



dairymark.com

Dairy permeates - a strategic review of opportunities and applications

Report #3 in DairyMark.com's 'Target business opportunities' series of publications

September 2007

Dairymark.com
A division of Shainwright Consulting and Research Group Pty Ltd
PO Box 3274
Norwood, SA 5067
AUSTRALIA

Email: info@dairymark.com





dairymark.com

Dairy permeates – a strategic review of opportunities and applications

A new report on dairy permeates reveals that not only is dairy permeate volume growing, but that conventional wisdom on disposal and utilization must be overcome if a more complete use and exploitation of this resource is to be addressed. The very fundamental of this is to develop a new recognition of dairy permeates as a rich source of carbohydrate – such carbohydrate can, in its own right, provide current growth and yet further emerging strategic value-added commercial opportunities for the dairy industry.

The report is the third in a series of publications produced by Dairymark.com entitled 'Target business opportunities'. It provides a solid overview of the nature and characteristics of dairy permeate utilisation arising from two key features:

- Developments in technology that are providing new and more commercial options for dairy permeate handling and processing
- Growing demand for a range of non-traditional value-added products in a wide sphere of industry sectors, including: food, feed, pharmaceutical, medical, cosmeceutical and technical

"There are two fundamental issues constraining ready disposal or use of dairy permeate", says Dairymark.com, publisher of the report, adding, "The high BOD of permeate along with increasingly stringent environmental regulations means that discarding the material in waterways is no longer an option for most companies. And building on this, the hygroscopic nature of the material has meant that traditional dairy industry drying practices are difficult for downstream processing of permeate".

The report discusses issues such as:

- New technology that allows the drying of highly hygroscopic dairy permeate
- Decalcification as a means of improving the quality of both lactose and permeate for further processing, with marketable milk calcium arising as a co-product
- Improvements in the processing of lactose derivatives that opens up new market opportunities. Examples that are discussed in some detail include:
 - Developments in the supply of lactulose anhydrate, as a more convenient material than its conventional concentrated syrup alternative
 - Fermentation practices and enzymatic oxidation providing high yield lactobionic acid for more mainstream market applications
- Commercial applications for mother liquor arising from lactose manufacture
- Established growth markets for a range of lactose derivatives, including lactulose and lactitol
- Growing interest in ethanol produced from whey permeate – not only for use as a fuel blend, but also in terms of commercial production for ultra-high purity spirits and lower purity industrial solvents

The report contains approximately 145 pages, and can be purchased for €uros 7,710 (Australian subscribers A\$13,570 including GST). For further information, contact:

Dairymark.com
A division of Shainwright Consulting and Research Group Pty Ltd
PO Box 3274
Norwood, SA 5067
AUSTRALIA

Telephone/Facsimile: +61-8-8339 8185

Email: info@dairymark.com



Scope and objectives of the report

The report considers strategic business opportunities for dairy industry participants in terms of opportunities and applications for dairy permeate. Opportunities are considered from two quite distinct though inter-related perspectives – each of which recognizes dairy permeate as a rich source of dairy carbohydrate rather than a more orthodox view on permeate as a waste stream that is proving problematic in disposal terms. The focus is on:

- The adoption of novel technology that provides a competitive edge in dairy permeate processing and utilization
- The development of commercial products that are aimed at both established growth markets and yet further emerging market opportunities

The report recognizes that the dairy permeate issue is a mounting concern for dairy processors – and particularly those that are producing WPC/WPI and MPC (which are themselves growth opportunities that in turn create increasing volumes of dairy permeates).

Real-life company examples are given discussing how some of the world's leading dairy companies are dealing with the dairy permeate issue. Dairy companies that are discussed include:

- Valio
- Fromageries Bel
- Murray Goulburn Co-operative
- Dairy Farmers of America
- Fonterra Co-operative Group
- Muller
- Carbery Group
- Morinaga Milk
- Kraft Foods

In addition, practical examples are discussed on the experiences of equipment suppliers, research organizations, and companies allied to the dairy industry (Illovo Sugar, Purac, Danisco, and Solvay Pharmaceuticals).

Pricing & timing:

The report is available to subscribers in hard copy format, dispatched by courier on receipt of payment.

- Orders will be priced at €uros 7,710 (Australian subscribers A\$13,570 including GST)
- Report available September 2007



Report Content: Table of contents

List of Tables	v
List of Figures	vii
Glossary of terms and abbreviations	viii
1. Executive Summary and Strategic Synopsis	1
1.1. Introduction.....	1
1.2. Executive summary	1
1.3. Executive Synopsis	3
2. Modified Milk Powder Made from Dairy Permeate – the Murray Goulburn Experience..	15
2.1. Murray Goulburn – background to the company.....	15
2.2. Manufacturing a modified milk powder from dairy permeate feedstock	16
2.3. Uses and applications	19
3. Permeate Drying – A Commercial Low Cost Process	22
3.1. Niro A/S – background to the company.....	22
3.2. The TIXOTHERM™ process.....	23
4. Ethanol from whey	27
4.1. Overview	27
4.2. Carbery Group.....	29
4.3. Earthanol, Inc	32
4.4. Melrose Dairy Proteins	33
4.5. Molkerei Alois Muller GmbH & Co.....	34
4.6. Golden Cheese Company of California.....	35
4.7. Recent research into ethanol production from whey	35
4.8. Ethanol as a transportation fuel – a U.S. perspective	37
5. Fonterra Co-operative Group – Ethanol Manufacture	39
5.1. Background to the company.....	39
5.2. Overview of Fonterra’s ethanol operations.....	39
5.3. Fonterra’s process - ethanol from acid whey	41
5.4. The crude economics of making ethanol from casein whey permeate	45
5.5. Expanding Fonterra’s ethanol production to N.Z., Australian & U.S. sites.....	46
5.6. Anchor Ethanol product range.....	46
5.7. End use applications for Anchor Ethanol products.....	48
5.8. Anchor Ethanol export trade.....	48
5.9. Bioethanol for fuel – the New Zealand perspective.....	48
5.10. Bioethanol for fuel – Fonterra’s understanding	50
5.11. Gull launch of whey permeate based bioethanol in New Zealand	50
5.12. Industry and public response to the Gull Force launch	51
6. Single cell protein production from whey	52
6.1. Background	52
6.2. Understanding the process	53
6.3. Industry considerations	54
6.4. Choice of substrate and process models	54
6.5. Whey and UF permeate in SCP manufacture	55
6.6. Food & feed applications for SCP	58
6.7. Economic considerations in SCP	58
6.8. SCP production using kefir yeast from liquid whey effluent	60
7. A Bio-processing Approach to Organic Acids from Whey	62
7.1. Issues with conventional bio-processing	62
7.2. A novel bio-reactor design to overcome constraints	62
7.3. A novel two-stage extractive process	63
7.4. Products arising from a continuous extractive fermentation process using immobilized cell bioreactors	63
7.5. Continuous extractive fermentation process using immobilized cell bioreactors with whey permeate feedstock... ..	64



8 Lactic Acid from UF Whey	66
8.1. Overview of lactic acid.....	66
8.2. Novel technology for manufacturing lactic acid from whey permeate	67
8.3. Mass balance	70
8.4. Capital costs.....	70
8.5. Operating costs	71
9. Polylactic Acid from Whey Permeate	72
9.1. Background	72
9.2. Cargill and other corporate initiatives	72
9.3. Dairy Farmers of America – Hycail PLA venture utilizing whey permeate feedstock	73
9.4. Economics of PLA manufacture – Cargill and Hycail perspectives.....	74
10. Mother Liquor as a Commercial Feed Opportunity – the Fonterra Experience	75
10.1. Proliq from mother liquor	75
10.2. Composition of Proliq	78
10.3. Farm set-up	80
10.4. Proliq versus alternative feed systems for dairy calves.....	81
10.5. Fonterra’s Proliq delivery & price arrangements	82
11. Fonterra Lactose/Mother Liquor Processes	83
11.1. Background	83
11.2. Kapuni site.....	83
11.3. Clandeboye site.....	85
11.4. Edendale site.....	88
11.5. Stirling site	90
12. Lactulose	93
12.1. Overview	93
12.2. Solvay Pharmaceuticals	96
13. Other Lactulose Businesses Exploiting Growing Market Opportunities	102
13.1. Illovo Sugar Limited – a non-dairy lactulose industry participant	102
13.2. Relax Limited.....	104
13.3. Morinaga – novel lactulose powder technology	108
14. Lactitol	113
14.1. Product overview.....	113
14.2. Danisco A/S.....	115
14.3. Purac Biochem	118
15. Lactobionic Acid Opportunities Depend on Increasing Commercial Yields.....	121
15.1. Background overview	121
15.2. Current and purported applications for lactobionic acid	123
15.3. High yielding lactobionic acid production using fermentation techniques	123
15.4. High yielding enzymatic oxidation process for lactobionic acid production	125
15.5. Use of lactobionic acid in mineral complexes for fortification of foods	126
15.6. Lactobionic acid use in cosmeceuticals	127
16. Whey salt from permeate.....	129
16.1. Issues and opportunities for whey salt	129
16.2. Valio’s whey salt technology	130
16.3. Whey salt cheese as a partial salt replacer in white salted cheese	134
16.4. Salt whey recovery	134
17. Milk Calcium from Permeate – Value-adding Extraction Strategies	137
17.1. Calcium as an ingredient – description and global market size	137
17.2. Milk calcium – key global supplier overview.....	137
17.3. Milk calcium global markets	139
17.4. Milk calcium as a fortifying agent	140
17.5. Conventional milk calcium processing	140
17.6. De-calcification of UF permeate as a milk calcium source.....	142



Report Content: List of Tables

Table 1: Overview of Murray Goulburn Co-operative manufacturing product mix	15
Table 2: Overview of production at Murray Goulburn plants	16
Table 3: Use of permeate-derived milk powders in food processing trials	20
Table 4: Conventional methods of further permeate processing	23
Table 5: Comparative energy consumption - TIXOTHERM™ vs. conventional process.....	26
Table 6: TIXOTHERM™ industrial plant available.....	26
Table 7: Carbery Group Anhydrous Ethanol Specification	30
Table 8: Carbery Group Neutral Spirit Specifications ^[1]	30
Table 9: Additional tests & specifications – Carbery Neutral Spirits ^[1]	31
Table 10: Anchor Ethanol – plant overview	40
Table 11: Potential further sites worldwide where Fonterra could manufacture ethanol from whey permeate	46
Table 12: Product Specifications – Anchor Ethyl Alcohol	47
Table 13: Types and end use applications for ethanol grades	48
Table 14: Micro-organisms used for SCP production using various carbon sources	52
Table 15: Effect of salinity of the whey on kefir production.....	61
Table 16: Removal of organic load in whey aerobic fermentation using kefir yeast in high capacity experiments.....	61
Table 17: Specifications for different types of lactic acid	66
Table 18: Composition of whey UF permeate used as feedstock	67
Table 19: Ionic composition of the clarified fermentation broth	69
Table 20: Mass balance of the lactic acid process proposed	70
Table 21: Costs for processing components in proposed lactic acid production plant	70
Table 22: Annual operating costs for lactic acid production	71
Table 23: Processing costs per stage.....	71
Table 24: Comparison of nutrient composition of Proliq versus competitive feed sources.....	77
Table 25: Typical analysis for Proliq	78
Table 26: Amino acid composition of Proliq.....	79
Table 27: Vitamin composition of Proliq	79
Table 28: Proliq mineral profile	80
Table 29: Indicated itemised set-up cost for Proliq system for 500 head dairy farm	81
Table 30: Comparison of common feedstuffs for calves (DM equivalent basis).....	81
Table 31: Estimated composition of whole milk/Proliq blends	82
Table 32: Composition of mother liquor arising from Clandeboye site	87
Table 33: Key events & effect of variables in Clandeboye mother liquor processing.....	88
Table 34: Typical composition of Vialac derived from whole protein whey.....	88
Table 35: Typical analysis – RO concentrate from Fonterra's Stirling plant	92
Table 36: Lactose & mother liquor production and yield data – Fonterra Stirling plant	92
Table 37: Ranking of lactulose amongst the leading pharmaceutical actives by value and volume	95
Table 38: Solvay's market position –global pharmaceutical industry	96
Table 39: Solvay Pharmaceuticals – typical analysis lactulose concentrate (50% w/w) ex Victoriaville plant.....	97
Table 40: Solvay Pharmaceuticals – typical analysis lactulose liquid 667g/l (50% w/w) ex Weesp plant	98



Table 41: Solvay Pharmaceuticals – typical analysis lactulose liquid 720g/l (54% w/w) ex Weesp plant	99
Table 42: Packaging of Solvay Pharmaceuticals' lactulose product.....	99
Table 43: Relax lactulose concentrate 66.0% (w/v).....	105
Table 44: Relax lactulose concentrate 70.0% (w/v).....	106
Table 45: Relax's international market profile for lactulose concentrate	107
Table 46: Morinaga lactulose powder trial procedures and results	112
Table 47: A comparison of key attributes – polyols	114
Table 48: Product data – Lacty-M from Purac	119
Table 49: Lonza data sheet on lactobionic acid.....	121
Table 50: Data sheet – Lonza Ltd lactobionic acid	122
Table 51: Novozymes enzymatic process – lactobionic acid production.....	125
Table 52: Typical mineral composition of whey (% by weight of DM).....	129
Table 53: Typical analysis of Valio's whey salt powders	131
Table 54: Typical composition of permeate mother liquor (% by weight DM).....	132
Table 55: Composition of whey salt from different feedstock sources (% by weight).....	133
Table 56: Typical analysis of key constituents of salt whey from cheddaring process	135
Table 57: Salt whey inclusion levels in various processed cheese products.....	136
Table 58: Typical composition of permeate feedstock (% of TS)	142
Table 59: Typical composition milk calcium.....	145



Report Content: List of Figures

Figure 1: Flow Chart – Preparation of Reduced-protein SMP from Dairy Permeate	18
Figure 2: Flow Chart – Preparation of Reduced-protein FCMP from Dairy Permeate.....	19
Figure 3: Flow Chart - TIXOTHERM™ Process for Dairy Permeate Processing	25
Figure 4: Dairy site process overview	28
Figure 5: Overview of ethanol from acid whey process	41
Figure 6: The distillation flow pattern for Fonterra's Reporoa distillery	42
Figure 7: Fonterra's Edgecumbe Ethanol Manufacturing Process	43
Figure 8: Growth curve of yeast used in ethanol manufacture from whey.....	44
Figure 10: Process for 50% food grade lactic acid production from whey permeate.....	68
Figure 11: Lactose and mother liquor processing – Fonterra Kapuni site	84
Figure 12: Kapuni monthly mother liquor production (million litres volume)	85
Figure 13: Lactose and mother liquor processing – Fonterra Clandeboye site	86
Figure 14: Clandeboye monthly mother liquor production (million litres volume)	87
Figure 15: Lactose and mother liquor processing – Fonterra Edendale site	89
Figure 16: Edendale monthly mother liquor production (million litres volume)	90
Figure 17: RO concentrate processing – Fonterra Stirling site	91
Figure 18: Illovo value-added production trends (mt, 1997-2006)	103
Figure 19: Illovo Sugar's Lactulose Network	104
Figure 20: Global split of milk calcium markets	139
Figure 21: Generic milk calcium process flow	141
Figure 22: GEA Filtration's decalcification process	144



Dairymark.com's credentials

Dairymark.com is a division of Shainwright Consulting & Research Group Pty Ltd, and is a specialist dairy industry intelligence and consulting organization. The company has completed a number of strategic, market and business development dairy research assignments for Australian and international clients. Recent examples include:

- Bangladesh dairy market study
- An overview of global dairy supply and demand
- A longitudinal dairy pricing study
- A strategic review of dairy industry patent activity
- A strategic review of dairy R&D activity
- A strategic review of trends in whey permeate utilization
- A study of the Australasian dairy industry
- Strategic research identifying trends and opportunities in Asian feed markets for dairy ingredients

In addition the company has published multi-client reports, including:

- Milk ingredients – a strategic review of opportunities and applications in the oral care industry
- Dairy carbohydrates – a strategic review of opportunities and applications

Contact details are advised as follows:

Dairymark.com
A division of Shainwright Consulting and Research Group Pty Ltd
PO Box 3274
Norwood, SA 5067
AUSTRALIA

Email: info@dairymark.com

Telephone/Facsimile: +61-8-8339 8185

COPYRIGHT

Information contained in Dairymark.com reports is confidential and for use only by clients and subscribers of Dairymark.com with valid contracts.

No part of this publication may be copied, reproduced, stored in a retrieval system, or transmitted in any form by any means electronic, mechanical, photocopying, recording or otherwise without the written permission of the publisher. All material published within this report is copyright Dairymark.com, a division of Shainwright Consulting & Research Group Pty Ltd.

LIABILITY

Whilst every effort has been made to ensure that the information contained in this report is accurate and the opinions expressed are sound, Shainwright Consulting & Research Group Pty Ltd cannot be made liable for any errors, omissions or incorrect information or for any loss or consequential losses arising as a result of decisions taken based on the contents of this report.