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APPENDIX

Comparison of the Economics of Cheddar Cheese Manufacture by Conventional and Milk Fractionation/Concentration Technologies

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Part 5 of a Research Effort on Cheddar Cheese Manufacturing

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Table A1 Building Areas and Land Requirement Factors for Model **Conventional** Cheese Plants of Different Sizes

Plant Size (Pounds of Milk per Day)	Building Area (Square Feet)	Land Factor[1]
720,000	25,742	1.525
960,000	28,668	1.422
1,440,000	38,357	1.184
2,400,000	53,996	.969

[1] Land acres per 10,000 square feet of building area.

Table A2 Building Areas and Land Requirement Factors for Model **1.5X UF** Cheese Plants of Different Sizes

Plant Size (Pounds of Milk per Day)	Building Area (Square Feet)	Land Factor[1]
720,000	26,242	1.506
960,000	29,168	1.406
1,440,000	38,857	1.175
2,400,000	54,621	.963

[1] Land acres per 10,000 square feet of building area.

Table A3 Building Areas and Land Requirement Factors for Model **1.2X RO** Cheese Plants of Different Sizes

Plant Size (Pounds of Milk per Day)	Building Area (Square Feet)	Land Factor[1]
720,000	25,992	1.516
960,000	29,043	1.410
1,440,000	38,732	1.177
2,400,000	54,621	.963

[1] Land acres per 10,000 square feet of building area.

Table A4 Building Areas and Land Requirement Factors for Model **1.2X Evaporation** Cheese Plants of Different Sizes

Plant Size (Pounds of Milk per Day)	Building Area (Square Feet)	Land Factor[1]
720,000	26,667	1.490
960,000	29,593	1.393
1,440,000	39,457	1.164
2,400,000	55,096	.959

[1] Land acres per 10,000 square feet of building area.

Table A5 Building Areas and Land Requirement Factors for Model **6.5X UF** Cheese Plants of Different Sizes

Plant Size (Pounds of Milk per Day)	Building Area (Square Feet)	Land Factor[1]
720,000	30,849	1.356
960,000	34,893	1.255
1,440,000	43,782	1.094
2,400,000	60,713	.909

[1] Land acres per 10,000 square feet of building area.

Table A6 Building Areas and Land Requirement Factors for Model **WPC** Plants to Accompany **Conventional** Cheese Plants of Different Sizes

Plant Size (Pounds of Milk per Day)	Building Area (Square Feet)	Land Factor[1]
720,000	8,504	3.416
960,000	9,052	3.253
1,440,000	9,984	3.015
2,400,000	11,257	2.750

[1] Land acres per 10,000 square feet of building area.

Table A7 Building Areas and Land Requirement Factors for Model **WPC** Plants to Accompany **1.5X UF** Cheese Plants of Different Sizes

Plant Size (Pounds of Milk per Day)	Building Area (Square Feet)	Land Factor[1]
720,000	8,454	3.432
960,000	8,852	3.311
1,440,000	9,759	3.068
2,400,000	11,182	2.764

[1] Land acres per 10,000 square feet of building area.

Table A8 Building Areas and Land Requirement Factors for Model **WPC** Plants to Accompany **1.2X RO or 1.2X Evaporation** Cheese Plants of Different Sizes

Plant Size (Pounds of Milk per Day)	Building Area (Square Feet)	Land Factor[1]
720,000	8,479	3.424
960,000	8,902	3.296
1,440,000	9,809	3.056
2,400,000	11,232	2.755

[1] Land acres per 10,000 square feet of building area.

Table A9 Building Areas and Land Requirement Factors for Model **WPC** Plants to Accompany **6.5X UF** Cheese Plants of Different Sizes

Plant Size (Pounds of Milk per Day)	Building Area (Square Feet)	Land Factor[1]
720,000	8,004	3.584
960,000	8,427	3.441
1,440,000	9,234	3.203
2,400,000	10,382	2.925

[1] Land acres per 10,000 square feet of building area.

Table A10 Building Areas and Land Requirement Factors for Model **Whey Powder** Plants to Accompany **Conventional, 1.5X UF, 1.2X RO or 1.2X Evaporation** Cheese Plants of Different Sizes

Plant Size (Pounds of Milk per Day)	Building Area (Square Feet)	Land Factor[1]
720,000	11,694	2.672
960,000	13,178	2.443
1,440,000	15,334	2.186
2,400,000	22,361	1.677

[1] Land acres per 10,000 square feet of building area.

Table A11 Total Initial Capital Investment for Model **Conventional** Cheese Plants of Different Sizes

Note: Does **not** include any whey plant investment.

Day) Capital Investment	Cheese Plant Size (1000 Pounds of Milk Per 720	960	1,440	2,400
	(Dollars)			
Land	145,207	150,790	167,985	193,535
Building	2,198,295	2,460,654	3,256,057	4,654,304
Equipment	4,143,199	4,591,888	5,886,160	8,359,799
Total Invest.	6,486,701	7,203,332	9,310,202	13,207,638

Table A12 Total Initial Capital Investment for Model **1.5X UF** Cheese Plants of Different Sizes

Note: Does **not** include any whey plant or permeate handling investment.

Capital Investment	Cheese Plant Size (1000 Pounds of Milk Per Day) 720	960	1,440	2,400
	(Dollars)			
Land	146,183	151,694	168,881	194,563
Building	2,302,295	2,505,702	3,301,140	4,710,541
Equipment	4,563,480	5,032,975	6,348,053	8,906,997
Total Invest. 13,812,101	7,011,958	7,690,371	9,818,074	

Table A13 Total Initial Capital Investment for Model **1.2X RO** Cheese Plants of Different Sizes

Note: Does **not** include any whey plant investment.

Capital Investment	Cheese Plant Size (1000 Pounds of Milk Per Day)			
	720	960	1,440	2,400
	(Dollars)			
Land	145,752	151,473	168,625	194,563
Building	2,220,990	2,494,488	3,289,880	4,710,541
Equipment	4,407,435	4,882,132	6,257,547	8,860,184
Total Invest.	6,774,177	7,528,093	9,716,052	13,765,288

Table A14 Total Initial Capital Investment for Model **1.2X Evaporation** Cheese Plants of Different Sizes

Note: Does **not** include any whey plant investment.

Capital Investment	Cheese Plant Size (1000 Pounds of Milk Per Day)			
	720	960	1,440	2,400
	(Dollars)			
Land	146,972	152,481	169,884	195,440
Building	2,289,227	2,551,696	3,364,103	4,762,386
Equipment	4,513,083	4,990,234	6,388,536	9,078,366
Total Invest.	6,949,282	7,694,411	9,922,523	14,036,192

Table A15 Total Initial Capital Investment for **Whey Protein Concentrate (WPC)** Plants to Accompany **Conventional** Cheese Plants of Different Sizes

Capital Investment	Cheese Plant Size (1000 Pounds of Milk Per Day)			
	720	960	1,440	2,400
	(Dollars)			
Land	107,452	108,919	111,344	114,506
Building	1,191,420	1,225,973	1,282,338	1,355,930
Equipment	3,217,366	3,429,007	3,739,248	4,026,914
Total Invest.	4,516,238	4,763,899	5,132,930	5,497,350

Table A16 Total Initial Capital Investment for **Whey Protein Concentrate (WPC)** Plants to Accompany **1.5X UF** Cheese Plants of Different Sizes

Capital Investment	Cheese Plant Size (1000 Pounds of Milk Per Day)			
	720	960	1,440	2,400
	(Dollars)			
Land	106,821	107,691	108,835	113,745
Building	1,186,696	1,207,935	1,260,980	1,349,026
Equipment	3,200,617	3,342,402	3,620,446	3,999,034
Total Invest.	4,494,134	4,658,028	4,990,261	5,461,805

Table A17 Total Initial Capital Investment for **Whey Protein Concentrate (WPC)** Plants to Accompany **1.2X RO or Evaporation** Cheese Plants of Different Sizes

Capital Investment	Cheese Plant Size (1000 Pounds of Milk Per Day)			
	720	960	1,440	2,400
	(Dollars)			
Land	107,136	108,299	109,392	114,252
Building	1,189,058	1,212,637	1,265,632	1,353,629
Equipment	3,206,391	3,351,660	3,631,993	4,019,424
Total Invest.	4,502,585	4,672,596	5,007,017	5,487,305

Table A18 Total Initial Capital Investment for **Whey Powder** Plants to Accompany **All** Cheese Plants of Different Sizes

Capital Investment	Cheese Plant Size (1000 Pounds of Milk Per Day)			
	720	960	1,440	2,400
	(Dollars)			
Land	115,578	119,082	123,988	138,707
Building	2,125,535	2,302,682	2,496,454	3,690,923
Equipment	3,743,347	4,190,124	4,956,822	6,176,772
Total Invest.	5,984,460	6,611,888	7,577,264	10,006,352

Table A19 Total Initial Capital Investment for **6.5X UF** Cheese Plants of Different Sizes

Capital Investment	Cheese Plant Size (1000 Pounds of Milk Per Day)			
	720	960	1,440	2,400
	(Dollars)			
Land	154,730	161,978	177,169	204,136
Building	2,620,479	2,987,240	3,721,187	5,241,386
Equipment	7,656,776	8,678,338	10,608,256	14,856,051
Total Invest.	10,431,985	11,827,556	14,506,612	20,301,573

Table A20 Total Initial Capital Investment for **Whey Protein Concentrate (WPC)** Plants to Accompany **6.5X UF** Cheese Plants of Different Sizes

Capital Investment	Cheese Plant Size (1000 Pounds of Milk Per Day)			
	720	960	1,440	2,400
	(Dollars)			
Land	101,135	101,399	102,980	105,606
Building	1,142,464	1,165,152	1,210,007	1,272,394
Equipment	2,765,876	2,892,212	3,085,940	3,210,278
Total Invest.	4,009,475	4,158,763	4,398,927	4,588,278

Table A21 Daily Labor, Electricity, Natural Gas, Water, and Sewage Requirements for **Conventional** Cheese Plants[1]

Input Items	Units	Cheese Plant Size (1000 Lbs Milk per Day) 720	960	1,440	2,400
Labor					
Supervisory	Hrs/Day	24	24	24	24
Fixed	Hrs/Day	38	39	51	55
Variable	Hrs/Day	315	357	393	463
Electricity					
Fixed	KWH/Op. Hrs	50	56	74	104
Variable	KWH/Million Lbs Milk	2,054	1,582	1,590	1,109
Natural Gas					
Fixed	Therms/Hour	350	367	507	662
Variable	Therms /Million Lbs Milk	1,797	1,897	1,697	1,603
Water	Gallons /Day	49,306	55,599	74,907	103,796
Sewage	Gallons /Day	46,846	52,863	70,907	97,916

[1] All plants operating 24 hours per day.

Table A22 Daily Labor, Electricity, Natural Gas, Water, and Sewage Requirements for WPC Plants Accompanying Conventional Cheese Plants[1]

Note: No permeate handling costs included.

Input Items	Units	Cheese Plant Size (1000 Lbs Milk per Day) 720	960	1,440	2,400
Labor					
Supervisory	Hrs/Day	8	8	8	8
Fixed	Hrs/Day	10	10	10	10
Variable	Hrs/Day	123	123	123	123
Electricity					
Fixed	KWH/Op. Hrs	19	21	22	24
Variable	KWH/Million Lbs Milk	508	413	306	214
Natural Gas					
Fixed	Therms/Hour	56	59	81	106
Variable	Therms /Million Lbs Milk	2,412	2,380	2,430	2,220
Water	Gallons /Day	20,024	22,489	28,789	35,086
Sewage	Gallons /Day	34,927	42,918	62,136	84,547

[1] All plants operating 24 hours per day.

Table A23 Daily Labor, Electricity, Natural Gas, Water, and Sewage Requirements for **Whey Powder** Plants Accompanying **Conventional** or **1.5X UF** Cheese Plants[1]

Input Items	Units	Cheese Plant Size (1000 Lbs Milk per Day) 720	960	1,440	2,400
Labor					
Supervisory	Hrs/Day	8	8	8	8
Fixed	Hrs/Day	8	8	8	9
Variable	Hrs/Day	128	128	128	151
Electricity					
Fixed	KWH/Op. Hrs	17	18	18	21
Variable	KWH/Million Lbs Milk	11,122	10,282	9,775	8,981
Natural Gas					
Fixed	Therms/Hour	0	0	0	0
Variable	Therms /Million Lbs Milk	1,797	1,897	1,697	1,603
Water	Gallons /Day	23,505	24,270	26,630	40,210
Sewage	Gallons /Day	89,955	113,673	161,179	265,592

[1] All plants operating 24 hours per day, and assuming no increase in cheese yields or milk throughput in the cheese plants.

Table A24 Daily Labor, Electricity, Natural Gas, Water, and Sewage Requirements for **1.5X UF** Cheese Plants[1]

Note: No permeate handling costs included.

Input Items	Units	Cheese Plant Size (1000 Lbs Milk per Day) 720	960	1,440	2,400
Labor					
Supervisory	Hrs/Day	24	24	24	24
Fixed	Hrs/Day	38	39	51	55
Variable	Hrs/Day	319	361	398	467
Electricity					
Fixed	KWH/Op. Hrs	51	57	75	106
Variable	KWH/Million Lbs Milk	2,127	1,637	1,627	1,141
Natural Gas					
Fixed	Therms/Hour	350	367	507	662
Variable	Therms /Million Lbs Milk	1,899	1,833	1,699	1,615
Water	Gallons /Day	49,306	55,599	74,907	103,796
Sewage	Gallons /Day	46,846	54,946	72,296	99,166

[1] All plants operating 24 hours per day, and assuming no increase in cheese yields or milk throughput.

Table A25 Daily Labor, Electricity, Natural Gas, Water, and Sewage Requirements for WPC Plants Accompanying 1.5X UF Cheese Plants[1]

Note: No permeate handling costs included.

Input Items	Units	Cheese Plant Size (1000 Lbs Milk per Day) 720	960	1,440	2,400
Labor					
Supervisory	Hrs/Day	8	8	8	8
Fixed	Hrs/Day	10	10	10	10
Variable	Hrs/Day	123	123	123	123
Electricity					
Fixed	KWH/Op. Hrs	19	20	21	24
Variable	KWH/Million Lbs Milk	511	403	297	212
Natural Gas					
Fixed	Therms/Hour	44	50	59	83
Variable	Therms /Million Lbs Milk	2,412	2,380	2,430	2,220
Water	Gallons /Day	19,184	21,565	25,333	34,606
Sewage	Gallons /Day	35,254	41,119	56,458	84,067

[1] All plants operating 24 hours per day, and assuming no increase in cheese yields or milk throughput.

Table A26 Daily Labor, Electricity, Natural Gas, Water, and Sewage Requirements for 1.2X RO Cheese Plants[1]

Input Items	Units	Cheese Plant Size (1000 Lbs Milk per Day) 720	960	1,440	2,400
Labor					
Supervisory	Hrs/Day	24	24	24	24
Fixed	Hrs/Day	38	39	51	55
Variable	Hrs/Day	319	361	398	467
Electricity					
Fixed	KWH/Op. Hrs	50	57	75	106
Variable	KWH/Million Lbs Milk	2,106	1,633	1,642	1,160
Natural Gas					
Fixed	Therms/Hour	350	367	507	662
Variable	Therms /Million Lbs Milk	1,899	1,833	1,699	1,615
Water	Gallons /Day	53,472	59,557	74,907	107,546
Sewage	Gallons /Day	51,012	56,821	70,907	101,666

[1] All plants operating 24 hours per day, and assuming no increase in cheese yields or milk throughput.

Table A27 Daily Labor, Electricity, Natural Gas, Water, and Sewage Requirements for **Whey Powder** Plants Accompanying **1.2X RO** or **1.2X Evaporation** Cheese Plants[1]

Input Items	Units	Cheese Plant Size (1000 Lbs Milk per Day) 720	960	1,440	2,400
Labor					
Supervisory	Hrs/Day	8	8	8	8
Fixed	Hrs/Day	8	8	8	9
Variable	Hrs/Day	128	128	128	151
Electricity					
Fixed	KWH/Op. Hrs	17	18	18	21
Variable	KWH/Million Lbs Milk	11,122	10,282	9,775	8,981
Natural Gas					
Fixed	Therms/Hour	0	0	0	0
Variable	Therms /Million Lbs Milk	1,695	1,795	1,595	1,501
Water	Gallons /Day	23,505	24,270	26,630	40,210
Sewage	Gallons /Day	77,041	96,454	135,351	222,546

[1] All plants operating 24 hours per day, and assuming no increase in cheese yields or milk throughput in the cheese plants.

Table A28 Daily Labor, Electricity, Natural Gas, Water, and Sewage Requirements for WPC Plants Accompanying 1.2X RO or 1.2X Evaporation Cheese Plants[1]

Input Items	Units	Cheese Plant Size (1000 Lbs Milk per Day) 720	960	1,440	2,400
Labor					
Supervisory	Hrs/Day	8	8	8	8
Fixed	Hrs/Day	10	10	10	10
Variable	Hrs/Day	123	123	123	123
Electricity					
Fixed	KWH/Op. Hrs	19	20	21	24
Variable	KWH/Million Lbs Milk	510	394	293	211
Natural Gas					
Fixed	Therms/Hour	50	58	70	96
Variable	Therms /Million Lbs Milk	2,412	2,379	2,430	2,220
Water	Gallons /Day	9,604	22,237	27,061	35,422
Sewage	Gallons /Day	5,674	41,791	58,186	84,883

[1] All plants operating 24 hours per day, and assuming no increase in cheese yields or milk throughput in the cheese plants.

Table A29 Daily Labor, Electricity, Natural Gas, Water, and Sewage Requirements for **1.2X Evaporation** Cheese Plants[1]

Input Items	Units	Cheese Plant Size (1000 Lbs Milk per Day) 720	960	1,440	2,400
Labor					
Supervisory	Hrs/Day	24	24	24	24
Fixed	Hrs/Day	38	39	51	55
Variable	Hrs/Day	327	369	406	475
Electricity					
Fixed	KWH/Op. Hrs	55	61	79	110
Variable	KWH/Million Lbs Milk	2,096	1,615	1,620	1,136
Natural Gas					
Fixed	Therms/Hour	350	367	507	662
Variable	Therms /Million Lbs Milk	2,853	2,801	2,378	2,297
Water	Gallons /Day	49,306	55,599	74,907	103,796
Sewage	Gallons /Day	46,846	52,863	70,907	97,916

[1] All plants operating 24 hours per day, and assuming no increase in cheese yields or milk throughput.

Table A30 Daily Labor, Electricity, Natural Gas, Water, and Sewage Requirements for 6.5X UF Cheese Plants[1]

Input Items	Units	Cheese Plant Size (1000 Lbs Milk per Day) 720	960	1,440	2,400
Labor					
Supervisory	Hrs/Day	24	24	24	24
Fixed	Hrs/Day	36	37	48	51
Variable	Hrs/Day	321	363	389	478
Electricity					
Fixed	KWH/Op. Hrs	51	59	78	112
Variable	KWH/Million Lbs Milk	2,630	2,368	2,109	1,564
Natural Gas					
Fixed	Therms/Hour	280	293	415	559
Variable	Therms /Million Lbs Milk	1,964	1,826	1,719	1,565
Water	Gallons /Day	41,880	51,009	63,785	87,900
Sewage	Gallons /Day	43,860	53,808	68,344	94,860

[1] All plants operating 24 hours per day, and assuming no increase in cheese yields or milk throughput.

Table A31 Daily Labor, Electricity, Natural Gas, Water, and Sewage Requirements for **WPC** Plants Accompanying **6.5X UF** Cheese Plants[1,2]

Input Items	Units	Cheese Plant Size (1000 Lbs Milk per Day) 720	960	1,440	2,400
Labor					
Supervisory	Hrs/Day	8	8	8	8
Fixed	Hrs/Day	10	10	10	10
Variable	Hrs/Day	119	119	119	119
Electricity					
Fixed	KWH/Op. Hrs	18	19	20	22
Variable	KWH/Million Lbs Milk	436	331	234	160
Natural Gas					
Fixed	Therms/Hour	56	59	81	106
Variable	Therms /Million Lbs Milk	2,412	2,379	2,430	2,220
Water	Gallons /Day	20,204	22,489	28,789	35,086
Sewage	Gallons /Day	31,927	38,918	57,136	78,547

[1] All plants operating 24 hours per day, and assuming a 10.57 lb per cwt cheese yield and no increase in milk throughput in the cheese plants.

[2] Due to the use of 6.5X UF, whey powder is not an option with this cheese making technology.

Table A32 Manufacturing Costs of Cheddar, WPC and Whey Powder in **Conventional** Cheese and Whey Operations for Four Plant Sizes Using Four Operating Schedules[1]

Note: Breakeven is assumed on the UF permeate produced in the WPC plants.

Manufacturing Cost & Plant Capacity[2]	Plant Operating Schedules			
	5 Days 18 Hours	6 Days 18 Hours	5 Days 24 Hours	7 Days 24 Hours
	(Dollars Per Cwt of Milk)			
Cheddar				
720,000	2.157	2.046	1.833	1.716
960,000	1.883	1.789	1.614	1.517
1,440,000	1.617	1.536	1.391	1.306
2,400,000	1.369	1.300	1.186	1.114
WPC				
720,000	0.926	0.850	0.745	0.662
960,000	0.750	0.690	0.606	0.541
1,440,000	0.574	0.531	0.469	0.422
2,400,000	0.409	0.381	0.340	0.309
Whey Powder				
720,000	1.151	1.052	0.929	0.821
960,000	0.970	0.888	0.787	0.697
1,440,000	0.764	0.701	0.624	0.555
2,400,000	0.626	0.576	0.516	0.461
Cheddar & WPC				
720,000	3.083	2.896	2.578	2.378
960,000	2.633	2.479	2.220	2.058
1,440,000	2.191	2.067	1.860	1.728
2,400,000	1.778	1.681	1.526	1.423
Cheddar & Whey Powder				
720,000	3.308	3.098	2.762	2.537
960,000	2.853	2.667	2.401	2.214
1,440,000	2.381	2.237	2.015	1.861
2,400,000	1.995	1.876	1.702	1.575

[1] The Cheddar plants are designed for standard stirred curd process, producing 640 lb blocks of 37% moisture commodity Cheddar. A cheese yield of 10.16 lbs is assumed for all methods with 93% fat retention and no increase in throughput.

[2] Plant capacities are in terms of pounds of raw milk received per day.

Table A33 Manufacturing Costs of Cheddar, WPC and Whey Powder in **1.5X UF** Cheese and Whey Operations for Four Plant Sizes Using Four Operating Schedules[1]

Note: Breakeven is assumed on the UF permeate produced.

Manufacturing Cost & Plant Capacity[2]	Plant Operating Schedules			
	5 Days 18 Hours	6 Days 18 Hours	5 Days 24 Hours	7 Days 24 Hours
	(Dollars Per Cwt of Milk)			
Cheddar				
720,000	2.196	2.077	1.855	1.729
960,000	1.905	1.805	1.625	1.520
1,440,000	1.626	1.541	1.392	1.302
2,400,000	1.367	1.295	1.178	1.102
WPC				
720,000	0.921	0.846	0.742	0.659
960,000	0.741	0.682	0.601	0.536
1,440,000	0.563	0.521	0.460	0.416
,400,000	0.407	0.379	0.340	0.308
Whey Powder				
720,000	1.151	1.052	0.929	0.821
960,000	0.970	0.888	0.787	0.697
1,440,000	0.764	0.701	0.624	0.555
2,400,000	0.626	0.576	0.516	0.461
Cheddar & WPC				
720,000	3.117	2.923	2.597	2.388
960,000	2.646	2.487	2.226	2.056
1,440,000	2.189	2.062	1.852	1.718
2,400,000	1.774	1.674	1.518	1.410
Cheddar & Whey Powder				
720,000	3.347	3.129	2.784	2.550
960,000	2.875	2.693	2.412	2.217
1,440,000	2.390	2.242	2.016	1.857
2,400,000	1.993	1.871	1.694	1.563

[1] The Cheddar plants are designed for standard stirred curd process, producing 640 lb blocks of 37% moisture commodity Cheddar. A cheese yield of 10.16 lbs is assumed for all methods with 93% fat retention and no increase in throughput.

[2] Plant capacities are in terms of pounds of raw milk received per day.

Table A34 Manufacturing Costs of Cheddar, WPC and Whey Powder in **1.2X RO** Cheese and Whey Operations for Four Plant Sizes Using Four Operating Schedules[1]

Note: Breakeven is assumed on the UF permeate produced in the WPC plants.

Manufacturing Cost & Plant Capacity[2]	Plant Operating Schedules			
	5 Days 18 Hours	6 Days 18 Hours	5 Days 24 Hours	7 Days 24 Hours
	(Dollars Per Cwt of Milk)			
Cheddar				
720,000	2.179	2.064	1.844	1.723
960,000	1.898	1.801	1.622	1.519
1,440,000	1.626	1.542	1.393	1.304
2,400,000	1.373	1.302	1.184	1.108
WPC				
720,000	0.922	0.847	0.742	0.660
960,000	0.742	0.683	0.601	0.536
1,440,000	0.565	0.523	0.461	0.417
2,400,000	0.408	0.380	0.340	0.309
Whey Powder				
720,000	1.144	1.045	0.922	0.814
960,000	0.963	0.881	0.780	0.690
1,440,000	0.757	0.694	0.617	0.548
2,400,000	0.619	0.569	0.509	0.455
Cheddar & WPC				
720,000	3.101	2.911	2.586	2.383
960,000	2.640	2.484	2.223	2.055
1,440,000	2.191	2.065	1.854	1.721
2,400,000	1.771	1.682	1.524	1.417
Cheddar & Whey Powder				
720,000	3.323	3.109	2.766	2.537
960,000	2.861	2.682	2.402	2.209
1,440,000	2.383	2.236	2.010	1.852
2,400,000	1.992	1.871	1.693	1.563

[1] The Cheddar plants are designed for standard stirred curd process, producing 640 lb blocks of 37% moisture commodity Cheddar. A cheese yield of 10.16 lbs is assumed for all methods with 93% fat retention with no increase in throughput.

[2] Plant capacities are in terms of pounds of raw milk received per day.

Table A35 Manufacturing Costs of Cheddar, WPC and Whey Powder in **1.2X Evaporation** Cheese and Whey Operations for Four Plant Sizes Using Four Operating Schedules[1]

Note: Breakeven is assumed on the UF permeate produced in the WPC plants.

Manufacturing Cost & Plant Capacity[2]	Plant Operating Schedules			
	5 Days 18 Hours	6 Days 18 Hours	5 Days 24 Hours	7 Days 24 Hours
	(Dollars Per Cwt of Milk)			
Cheddar				
720,000	2.243	2.125	1.900	1.775
960,000	1.952	1.853	1.671	1.565
1,440,000	1.663	1.577	1.424	1.334
2,400,000	1.405	1.332	1.211	1.134
WPC				
720,000	0.922	0.847	0.742	0.660
960,000	0.742	0.683	0.601	0.536
1,440,000	0.565	0.523	0.461	0.417
2,400,000	0.408	0.380	0.340	0.309
Whey Powder				
720,000	1.144	1.045	0.922	0.814
960,000	0.963	0.881	0.780	0.690
1,440,000	0.757	0.694	0.617	0.548
2,400,000	0.619	0.569	0.509	0.455
Cheddar & WPC				
720,000	3.165	2.972	2.642	2.435
960,000	2.694	2.536	2.272	2.101
1,440,000	2.228	2.100	1.885	1.751
2,400,000	1.813	1.712	1.551	1.443
Cheddar & Whey Powder				
720,000	3.387	3.170	2.822	2.589
960,000	2.915	2.734	2.451	2.255
1,440,000	2.420	2.271	2.041	1.882
2,400,000	1.024	1.901	1.720	1.589

[1] The Cheddar plants are designed for standard stirred curd process, producing 640 lb blocks of 37% moisture commodity Cheddar. A cheese yield of 10.16 lbs is assumed for all methods with 93% fat retention with no increase in throughput.

[2] Plant capacities are in terms of pounds of raw milk received per day.

Table A36 Manufacturing Costs of Cheddar, and WPC in **Conventional** Cheese and Whey Operations Using **Automatic Cheddaring** for Four Plant Sizes Using Four Operating Schedules[1]

Notes: 1) These estimates are provided for comparison with the manufacturing costs of using 6.5X UF, which also uses an automatic Cheddaring system.
2) Breakeven is assumed on the UF permeate produced in the WPC plants.

Manufacturing Cost & Plant Capacity[2]	Plant Operating Schedules			
	5 Days 18 Hours	6 Days 18 Hours	5 Days 24 Hours	7 Days 24 Hours
	(Dollars Per Cwt of Milk)			
Cheddar				
720,000	2.253	2.128	1.901	1.770
960,000	1.962	1.857	1.671	1.562
1,440,000	1.651	1.564	1.414	1.322
2,400,000	1.383	1.310	1.195	1.117
WPC				
720,000	0.926	0.850	0.745	0.662
960,000	0.750	0.690	0.606	0.602
1,440,000	0.574	0.531	0.469	0.422
2,400,000	0.409	0.381	0.340	0.309
Cheddar & WPC				
720,000	3.179	2.978	2.646	2.432
960,000	2.712	2.547	2.277	2.164
1,440,000	2.225	2.095	1.883	1.744
2,400,000	1.792	1.691	1.535	1.426

[1] The Cheddar plants are designed for automatic Cheddaring, producing 640 lb blocks of 37% moisture commodity Cheddar. A cheese yield of 10.16 lbs is assumed for all methods with 93% fat retention with no increase in throughput.

[2] Plant capacities are in terms of pounds of raw milk received per day.

Table A37 Manufacturing Costs of Cheddar, and WPC in **6.5X UF** Cheese and Whey Operations for Four Plant Sizes Using Four Operating Schedules[1,2]

Note: Breakeven is assumed on the UF permeate produced in the WPC plants.

Manufacturing Cost & Plant Capacity[2]	Plant Operating Schedules 5 Days 18 Hours	6 Days 18 Hours	5 Days 24 Hours	7 Days 24 Hours
		(Dollars Per Cwt of Milk)		
Cheddar				
720,000	2.487	2.314	2.049	1.870
960,000	1.168	1.020	1.799	1.646
1,440,000	1.800	1.678	1.499	1.374
2,400,000	1.497	1.395	1.253	1.148
WPC				
720,000	0.842	0.775	0.682	0.606
960,000	0.675	0.622	0.550	0.490
1,440,000	0.508	0.471	0.420	0.376
2,400,000	0.355	0.332	0.299	0.271
Cheddar & WPC				
720,000	3.329	3.089	2.731	2.476
960,000	2.843	2.642	2.349	2.136
1,440,000	2.308	2.149	1.919	1.750
2,400,000	1.852	1.727	1.552	1.419

[1] The Cheddar plants are designed for automatic Cheddaring with a DMC, producing 640 lb blocks of 37% moisture commodity Cheddar. A cheese yield of 10.57 lbs is assumed with 93% fat retention with no increase in throughput.

[2] Due to the nature of using 6.5X UF, producing whey powder is not an option with this technology.

[3] Plant capacities are in terms of pounds of raw milk received per day.

Table A38 Estimated Profitability of Cheddar and Whey Operations in **Conventional** Plants Usng No Milk Fractionation/ Concentration Technologies Compared to Plants Using **1.5X UF** with Increased Cheese Yields, Four Plant Sizes[1]

Plant Capacity (Lbs Milk Per Day)	Conventional Cheese Plant 10.16 Lbs/Cwt	1.5X UF Cheese Plant 10.185 Lbs/Cwt	10.21
		Profit ($/Cwt)	
Cheddar and WPC			
720,000	-.38	-.38	-.35
960,000	-.03	-.01	.02
1,440,000	.33	.37	.40
2,400,000	.67	.70	.73
Cheddar and Whey Powder			
720,000	-.71	-.70	-.67
960,000	-.34	-.33	-.30
1,440,000	.04	.07	.10
2,400,000	.36	.39	.42

[1] All plants receive the same amount of milk and are assumed to be operating 5 days per week, 24 hours per day with 93% fat retention.

[2] If Cheddar yields increased due to using 1.5X UF in the cheese plant, whey product yields would decline slightly. This is taken into account in the profitability calculations.

[3] Product prices used in determining these profitability estimates can be found in Table 4 in the main document.

Table A39 Estimated Profitability of Cheddar and Whey Operations in Conventional Plants Using No Milk Fractionation/ Concentration Technologies Compared to Plants Using 1.2X RO with Increased Cheese Yields, Four Plant Sizes[1]

Plant Capacity (Lbs Milk Per Day)	Conventional Cheese Plant 10.16 Lbs/Cwt	1.2X RO Cheese Plant 10.20 Lbs/Cwt	10.24 Lbs/Cwt
		Profit ($/Cwt)	
Cheddar and WPC			
720,000	-.38	-.35	-.30
960,000	-.03	-.02	.06
1,440,000	.33	.38	.43
2,400,000	.67	.72	.76
-Cheddar and Whey Powder			
720,000	-.71	-.66	-.62
960,000	-.34	-.30	-.25
1,440,000	.04	.09	.14
2,400,000	.36	.41	.46

[1] All plants receive the same amount of milk and are assumed to be operating 5 days per week, 24 hours per day with 93% fat retention.

[2] If Cheddar yields increased due to using 1.2X RO in the cheese plant, whey product yields would decline slightly. This is taken into account in the profitability calculations.

[3] Product prices used in determining these profitability estimates can be found in Table 4 in the main document.

Table A40 Estimated Profitability of Cheddar and Whey Operations in Conventional Plants Using No Milk Fractionation/ Concentration Technologies Compared to Plants Using **1.2X Evaporation** with Increased Cheese Yields, Four Plant Sizes[1]

Plant Capacity (Lbs Milk Per Day)	Conventional Cheese Plant 10.16 Lbs/Cwt	1.2X Evaporation Cheese Plant 10.20 Lbs/Cwt	10.24 Lbs/Cwt
		Profit ($/Cwt)	
Cheddar and WPC			
720,000	-.38	-.40	-.36
960,000	-.03	-.03	.01
1,440,000	.33	.35	.40
2,400,000	.67	.69	.73
Cheddar and Whey Powder			
720,000	-.71	-.72	-.67
960,000	-.34	-.35	-.30
1,440,000	.04	.06	.11
2,400,000	.36	.38	.43

[1] All plants receive the same amount of milk and are assumed to be operating 5 days per week, 24 hours per day with 93% fat retention.

[2] If Cheddar yields increased due to using 1.2X evaporation in the cheese plant, whey product yields would decline slightly. This is taken into account in the profitability calculations.

[3] Product prices used in determining these profitability estimates can be found in Table 4 in the main document.

Table A41 Composition and Yields of Milk, Cheese, and WPC When Using 6.5X UF in a 960,000 lb Capacity Plant, **Assuming a 4% Increase in Cheese Yields**[1]

	Lbs	Percent
RAW MILK	960,000	
Fat	35,328.00	3.680
Protein	31,454.40	3.276
Lactose	46,080.00	4.800
CREAM	5,073	
Fat	2,029.20	40.000
Protein	103.49	2.040
Lactose	151.68	2.990
STANDARDIZED MILK	965,073	
Fat	37,357.20	3.871
Protein (total nitrogen)	31,557.89	3.270
Casein	24,615.15	2.551
Whey Protein	5,364.84	0.556
Non-Protein Nitrogen	1,577.89	0.164
Lactose	46,231.68	4.790
Minerals	6,720.00	0.696
6.5X UF RETENTATE	148,472.70	
Fat	37,357.20	25.161
Protein (total nitrogen)	30,222.74	20.356
Casein	24,615.15	16.582
Whey Protein	5,364.84	3.614
Non-Protein Nitrogen	242.75	0.164
Lactose	7,112.57	4.790
Minerals	4,776.58	3.217
UF PERMEATE	816,600.20	
Non-Protein Nitrogen	1,335.14	0.164
Lactose	39,119.11	4.790
Minerals	1,943.42	0.238
Permeate Solids	42,397.68	5.192
UF CHEESE YIELD (**10.566 lbs/cwt**)	101,437.40	
Fat	34,742.19	34.250
Protein (total nitrogen)	24,344.98	24.000
Casein	23,630.54	23.300
Non-Protein Nitrogen	67.96	0.067
Lactose	1,795.44	1.770
Minerals	2,262.05	2.230

Table A41 Composition and Yields of Milk, Cheese, and WPC When Using 6.5X UF in a 960,000 lb Capacity Plant, **Assuming a 4% Increase in Cheese Yields** cont.[1]

UNSEPARATED UF WHEY	47,035.32	
Fat	2,615.00	5.560
Protein (total nitrogen)	5,877.76	12.496
Non-Protein Nitrogen	174.79	0.372
Lactose	5,317.12	11.305
Minerals	2,514.52	5.346
Solids	16,324.40	34.707
UNSEPARATED UF WHEY (with some UF permeate added)	110,566.81	
Fat	2,615.00	2.365
Protein (total nitrogen)	5,877.76	5.316
Non-Protein Nitrogen	278.66	0.252
Lactose	8,360.59	7.562
Minerals	2,665.72	2.411
Solids	19,622.94	17.748
WHEY CREAM	6,486.52	
Fat	2,594.61	40.000
Protein (total nitrogen)	211.91	3.267
Non-Protein Nitrogen	10.05	0.155
Lactose	301.42	4.647
Minerals	96.11	1.482
Solids	3,204.04	49.395
SEPARATED UF WHEY	104,080.30	
Fat	20.40	0.020
Protein (total nitrogen)	5,665.85	5.444
Non-Protein Nitrogen	268.62	0.258
Lactose	8,059.17	7.743
Minerals	2,569.61	2.469
Solids	16,418.91	15.775

Protein as Percent of Solids = 34.5%

Theoretical WPC Yield = 16,926.71 lbs (1.763 lbs per cwt raw milk)

Expected WPC Yield (80% of theoretical) = 13,541.37 lbs (1.411 lbs per cwt raw milk)

[1] Assumes plant is operating at full capacity, but with no increased throughput.

Table A42 Composition and Yields of Milk, Cheese, and WPC When Using 6.5X UF in a 960,000 lb Capacity Plant, **Assuming a 6% Increase in Cheese Yields**[1]

	Lbs	Percent
RAW MILK	960,000	
Fat	35,328.00	3.680
Protein	31,476.50	3.279
Lactose	46,080.00	4.800
CREAM	6,870	
Fat	2,748.00	40.000
Protein	140.15	2.040
Lactose	205.41	2.990
STANDARDIZED MILK	966,870	
Fat	38,076.00	3.938
Protein (total nitrogen)	31,616.65	3.270
Casein	24,660.98	2.551
Whey Protein	5,374.83	0.556
Non-Protein Nitrogen	1,580.83	0.164
Lactose	46,285.41	4.787
Minerals	6,720.00	0.695
6.5X UF RETENTATE	148,749.20	
Fat	38,076.00	25.597
Protein (total nitrogen)	30,279.02	20.356
Casein	24,660.98	16.579
Whey Protein	5,374.83	3.613
Non-Protein Nitrogen	243.20	0.164
Lactose	7,120.83	4.787
Minerals	4,776.58	3.211
UF PERMEATE	818,120.80	
Non-Protein Nitrogen	1,337.63	0.164
Lactose	39,164.58	4.787
Minerals	1,943.42	0.238
Permeate Solids	42,445.63	5.188
UF CHEESE YIELD (**10.770 lbs/cwt**)	103,388.10	
Fat	34,410.68	34.250
Protein (total nitrogen)	24,813.15	24.000
Casein	23,674.54	22.900
Non-Protein Nitrogen	67.27	0.067
Lactose	1,829.97	1.770
Minerals	2,305.56	2.230

Table A42 Composition and Yields of Milk, Cheese, and WPC When Using 6.5X UF in a 960,000 lb Capacity Plant, **Assuming a 6% Increase in Cheese Yields** cont.[1]

UNSEPARATED UF WHEY	45,361.07	
Fat	2,665.32	5.876
Protein (total nitrogen)	5,465.86	12.050
Non-Protein Nitrogen	173.93	0.383
Lactose	5,290.86	11.664
Minerals	2,471.02	5.447
Solids	15,893.06	35.037
UNSEPARATED UF WHEY (with some UF permeate added)	95,266.43	
Fat	2,665.32	2.798
Protein (total nitrogen)	5,465.86	5.737
Non-Protein Nitrogen	255.53	0.268
Lactose	7,679.90	8.061
Minerals	2,589.57	2.718
Solids	18,428.24	19.401
WHEY CREAM	6,611.33	
Fat	2,644.53	40.000
Protein (total nitrogen)	234.14	3.541
Non-Protein Nitrogen	10.95	0.166
Lactose	328.99	4.976
Minerals	110.93	1.678
Solids	3,318.59	50.196
SEPARATED UF WHEY	88,655.11	
Fat	20.79	0.023
Protein (total nitrogen)	5,231.72	5.901
Non-Protein Nitrogen	244.58	0.276
Lactose	7,350.91	8.292
Minerals	2,478.64	2.796
Solids	15,163.65	17.104

Protein as Percent of Solids = 34.5%

Theoretical WPC Yield = 15,632.63 lbs (1.628 lbs per cwt raw milk)

Expected WPC Yield (80% of theoretical) = 12,506.10 lbs (1.303 lbs per cwt raw milk)

[1] Assumes plant is operating at full capacity, but with no increased throughput.

Table A43 Composition and Yields of Milk, Cheese, and WPC When Using 6.5X UF in a 960,000 lb Capacity Plant, **Assuming a 8% Increase in Cheese Yields**[1]

	Lbs	Percent
RAW MILK	960,000	
Fat	35,328.00	3.680
Protein	31,498.58	3.281
Lactose	46,080.00	4.800
CREAM	8,665	
Fat	3,466.00	40.000
Protein	176.77	2.040
Lactose	259.08	2.990
STANDARDIZED MILK	968,665	
Fat	38,794.00	4.005
Protein (total nitrogen)	31,675.35	3.270
Casein	24,706.76	2.551
Whey Protein	5,384.81	0.556
Non-Protein Nitrogen	1,583.77	0.164
Lactose	46,339.08	4.784
Minerals	6,720.00	0.694
6.5X UF RETENTATE	149,025.30	
Fat	38,794.00	26.032
Protein (total nitrogen)	30,335.23	20.356
Casein	24,706.76	16.579
Whey Protein	5,384.81	3.613
Non-Protein Nitrogen	243.66	0.164
Lactose	7,129.09	4.784
Minerals	4,776.58	3.205
UF PERMEATE	819,639.70	
Non-Protein Nitrogen	1,340.11	0.164
Lactose	39,209.99	4.784
Minerals	1,943.42	0.237
Permeate Solids	42,493.52	5.184
UF CHEESE YIELD (**10.973 lbs/cwt**)	105,338.80	
Fat	36,078.42	34.250
Protein (total nitrogen)	25,281.33	24.000
Casein	23,718.49	22.516
Non-Protein Nitrogen	70.58	0.067
Lactose	1,864.50	1.770
Minerals	2,349.06	2.230

Table A43 Composition and Yields of Milk, Cheese, and WPC When Using 6.5X UF in a 960,000 lb Capacity Plant, **Assuming a 8% Increase in Cheese Yields** cont.[1]

UNSEPARATED UF WHEY	43,686.50	
Fat	2,715.58	6.216
Protein (total nitrogen)	5,053.90	11.569
Non-Protein Nitrogen	173.08	0.396
Lactose	5,264.59	12.051
Minerals	2,427.52	5.557
Solids	15,461.59	35.392
UNSEPARATED UF WHEY (with some UF permeate added)	79,832.61	
Fat	2,715.58	3.402
Protein (total nitrogen)	5,053.90	6.331
Non-Protein Nitrogen	232.18	0.291
Lactose	6,993.75	8.761
Minerals	2,513.22	3.148
Solids	17,335.55	21.715
WHEY CREAM	6,736.00	
Fat	2,694.40	40.000
Protein (total nitrogen)	264.87	3.932
Non-Protein Nitrogen	12.17	0.181
Lactose	366.53	5.441
Minerals	131.71	1.955
Solids	3,457.51	51.329
SEPARATED UF WHEY	73,096.61	
Fat	21.18	0.029
Protein (total nitrogen)	4,789.04	6.552
Non-Protein Nitrogen	220.01	0.301
Lactose	6,627.22	9.066
Minerals	2,381.51	3.258
Solids	13,878.04	18.986

Protein as Percent of Solids = 34.5%

Theoretical WPC Yield = 14,307.26 lbs (1.490 lbs per cwt raw milk)

Expected WPC Yield (80% of theoretical) = 11,445.80 lbs (1.192 lbs per cwt raw milk)

[1] Assumes plant is operating at full capacity, but with no increased throughput.

Permeate Handling and Sensitivity Analysis

Because of permeate's low solids content and high volume and perishability, processing it to recover the milk solids is very costly. In most cases, the value of low-purity lactose (i.e. dried permeate) is relatively low, while drying costs can be quite high. However, further processing and purification of the lactose can substantially increase its value, particularly for specialized pharmaceutical applications. Unfortunately, the current supply of lactose exceeds the demand, especially for the higher value lactose products. Thus, a producer of WPC (regardless of technology) must have an outlet for either the raw permeate (e.g. landspreading, animal feed, etc.), or feel assured enough of a continuing market for higher value products to undertake the processing costs.

No permeate processing is required for Cheddar and whey powder operations, even when using milk fractionation/concentration in the cheese plant. As an example, if 1.5X UF was used to make Cheddar, the UF permeate would be mixed back with the whey from the cheese vats prior to producing whey powder, thus resulting in no change in whey volume and no permeate to be processed. However, regardless of technology (and assuming values of $0.18 and $0.72 per lb of whey powder and WPC respectively), it would remain more profitable to produce WPC than whey powder until permeate handling losses exceeded $0.06 per lb of permeate solids.

Profitability Sensitivity to Permeate Assumptions

Due to the variety of options for permeate handling, as well as the high level of uncertainty, the following assumption was made. In all cost/profitability analyses of cheese and WPC operations (including conventional plants as well as 1.5X UF, 1.2X RO, and 1.2X evaporation), it was assumed that any permeate processing costs (including capital investment costs) would be covered by revenues received for the permeate end-product, whatever that might be (i.e. a breakeven situation).

However, realizing that the effects on Cheddar and WPC profitability of possible gains or losses from permeate would be large, a sensitivity analysis was performed based on various levels of profit or loss realized from each lb of permeate solids (Table P?). Because the amount of permeate solids remains constant per cwt of raw milk, the effect of either a gain or loss of revenues from permeate is also constant per cwt of raw milk, regardless of plant size.

Table 44 Effects of Gains or Losses in Handling Permeate on Cheddar and WPC Profitability for Conventional Cheese Plants and Plants Using 1.5X UF, 1.2X RO, and 1.2X Evaporation for All Plant Sizes[1]

Permeate Handling Gain or Loss (Dollars/Lb Permeate Solids)	Effects on Profitability Per Cwt of Raw Milk
	(Dollars per Cwt)
$0.02 Gain	+$0.07
Breakeven	0
$0.02 Loss	-$0.07
$0.06 Loss	-$0.22
$0.12 Loss	-$0.44

[1] Assumes Cheddar and WPC yields of 10.16 and 1.64 lbs respectively per cwt raw milk, with 3.64 lbs of permeate solids per cwt raw milk.

Other Agricultural Economics Research Publications

No. 91-02	1991 Budget Guide, Estimated Prices for Crop Operating Inputs and Capital Investments Items	Darvin P. Snyder
No. 91-03	Meeting the Needs: A Summary and Evaluation of New York FarmNet	John R. Brake Bill Phelan
No. 91-04	U.S. Commodity Promotion Organizations: Objectives, Activities and Evaluation Methods	John E. Lenz Olan D. Forker Susan Hurst
No. 91-05	Dairy Farm Management Business Summary New York	Stuart F. Smith Wayne A. Knoblauch Linda D. Putnam
No. 91-06	The Budgetary Implications of Reducing US Income Inequality Through Income Transfer Programs	Richard N. Boisvert Christine Ranney
No. 91-07	Annotated Bibliography of Generic Commodity Promotion Research (Revised)	Susan Hurst Olan Forker
No. 91-08	Geographic Price Relationships Under Federal Milk Marketing Orders	Andrew Novakovic James Pratt
No. 91-09	Dairypert: An Expert Systems Approach for Improving Dairy Farm Management Practices	Robert J. Kalter Andrew L. Skidmore
No. 91-10	Measuring Hicksian Welfare Changes from Marshallian Demand Functions	Jesus C. Dumagan Timothy D. Mount
No. 92-01	Comparison of the Economics of Cheddar Cheese Manufacture by Conventional and Milk Fractionation/Concentration Technologies	Richard D. Aplin David M. Barbano Susan J. Hurst