (3.34c/L)	$3.22m (3.24c/L)
2 Sydney	$3.41m (2.21c/L)	$3.26m (2.11c/L)
3 Riverina	$0.87m (3.76c/L)	$0.85m (3.66c/L)
4 South east	$2.92m (2.51c/L)	$2.41m (2.41c/L)

Table 5. Interstate trade under current transport costs at ranged manufacturing milk prices (mL).

Manufacturing milk price (c/l)	Interstate trade North-Vic to Sydney	NC01 to Brisbane	NC02 to Brisbane
21.7	0.00	0.00	0.00
20.7	0.00	0.00	0.00
19.7	0.00	0.00	0.00
18.7	41.17	0.00	0.00
17.7	95.04	1.24	0.21
16.7	120.03	0.13	0.38

Note: NC01 - North Coast New South Wales farm type 1
NC02 - North Coast New South Wales farm type 2

Table 6. Interstate trade under reverse osmosis transport costs for ranged manufacturing milk prices.

Ranged milk price (c/l)	North-Vic to Sydney	NC01 to Brisbane	Interstate trade NC02 to Brisbane
21.7	52.82	0.00	0.00
20.7	54.45	0.00	0.00
19.7	51.62	0.00	0.00
18.7	110.22	0.00	0.00
17.7	347.93	0.23	0.13
16.7	407.26	0.13	0.79

Table 7. Quarterly interstate trade from Northern Victoria to Sydney (mL).

Ranged milk price	Quarterly interstate trade (mL) Jan-Mar.	Apr-Jun.	Jul-Sept.	Oct-Dec.
21.7	0.00	17.09	35.72	0.00
20.7	0.00	30.34	24.11	0.00
19.7	0.00	32.44	19.18	0.00
18.7	8.02	49.53	52.66	0.00
17.7	90.21	98.03	81.66	78.02
16.7	100.28	104.56	106.92	95.50

Source: ABARE, 1989

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