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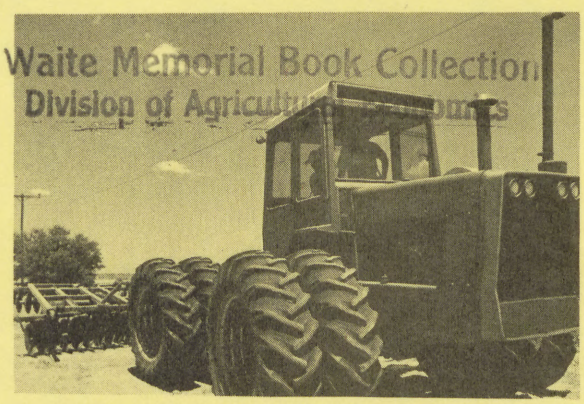

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ECONOMIC ANALYSIS OF ALTERNATIVE

MILK CONCENTRATION METHODS

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ABSTRACT

dly increasing energy costs dictate a reappraisal of present methods of sporting fluid milk between surplus and deficit regions. Methods which it transportation of a concentrated product which can be reconstituted whole fluid product near the point of consumption have the potential reducing energy use and consumer prices. Processing, transportation, reconstitution costs for five alternative concentration options are mated and compared with the present method of whole fluid distribution valuate economic benefits at varying distances from assembly points to lers.

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PREFACE

This paper was prepared as part of a USDA task force effort to evaluate the technical, economic, and legal feasibility of alternative fluid milk concentration/ reconstitution methods, including membrane reduction techniques. Numerous equipment manufacturers provided valuable information on equipment and operating costs. Prof. A. C. Johnson, Jr. developed an indexing procedure for updating transportation costs.

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ECONOMIC ANALYSIS OF ALTERNATIVE MILK CONCENTRATION METHODS

Summary

There are substantial economic incentives to whole milk (for fluid use) concentration and reconstitution when distances between production and consumption points exceed 100 miles. Whole milk transportation costs presently exceed 0.3 cents/cwt./mile, and whole milk contains 87% water. Any method of reducing this high water content reduces transportation costs proportionately, and all methods become increasingly attractive as the length of haul increases.

Under the present state of the arts with respect to milk processing technology, thermal evaporation of whole milk to 36-40 percent solids (about 2/3 of the water removed) is the least expensive concentration method for distances up to about 900 miles. At greater distances, it is less expensive to concentrate to dry ingredients (butter and non-fat dry milk). For shipping distances less than 100 miles, it is cheaper to ship milk in unconcentrated form.

Thermal evaporation is neither an exotic nor a sophisticated process. Substantial thermal-evaporator capacity is available in the United States which is presently used for condensing skim milk prior to drying. The same equipment and procedures are applicable to whole milk condensation. Consequently, this concentration option represents a limited departure from existing practices, and one that could be rapidly implemented.

Concentration to and subsequent reconstitution of butter (or butter oil) and non-fat dry milk has received more publicity than other concentration

reconstitution methods for several reasons -- large quantities of butter nd powder are presently produced and sold to the Government through the airy price support program; the option is wholly compatible with existing airy processing practices; and maximum concentration is economically ppealing for long hauls. But, compared with partial concentration of hole milk, butter-powder concentration loses some of its appeal. Cream eparation, butter production, and skim milk drying add considerably to he cost of reducing water content of milk, and spray drying, in particular, s a liquid fuel-intensive process. The taste characteristics of butter-owder reconstituted products would likely be both inferior to and more ariable than reconstituted whole milk. Unrealistically long hauls are ecessary for butter-powder to be competitive with thermal-evaporation of hole milk.

Membrane reduction techniques (ultrafiltration and reverse osmosis) are attractive milk concentration methods because they do not rely on heat. Ultrafiltration is used extensively in whey reduction and reverse osmosis has sucessfully been employed in concentrating skim milk. Problems of fat buildup on membranes has limited the use of reverse osmosis for whole milk concentration, but recent advances in membrane technology suggest the imminent, if not current, feasibility of reverse osmosis for whole milk. Under existing energy cost conditions, membrane reduction does not appear competitive with thermal evaporation for large-scale in-plant operations. This is largely because membrane reduction yields a lower concentration level. But expected improvements in membrane efficiency could rapidly change present competitive relationships.

Use of reverse osmosis whole milk reduction on the dairy farm is an especially promising, though untested, concentration option. This process would involve a membrane reduction unit in line with the milking system. Cost considerations would probably limit use of on-farm RO to large dairy farms with high farm hauling charges. Moreover, concentration levels would be less than that possible with conventional large-scale heat evaporation at a central assembly point. But tentative analysis of possible cost savings associated with on-farm RO, especially for shorter assembly point-to-bottler hauls, indicates a need for further developmental research on RO units scaled for on-farm use.

Introduction

Rising energy costs and increasing interest in reconstituted milk force a re-examination of the economics of moving milk from farmer to bottler. Mergers of milk marketing orders have increased the distance milk normally moves within order regions, and inter-order surplus-deficit transfers involve distances exceeding 1,500 miles. Concentration of whole milk at assembly points prior to shipment to bottlers seems to hold considerable promise as a means of reducing transportation costs.

Costs of several alternative means of milk concentration were examined and compared with the prevailing method of country assembly and bulk transport of whole fluid milk. Some of the alternatives involve well-developed technology; others assume evolving technology will shortly permit their employment. In most cases, estimates of costs are synthetic and must be viewed as approximations of what might be incurred under real-life operating conditions. Reconstituted milk products were necessarily assumed to be equivalent to fresh whole milk in terms of consumer acceptance.

Concentration Options

Five options were evaluated. They are summarized in Table 1 and schematically illustrated in Figure 1. Figure 1 also shows the flow rate (quantity to be transported) between farm and central assembly point and between central assembly point and bottling plant. Processing and transportation costs for each option are compared with a baseline, the conventional method of distributing unconcentrated whole fluid milk. The ordering of the options corresponds roughly to their departure from conventional milk processing procedures.

Baseline

Fresh milk is assembled from dairy farmers in bulk on an every-other-day basis. The milk is held (38-40 degrees F) at a receiving station for subsequent transport to bottlers, where it is pasturized, standardized, homogenized, and distributed to consumers as beverage milk. One cwt. of milk from farmers yields one cwt. of milk at the bottling plant (ignoring losses). Since this case serves as a base, the central receiving station is viewed as a "sunk" cost, that is, facilities and administrative and overhead personnel are assumed to be adequate for all other options. This permits equipment and expenses specific to other options to be interpreted as incremental to the baseline.

Option #1 -- Butter-Powder Reconstitution

This option represents maximum concentration at the assembly point. Technology employed is standard. The novelty lies in commercial reconstitution of the dry products in contrast to their normal sale as final products. The advantages of concentration to dry ingredient form (butter and nonfat

Table 1.--Fluid Milk Processing Options

Baseline: Assembly of whole milk at central receiving station; transportation in unconcentrated form to point of consumption for processing (pasturization, standardization, homogenization, etc.) and bottling.

Option #1: Assembly of whole milk at central receiving station; cream/ skim milk separation; continuous churn butter production; nonfat dry milk production using thermal-evaporation and spray drying of skim milk; transportation of dry components to point of consumption for reconstitution, processing, and bottling.

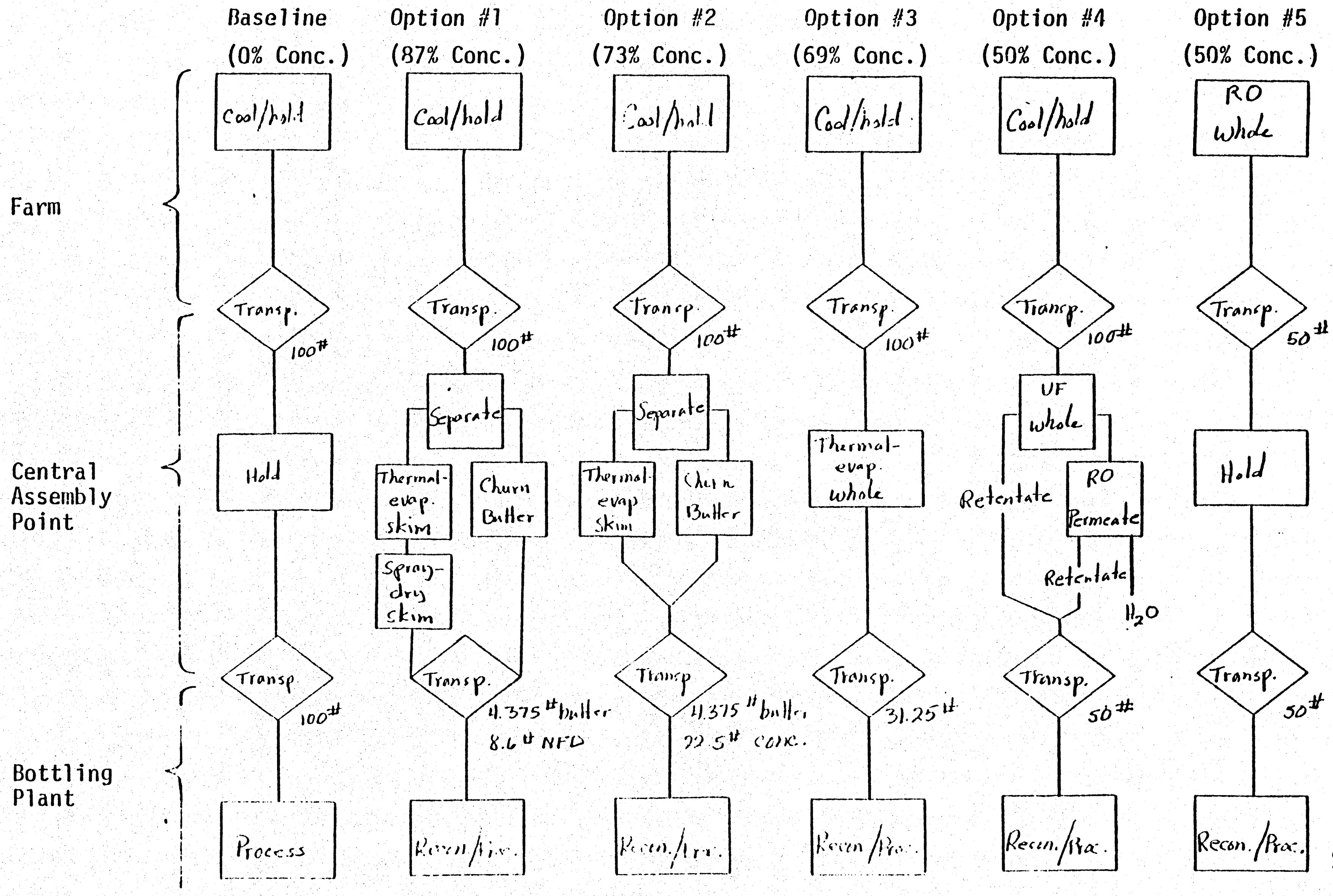
Option #2: Assembly of whole milk at central receiving station; cream/ skim milk separation; continuous churn butter production; concentration of skim milk using thermal-evaporation; transportation of concentrate and butter to point of consumption for reconstitution, processing, and bottling.

Option #3: Assembly of whole milk at central receiving station; concentration of whole milk using thermal-evaporation; transportation of concentrate to point of consumption for reconstitution, processing, and bottling.

Option #4: Assembly of whole milk at central receiving station; concentration of whole milk using two-stage ultrafiltration/reverse osmosis process; transportation of concentrate to point of consumption for reconstitution, processing, and bottling.

Option #5: On-farm concentration of whole milk using single-stage reverse osmosis; assembly of concentrate at central receiving station; transportation of concentrate to point of consumption for reconstitution, processing, and bottling.

Figure 1. -- Flow diagrams for alternative methods of fluid milk concentration.



dry milk) is that transportation costs from assembly point to the point of final consumption are minimized -- only 13 pounds of solids remain from a hundredweight of milk produced on the farm. However, spray drying of skim milk is costly, requiring considerable amounts of liquid fuel for heating (Appendix Table 1).

Option #2 -- Butter-Concentrated Skim Milk Reconstitution

This is a modification of option #1. Skim milk is conventionally evaporated to forty percent solids content, but shipped to bottlers in the concentrated form rather than dried. Potential advantages lie in omission of the costly spray drying process. Moreover, this option represents only a minor deviation from conventional practices. However, 27 lbs. of ingredients must be transported, more than double the quantity under butter-powder reconstitution. Stability characteristics of concentrated skim milk are not well known.

Option #3 -- Concentrated Whole Milk Using Thermal-Evaporation

The technology for thermal-evaporation of whole milk is fairly well developed. It is employed in the production of evaporated milk and Ultra High Temperature (UHT) milk concentrates,* but it is not used for whole milk destined for commercial reconstitution. The concentration level is limited to 40 percent solids (about 70 percent of the water of whole milk removed) because of stability problems. The likely useful life of the product following concentration would be 3 - 4 days.

*UHT milk concentrates are common in Europe and some other countries. Several unsucessful attempts were made to market the product in the U.S. in the late 1950's and early 1960's.

Regardless of questions relating to high perishability and stability, ole milk concentration has potential for reducing costs of milk proces- ng and shipment. Specifically, cream separation and butter manufacture e omitted; benefits which must be compared with the disadvantage of higher ipping weights relative to options involving butter and skim milk or nonfat y milk.

tion #4 -- Concentrated Whole Milk Using Ultrafiltration and Reverse Osmosis

Two-stage ultrafiltration (UF) followed by reverse osmosis (RO) replaces nventional thermal-evaporation for milk concentration in this option. UF tains milk fat and protein, but removes lactose, salts, and ash. These mponents are recovered by using reverse osmosis on what is removed by UF ermeate), and returned to what remains (retentate). While this process is t commercially used at this time in the U.S., extensive experimentation has cumented its commercial feasibility. It is commercially employed in con- ntration of cheese whey.

The advantage of UF-RO over thermal-evaporation is in reduced liquid iel requirements. Energy use is mainly electrical power for maintaining essure in the systems. However, the process is more sophisticated than nventional evaporation and has not been commercially tested on whole milk r fluid use.

tion #5 -- On-Farm Concentration by Reverse Osmosis

In this option, whole milk is concentrated by 50 percent using a reverse smosis unit connected directly to a milking parlor pipeline. The unit is emi-automatic, and can be operated in conjunction with the milking operation. resh milk temperatures (about 90 degrees F) are believed to be optimal for he RO process.

Costs were synthesized for three herd sizes -- 100, 500, and 1,000 cows (Appendix Table 4). Processing capacity is designed for "flush" milk production of 100 lbs. of milk per cow per day, and the unit is assumed to operate only during milking hours (4 hours, 8 hours, and 16 hours per day, respectively, for the three herd sizes).

This is a speculative option. Dairy technologists and processing equipment manufacturers disagree on the current feasibility of single-stage RO concentration of whole milk. The success of experiments has been mixed. But the conceptual attractiveness of the process is obvious. Compared to present practices, farm to assembly point as well as assembly point to bottler transportation costs could be reduced.

Cost Comparisons

Processing costs for the five concentration options were estimated using updated published estimates and synthesized costs. Processing costs for option #1, butter-powder reconstitution are specified as 90 cents per cwt. of raw fluid milk. This is approximately the cost used by Hammond, Buxton, and Thraen* in their 1979 study of reconstituted milk. Processing costs for the remaining options are based on equipment investment and operating data provided by dairy equipment manufacturers. Data and underlying assumptions are specified in the appendix.

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* Hammond, J. W., Buxton, B.M., and C. S. Thraen, Potential Impacts of Reconstituted Milk on Regional Prices, Utilization, and Production, Station Bulletin 529, University of Minnesota. While this publication is based on 1976 conditions, the 90 cents/cwt. is believed to be currently applicable in large, efficient butter-powder plants. The authors note that actual costs (from surveys) in 1976 were well below 90 cents. Moreover, the other concentration options involve synthetic costs based on new equipment and highly efficient technology.

Based on Hammond, Buxton, and Thraen, reconstitution costs at the bottling plant are specified as 6 cents per cwt. of fluid milk equivalent for butter-powder and butter-skim milk concentrate reconstitution, and 5 cents per cwt. for options not requiring butterfat mixing.

Transportation costs were estimated by updating recent survey and synthesized hauling costs to April 1980 using selected price indexes. Transportation costs are summarized in Appendix Table 5.

Assembly, Processing, and Reconstitution (APR) Costs

Costs of alternative concentration options up to the receiving station loading dock are summarized in Table 2. Given the assumptions used (sunk costs for plant and administration and overhead), the baseline exhibits the lowest costs when receiving station plant-to-bottler costs are not considered. The concentration options show costs ranging from 2 to 5 times baseline costs. Substantial economies to scale are noted for on-farm reverse osmosis. APR costs, mainly in processing, for the small herd are more than 3 times the level for 1,000 cows. The low charge for farm hauling of whole milk results in the large herd on-farm reverse osmosis option showing the lowest costs of the concentration options.

Costs Delivered to Bottler

The six methods of handling whole milk represent different levels of concentration, resulting in different costs of delivery from assembly point to bottler. Delivery costs can be added to the APR costs shown in Table 2 to determine total delivered cost according to distance between assembly point and bottler. These costs are shown for distances up to 1,750 miles in Table 3.

Table 2. -- Estimated Costs of Raw Milk Assembly, Processing, and Reconstitution for Alternative Fluid Milk Concentration Options

Option	Assembly	Processing	Reconst.	Total
	-------------cents per cwt.-------------			
Baseline	30.9	-0-	-0-	30.9
1 - butter-powder	30.9	90.0	6.0	126.9
2 - butter-skim conc.	30.9	65.0	6.0	101.9
3 - thermal-evap. whole	30.9	21.0	5.0	56.9
4 - UF-RO whole	30.9	27.9	5.0	63.8
5 - on-farm RO - 50 cows	15.4	137.0	5.0	157.4
500 cows	15.4	54.0	5.0	74.4
1,000 cows	15.4	32.0	5.0	52.4

Table 3. -- Estimated Costs to Process and Transport 100 Lbs. of Fluid Milk

Concentration Option	A-P-R Cost 1)	Total Cost Distance, Assembly Point to Bottling Plant, Miles							
		100	250	500	750	1000	1250	1500	1750
		dollars per cwt. of whole fluid milk							
Baseline - whole unconc.	.31	.73	1.23	2.05	2.87	3.67	4.51	5.34	6.16
1 - butter-powder	1.27	1.35	1.38	1.44	1.50	1.55	1.61	1.66	1.72
2 - butter-conc. skim	1.02	1.16	1.29	1.51	1.73	1.95	2.17	2.39	2.61
3 - thermal-evap. whole	.57	.70	.86	1.11	1.37	1.63	1.88	2.14	2.40
4 - UF-RO whole	.64	.85	1.10	1.51	1.92	2.33	2.74	3.15	3.56
5 - on-farm RO: 100 cows	1.57	1.78	2.03	2.44	2.85	3.26	3.67	4.08	4.49
500 cows	.74	.95	1.20	1.61	2.02	2.43	2.84	3.25	3.66
1,000 cows	.52	.73	.98	1.39	1.80	2.21	2.62	3.03	3.44

1) Assembly, processing and reconstitution

The relative cost differences among and between the options and the baseline change dramatically as mileage increases. At 100 miles, thermal-evaporation of whole milk is cheaper than unconcentrated milk shipment. Thermal evaporation remains the least-cost option up to a distance of about 1,000 miles, where butter-powder reconstitution becomes the least expensive alternative.

The other options are redundant in the sense that their total costs exceed those of other options at any distance. Costs for butter-concentrated skim rise at a slower rate than costs for thermal-evaporated whole milk, but are greater at all distances shown. Compared with thermal-evaporated whole milk, the higher processing costs associated with butter-concentrated skim are not completely offset by lower transportation costs.

Two-stage ultrafiltration-reverse osmosis of whole milk exhibits total delivered costs close to those for thermal evaporation at short distances. However, the lower concentration of UF-RO (50 percent compared to 68.75 percent) places the option at a comparative disadvantage in long assembly point-to-bottler hauls.

Total delivered costs for on-farm reverse osmosis depend on herd size. For the small herd, costs exceed all other options except for the longer distances. But costs for the 500-cow herd compare favorably with two-stage UF-RO (option #4), and range from $.25 to $1.26 above thermal evaporation costs (option #3). For the 1,000-cow herd, costs are even more advantageous, especially at short assembly point-to-bottler hauls. The feasibility of on-farm RO is quite sensitive to farm hauling rates; increases make the alternative increasingly less costly relative to the other options.

The three options with the lowest combined costs are plotted against distance in Figure 2. Up to 86 miles between assembly point and bottler, conventional (baseline) practices result in minimum costs. Between 86 and 907 miles, thermal evaporation of whole milk is most economical, while the butter-powder option is cheapest at distances greater than 907 miles.

Effect of Energy Cost Increases

To appraise how costs might be influenced by higher fuel and electricity prices, direct energy costs for processing and transportation were doubled. Recalculated costs for raw milk assembly, processing, delivery to bottlers, and reconstitution are shown in Table 4. All cost figures are elevated considerably, but few relative changes are apparent. On-farm reverse osmosis becomes a bit more attractive, but delivered costs (large herd unit) are still slightly above the baseline or the thermal-evaporated whole milk option at all distances. Least-cost alternatives for the higher energy cost case are illustrated in Figure 3. Compared to the current energy cost case (Figure 2), the zone in which unconcentrated milk possesses a cost advantage expands from 86 to 106 miles. Thermal-evaporated milk is cheapest up to 954 miles, where the butter-powder option gains an edge.

Conclusions, Observations, and Caveats

1. Substantial economic incentives to concentration and reconstitution of whole milk for fluid use are apparent whenever milk needs to be transported more than about 100 miles from an assembly point. Of course, this brief economic analysis assumes away many of the tehnological and institutional impediments to employment of the options considered. Limited knowledge is available concerning technological feasibility, product stability, sanitation requirements, consumer acceptance, and other problems. Institutional

Figure 2. -- Delivered cost of fluid milk by distance from assembly point to bottler

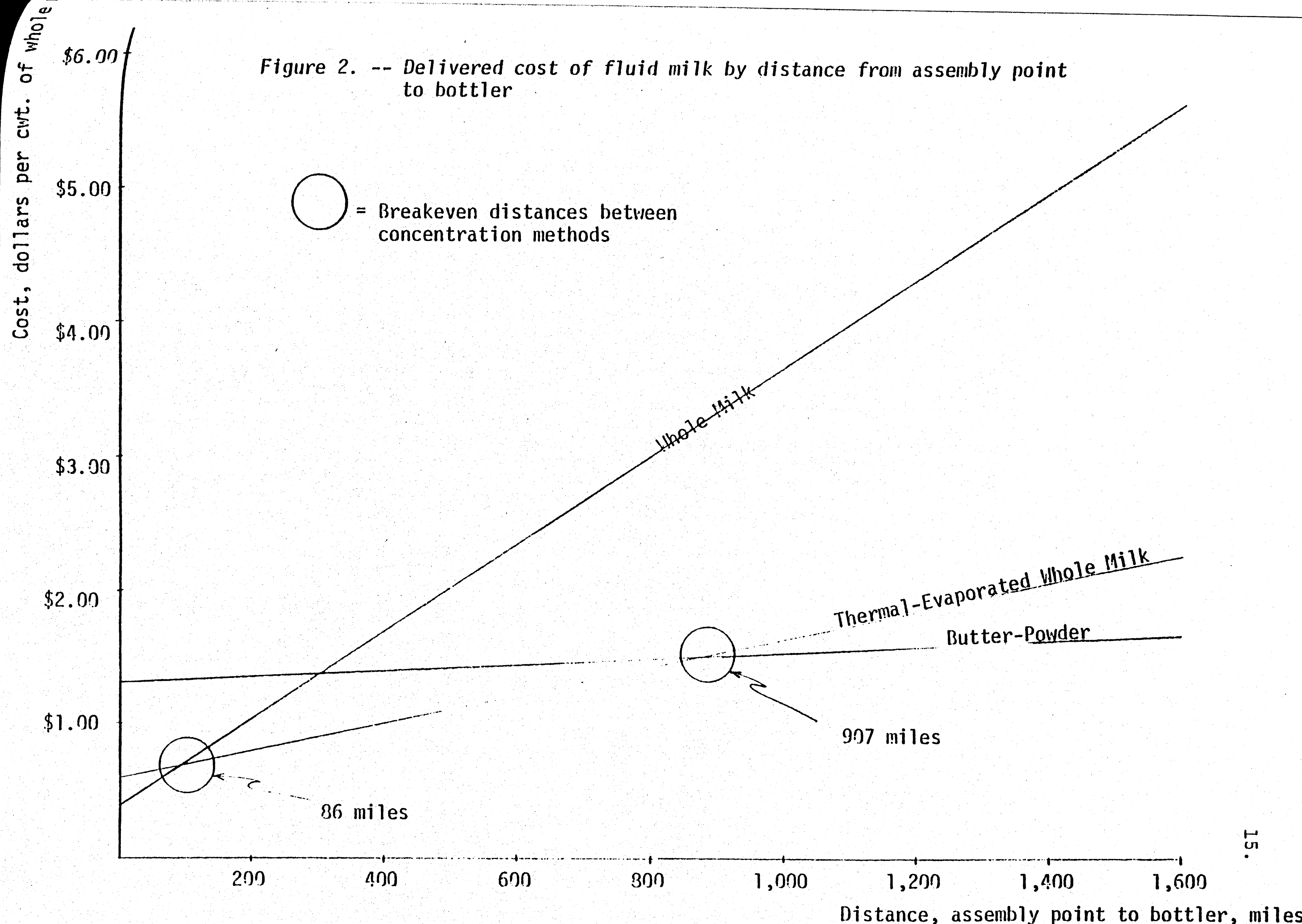

Table 4. -- Estimated Costs to Process and Transport 100 Lbs. of Fluid Milk, Doubling of Current (April 1980) Direct Energy Costs

Concentration Option	A-P-R Cost 1)	Total Cost Distance, Assembly Point to Bottling Plant, Miles							
		100	250	500	750	1000	1250	1500	1750
		----------------dollars per cwt. of whole fluid milk----------------							
Baseline - whole unconc.	.37	.87	1.48	2.50	3.52	4.54	5.55	6.57	7.59
1 - butter-powder	1.65	1.74	1.78	1.85	1.92	1.99	2.06	2.13	2.20
2 - butter-conc. skim	1.28	1.44	1.61	1.88	2.15	2.42	2.69	2.97	3.24
3 - thermal-evap. whole	.73	.89	1.08	1.40	1.71	2.03	2.35	2.67	2.99
4 - UF-RO whole	.78	1.04	1.34	1.85	2.35	2.86	3.37	3.88	4.39
5 - on-farm RO: 100 cows	1.77	2.02	2.33	2.84	3.34	3.85	4.36	4.87	5.38
500 cows	.88	1.13	1.44	1.95	2.45	2.96	3.47	3.98	4.49
1,000 cows	.64	.89	1.20	1.71	2.21	2.72	3.23	3.74	4.25

1) Assembly, processing and reconstitution

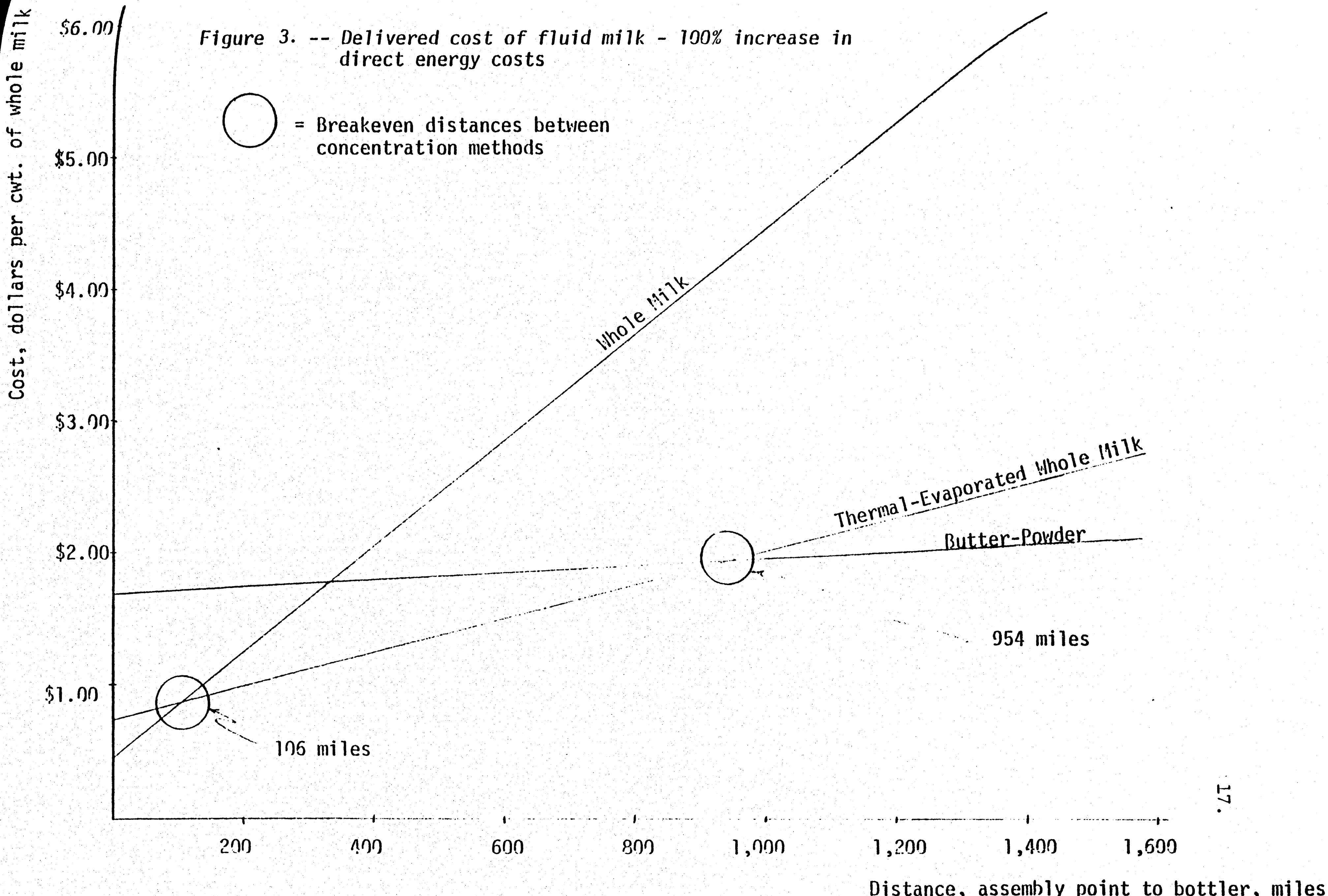

Figure 3. -- Delivered cost of fluid milk - 100% increase in direct energy costs
= Breakeven distances between concentration methods
Cost, dollars per cwt. of whole milk
$6.00
$5.00
$4.00
$3.00
$2.00
$1.00
Whole Milk
Thermal-Evaporated Whole Milk
Butter-Powder
954 miles
106 miles
200
400
600
800
1,000
1,200
1,400
1,600
Distance, assembly point to bottler, miles

considerations include the status of concentrated milk products under state and Federal regulations, and the possible opposition of truckers' unions to concentration.

2. Tradeoffs between transportation and processing costs yield a cost advantage to thermal-evaporated whole milk over a range from about 100 to 900 miles between assembly point and bottler. At a distance less than 100 miles, delivery of unconcentrated milk is the least expensive method, while butter-powder reconstitution minimizes costs at distances greater than 900 miles. The apparent superiority of the thermal-evaporation option must be viewed with some skepticism. There are many unanswered technical questions concerning transportation of whole milk concentrate. In addition, estimated processing costs are quite low (21 cents per cwt. of raw milk) and may be based on optimistic evaporation efficiency or failure to include some associated costs. On the other hand, if thermal-evaporation can be successfully employed to reduce whole milk to one-third original volume, then processing costs substantially higher than those used in this analysis could be incurred without eliminating the option's comparative advantage at "middle distance" assembly point-to-bottler hauls.* The thermal-evaporation option would seem to merit additional study based on its economic advantage.

3. On-farm reverse osmosis also holds considerable promise, even though it entailed marginally higher delivered fluid milk costs than the optimal options. RO membrane technology has advanced rapidly in recent years, and while experts disagree on the current feasibility of on-farm RO, few would dispute the longer-term feasibility.

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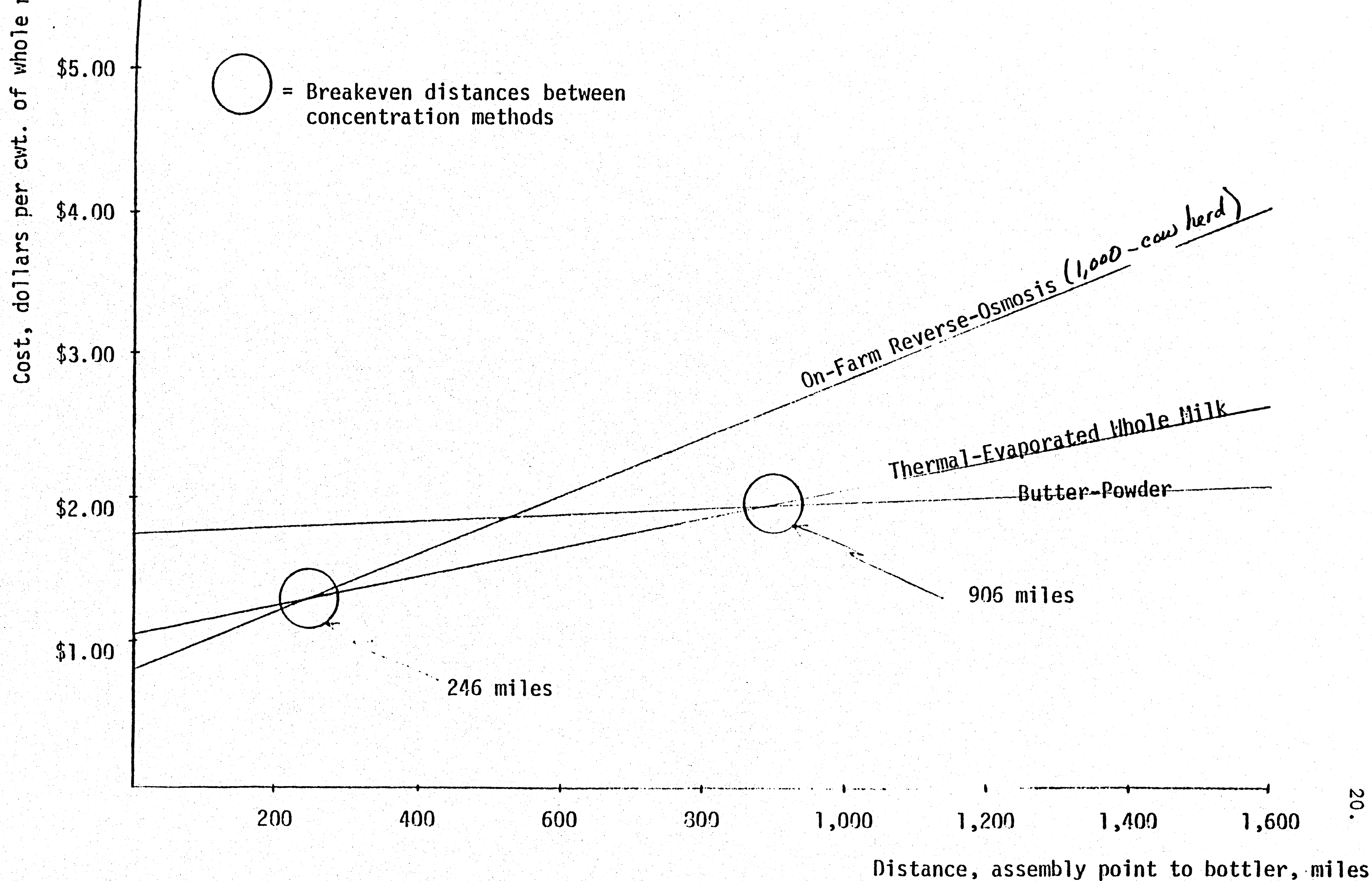
*For example, if thermal-evaporation processing costs were doubled (to 42 cents per cwt.,), the assembly point-to-bottler range over which the option would be least costly would change from (86 - 906) miles to (179 - 645) miles.

On-farm RO is particularly attractive for large dairy farms and where farm hauling charges are high. Hauling rates used in comparing options were modified to examine levels which would increase the attractiveness of the process. With a farm-to-assembly point hauling charge of 75 cents per cwt., on-farm RO for the 1,000 cow herd becomes less costly than whole milk assembly regardless of the distance the milk is hauled to bottlers. That is, combined milk assembly, processing, and reconstitution costs for on-farm RO are less than whole milk assembly costs. In this case, on-farm RO would be the cheapest means of concentration up to a distance of 246 miles from assembly point to bottler (see Figure 4). Between 246 and 906 miles, thermal-evaporation of whole milk is the least-cost option, with butter-powder concentration/reconstitution cheapest at distances greater than 906 miles.

An added advantage of on-farm RO is a reduction in farm bulk cooling tank investment and operating costs. Reduced electrical requirements for cooling are estimated to equal one-fourth of the RO unit electrical requirements. Also, RO permeate might be used to supplement dairy farm water needs.

On the negative side of the ledger, the large required investment and apparent size economies of on-farm RO might accelerate small dairy farm displacement. Moreover, the absence of existing operating units suggests that many costs associated with on-farm RO might well have been ignored in this brief economic overview.

Figure 4. -- Delivered cost of fluid milk - increase in farm hauling rates to 75 cents per cwt.



Appendix Table 1. -- Estimated Spray Drying Cost for Nonfat Dry Milk

Spray drying investment -- $1.35 mil., including bulk holding, handling, and loading equipment.

Annual investment cost @ 16.17% 1/	$218,250	
Labor	52,500	
Electricity	125,000	
Cleaning supplies; misc.	50,000	
Total annual fixed cost	$445,750	
Fixed cost/cwt. of raw milk		.1114
Added evap. cost/cwt. 2/		.0106
Steam cost/cwt. 3/		.1230
Total cost/cwt. of raw milk		$0.25

1/ Depr. = 6.67%; int. on inv. = 6.0%; and repairs, maintenance, and ins. = 3.5% of initial investment. Unit is assumed to be capable of reducing 4.0 mil. cwt. of raw milk annually.

2/ Skim milk as assumed to be reduced to 48% solids prior to introduction into the spray dryer. It is reduced to 40% if concentrate is to be shipped (Option 2).

3/ Estimated steam requirements are 2,100 BTU's per lb. of water removed.

Appendix Table 2. -- Estimated Costs of Conventional Thermal-Evaporation of Whole Milk, 80,000 Lbs./Hr. Raw Milk Feed Rate and 40% Final Solids

Annual Investment Costs [1]	
Depreciation (15 year life, straight-line)	$100,000
Interest on investment (12% of mid-life value)	90,000
Repairs, maintenance, ins. (3½% of initial inv.)	52,500
	$242,500
Annual Operating Costs [2]	
Labor (5,750 hrs. @ $10.50)	$ 60,000
Electricity [3]	30,000
Expendable supplies (mainly cleaning reagents	130,000
Steam [4]	366,000
	$586,000
Total annual cost at 100% capacity	$828,500
cost per cwt. of milk evaporated	0.21

1) Based on initial investment of $1.5 mil. for equipment, installation, and utility hookups. It is assumed that an appropriate plant site, building, and other administrative overhead is available as part of an existing milk assembly facility. Hence, overhead costs are <u>not</u> charged to the evaporation operation.

2) Based on 5,000 yrs./hr. operating time at 800 cwt. per hour input plus 750 hrs./year cleanup.

3) Horsepower requirements are 125 hp during evaporation and 200 hp during cleaning/sanitizing. Rate used is $0.05/kwh.

4) Water removed from fresh whole milk @ 12.5% solids with final concentration of 40% solids is 68.75 lbs. With 1 lb. steam required to remove 4.5 lbs. of water, steam use per cwt. of whole milk input is 15.25 lbs. Steam costs are charged at $6.00/1,000#, which is high for boilers fired by natural gas and low for boilers fired by fuel oil.

Appendix Table 3. -- Estimated costs of two-stage ultrafiltration-reverse osmosis of whole fluid milk, 80,000 lbs./hr. raw milk feed rate and 18% final solids (2 to 1 concentration)

Investment:	Ultrafiltration unit -	$1,450,000
	Reverse osmosis unit -	700,000
	Pasturizer -	100,000
		$2,250,000

Annual Costs

Annual investment cost @ 16.17% [1)]	$ 365,000	
Labor	52,500	
Electricity	137,600	
Cleaning supplies, misc.	67,500	
Membrane replacement	293,000	
Cooling water and pasturizer steam [2)]	202,300	
Total annual costs	$1,117,900	
Annual costs per cwt. of raw milk		.279

[1)] Depr. @ 6.67%; int. on inv. @ 6%; and repairs, maintenance, and insurance @ 3.5% of initial investment.

[2)] Steam for pasturizer @ 4,960 #/hr.; steam for cleaning UF and RO units @ 2,564 #/day; and 236,000 # cooling water/day @ $.07/1000#.

Appendix Table 4 -- Estimated Costs of On-Farm Reverse Osmosis Concentration of Whole Milk

	Herd Size (No. of Cows)		
	100	500	1,000
Unit Size:			
(1) No. of RO modules	16	40	40
(2) Recycle pumps - no. and cap.	1-24,000#/hr.	2-26,400#/hr.	2-26,400#/hr.
Hours per day operated	4	8	16
Annual volume of milk produced (cwt.)	15,000	75,000	150,000
Total initial investment	$75,000	$120,000	$120,000
Annual investment costs			
Depreciation [1]	$ 5,000	$ 8,000	$ 8,000
Interest on investment [2]	4,500	7,200	7,200
Repairs, maintenance, ins. [3]	2,625	4,200	4,200
Total	12,125	19,400	19,400
Annual operating costs			
Membrane replacement [4]	$ 2,000	$ 5,000	$ 6,500
Cleaning materials and supplies	3,500	8,750	8,750
Electricity [5]	2,900	7,700	12,800
	8,400	21,450	28,050
Total annual costs	20,525	40,850	47,450
Cost per cwt.	1.37	0.54	0.32

1) Straight-line, 15 year life on all equipment
2) Twelve percent on mid-life investment
3) Based on 3.5% of initial investment
4) Replace every two years for 100 and 500 cow units, every 18 months for 1,000 cow unit. Replacement cost (installed) at $250 per module.
5) Based on operating time plus 4 hours/day cleaning and sanitizing. Kw requirements are 20 kw for 100 cow units and 35 kw for 500 and 1,000 cow units.

Appendix Table 5. -- Estimated Transportation Costs for Milk, April 1980. All Costs in Terms of Dollars per Cwt. of Whole Milk Equivalent

I. Farm to first receiving station: $.309/cwt.

Based on Keaton, Mark, Final Report to the Wisconsin Transportation Commission, Wisconsin Department of Transportation, MC-1959, Madison, August 1979

II. Receiving station to bottler

(1) Baseline--unconcentrated whole milk:

Cost/cwt. ($) = $.0943 + $.3289 (one-way distance in 100 miles)

Based on Lough, Harold W., Truck Transportation Costs of Bulk Milk, AGERS-33, Econ. Res. Ser., U.S. Dept. of Agr., August 1977

(2) Butter - powder

Cost/cwt. ($) = $.0571 + .02255 (one-way distance in 100 miles)

Based on Hammond, J.W., Buxton, B.M., and C.W. Thraen, Potential Impacts of Reconstituted Milk on Regional Prices, Utilization and Production, Station Bulletin 529, University of Minnesota

(3) Butter - concentrated skim

Cost/cwt. ($) = $.0558 + .0878 (one-way distance in miles)

(4) Thermal-evaporated whole

Cost/cwt. ($) = $.0295 + .1028 (one-way distance in miles)

(5) Membrane reduction (options 4 and 5)

Cost/cwt. ($) = $.0472 + .1644 (one-way distance in miles)