

Detergent Alcohols

Table of Contents

A Report by NexantThinking™

Process Evaluation/Research Planning (PERP) Program

PERP Report 2014S10– Published December 2014

www.nexantthinking.com

Section	Page
1 Executive Summary	1
1.1 TECHNOLOGY OVERVIEW.....	2
1.1.1 Synthetic Routes	2
1.1.2 Natural Routes	6
1.2 PROCESS ECONOMICS OVERVIEW	10
1.3 MARKET OVERVIEW	13
1.3.1 Applications of Detergent Range Alcohols.....	13
1.3.2 Demand.....	14
1.3.3 Supply	15
1.3.4 Supply, Demand, and Trade	16
1.3.5 Global Trade.....	16
2 Introduction	18
2.1 THE ROLE OF DETERGENT ALCOHOLS IN THE INDUSTRY.....	18
2.2 VALUE CHAIN ANALYSIS.....	20
2.3 TECHNOLOGY OVERVIEW.....	21
2.3.1 Synthetic Route Overview	21
2.3.2 Natural Route Overview	22
3 Technologies Based on Synthetic Routes	24
3.1 OVERVIEW	24
3.2 PROCESS CHEMISTRY.....	24
3.2.1 Hydroformylation	24
3.2.2 Ziegler Process	27
3.3 ALCOHOLS PRODUCED VIA OLEFIN HYDROFORMYLATION.....	28
3.3.1 Conventional Oxo Alcohol Process.....	28
3.3.2 Shell's Modified Oxo Process	33

3.4	ALCOHOLS PRODUCED VIA ZIEGLER PROCESSES	36
3.4.1	Overview	36
3.4.2	Alfol Process	36
3.4.3	Epal Process	37
3.5	DEVELOPMENTS IN THE SYNTHETIC ROUTES	39
4	Technologies Based on Natural Routes.....	40
4.1	OVERVIEW	40
4.2	NATURAL OIL FEEDSTOCK.....	40
4.2.1	Palm Kernel Oil (PKO)	41
4.2.2	Coconut Oil (CNO)	42
4.3	PROCESS CHEMISTRY.....	42
4.3.1	Methyl Ester Route.....	42
4.3.2	Fatty Acid Route.....	44
4.4	LURGI TECHNOLOGY	45
4.4.1	Historical Developments – Direct Hydrogenation of Fatty Acids	45
4.4.2	Production of Fatty Alcohols via Methyl Esters using a Fixed Bed Process	48
4.4.3	Production of Fatty Alcohols via Wax Ester Route	53
4.5	DAVY TECHNOLOGY	57
4.5.1	Production of Fatty Alcohols via Methyl Esters	57
4.5.2	Developments in the Davy Process	61
4.6	OTHER TECHNOLOGIES AND DEVELOPMENTS IN NATURAL ROUTES	62
4.6.1	Variation in the Methyl Ester Route.....	62
4.6.2	Production of Fatty Alcohols Based on Biosynthesis Route	64
5	Process Economics.....	65
5.1	OVERVIEW	65
5.2	COSTING BASIS	65
5.2.1	Investment Basis	65
5.2.2	Pricing Basis.....	66
5.2.3	Cost of Production Basis	66
5.3	PRODUCTION COST ESTIMATES.....	67
5.3.1	Synthetic Alcohols	67
5.3.2	Natural Alcohols	83
5.4	SUMMARY OF COST ESTIMATES	93
5.5	SENSITIVITY ANALYSIS OF COST OF PRODUCTION	96

5.5.1	Sensitivity to Raw Material Price	96
5.5.2	Sensitivity to Capacity	97
6	Regional Market Analysis.....	99
6.1	GLOBAL SUMMARY.....	99
6.1.1	Applications of Detergent Range Alcohols.....	99
6.1.2	Demand.....	100
6.1.3	Supply	100
6.1.4	Supply, Demand, and Trade	101
6.1.5	Global Trade.....	102
6.2	NORTH AMERICA	103
6.2.1	Demand.....	103
6.2.2	Supply	103
6.2.3	Supply, Demand, and Trade	103
6.3	WESTERN EUROPE	105
6.3.1	Demand.....	105
6.3.2	Supply	105
6.3.3	Supply, Demand, and Trade	106
6.4	SOUTHEAST ASIA	106
6.4.1	Demand.....	106
6.4.2	Supply	107
6.4.3	Supply, Demand, and Trade	107
6.5	REST OF WORLD	109
6.5.1	Demand.....	109
6.5.2	Supply	109
6.5.3	Supply, Demand, and Trade	110
7	Glossary	111
8	References	112

	Appendix	Page
A	Definition of Capital Cost Terms Used in Process Economics	A-1
B	Definition of Operating Cost Terms Used in Process Economics.....	B-1
C	Cost of Production Estimates for Linear Alpha Olefins and Synthesis Gas.....	C-1
D	PERP Program Title Index (2005 - 2014)	D-1

Figure	Page
1.1 Detergent Alcohol and Surfactant Value Chain (Illustrative)	1
1.2 Synthetic Routes for Producing Detergent Range Alcohols	2
1.3 Natural Routes for Producing Detergent Range Alcohols.....	6
1.4 Structure of an Oil and Fat Molecule.....	7
1.5 Transesterification of Oils and Fats into Methyl Esters Reaction Chemistry	8
1.6 Esterification of Fatty Acids into Methyl Esters Reaction Chemistry.....	8
1.7 Hydrogenation of Methyl Esters into Fatty Alcohols Reaction Chemistry.....	9
1.8 Hydrolysis of Triglycerides into Fatty Acids and Glycerin	9
1.9 Direct Hydrogenation of Fatty Acid to Fatty Alcohol Reaction Chemistry	9
1.10 Production of Wax Ester from Fatty Acids and Alcohol Reaction Chemistry	10
1.11 Hydrogenation of Wax Ester to Fatty Alcohol Reaction Chemistry.....	10
1.12 C ₁₂ -C ₁₄ Alcohol Demand by Derivative	14
1.13 Global Fatty Alcohol Capacity by Region	15
1.14 Global Fatty Alcohol Supply, Demand, and Trade	16
1.15 Global Fatty Alcohol Trade.....	17
2.1 Detergent Alcohol and Surfactant Value Chain (Illustrative)	18
2.2 Relative Weight and Value of Surfactants in Typical Detergents.....	19
2.3 Ethylene-Based Detergent Alcohol Value Chain	20
2.4 Value Added Potential of the Ethylene-Derived Surfactant	21
2.5 Synthetic Routes for Producing Detergent Range Alcohols	22
2.6 Natural Routes for Producing Detergent Range Alcohols.....	23
3.1 Chain Length Distribution of Ziegler Alcohols	28
3.2 Sasol LAO/Branched Olefins Distribution (Illustrative).....	29
3.3 Simplified Value Chain for <i>n</i> -Paraffin-Based Olefins	29
3.4 Conventional Detergent Range Oxo Alcohol Process (Unmodified Cobalt Catalysis)	31
3.5 Simplified Block Flow Diagram of the Modified Sasol Process	32
3.6 LAO/LIO Distribution from SHOP Process	33
3.7 Modified Detergent Range Oxo Alcohol Process (Shell's Modified Cobalt Catalysis	35
3.8 Ziegler Alcohol Process (Alfol)	38
4.1 Structure of an Oil and Fat Molecule.....	40
4.2 Natural Oil Component by Carbon Number	41
4.3 Transesterification of Oils and Fats into Methyl Esters Reaction Chemistry	43
4.4 Esterification of Fatty Acids into Methyl Esters Reaction Chemistry.....	43
4.5 Hydrogenation of Methyl Esters into Fatty Alcohols Reaction Chemistry	43

4.6	Hydrolysis of Triglycerides into Fatty Acids and Glycerin	44
4.7	Direct Hydrogenation of Fatty Acid to Fatty Alcohol Reaction Chemistry	44
4.8	Production of Wax Ester from Fatty Acids and Alcohol Reaction Chemistry	44
4.9	Hydrogenation of Wax Ester to Fatty Alcohol Reaction Chemistry.....	44
4.10	Direct Hydrogenation of Fatty Acids to Fatty Alcohol Block Flow Diagram	46
4.11	Direct Hydrogenation of Fatty Acid to Fatty Alcohol (Lurgi)	47
4.12	Block Flow Diagram of Fatty Alcohol Production via Methyl Ester Route.....	48
4.13	Soap Formation Chemistry from Free Fatty Acids and Sodium Methoxide Catalyst.....	48
4.14	Transesterification of Triglycerides to Methyl Esters (Lurgi)	50
4.15	Fixed Bed High Pressure Hydrogenation of Methyl Esters (Lurgi)	52
4.16	Fixed Bed Fatty Alcohol Production from Fatty Acid via Wax Ester Block Flow Diagram	53
4.17	Wax Ester Route for Fatty Alcohol Production (Lurgi)	56
4.18	Fatty Alcohol Production via Fatty Acid Esterification Block Flow Diagram.....	57
4.19	Ester Removal via Wax Ester Formation Reaction Chemistry.....	59
4.20	Ester Recovery from Wax Ester Reaction Chemistry	59
4.21	Fixed Bed Methyl Ester Hydrogenation Process (Davy).....	60
4.22	Co-Production of Fatty Alcohol Composites Block Flow Scheme.....	61
4.23	Transesterification to Methyl Esters (Henkel Process)	63
5.1	Cost Summary for Synthetic Detergent Alcohol Processes	93
5.2	Cost Summary for Natural Detergent Alcohol Processes	94
5.3	Sensitivity of Detergent Alcohol Production Costs to Feedstock Prices in Malaysia	96
5.4	Sensitivity of Detergent Alcohol Production Costs to Feedstock Prices in USGC	97
5.5	Sensitivity of Detergent Alcohol Production Costs to Economy of Scale in Malaysia.....	97
5.6	Sensitivity of Detergent Alcohol Production Costs to Economy of Scale in USGC	98
6.1	C ₁₂ -C ₁₄ Alcohol Demand by Derivative	99
6.2	Global Fatty Alcohol Capacity by Region.....	101
6.3	Global Fatty Alcohol Supply, Demand, and Trade	101
6.4	Global Fatty Alcohol Trade.....	102
6.5	North America Fatty Alcohol Supply, Demand, and Trade	104
6.6	Western European Fatty Alcohol Supply, Demand, and Trade	106
6.7	Southeast Asia Fatty Alcohol Supply, Demand, and Trade	108
6.8	Rest of the World Fatty Alcohol Supply, Demand, and Trade	110

Table	Page
1.1 Prices Used in Cost of Production Tables (First Quarter of 2014 Basis)	11
1.2 Summary of Economics for Production of Synthetic Detergent Alcohols	11
1.3 Summary of Economics for Production of Natural Detergent Alcohols.....	12
1.4 Overall Summary of Economics for Production of Detergent Range Alcohols	13
1.5 Global Fatty Alcohol Demand.....	15
1.6 Global Fatty Alcohol Supply, Demand, and Trade	16
4.1 Top Palm Kernel Oil Producing Countries, 2014 Estimates	41
4.2 Top Coconut Oil Producing Countries, 2014 Estimates.....	42
5.1 Prices used in Cost of Production Tables (First Quarter of 2014 Basis)	66
5.2 Cost of Production Estimate for: Fatty Alcohols (Synthetic) Process: Conventional Oxo Process in China	69
5.3 Cost of Production Estimate for: Fatty Alcohols (Synthetic) Process: Conventional Oxo Process in Malaysia.....	70
5.4 Cost of Production Estimate for: Fatty Alcohols (Synthetic) Process: Conventional Oxo Process in Northwest Europe	71
5.5 Cost of Production Estimate for: Fatty Alcohols (Synthetic) Process: Conventional Oxo Process in the U.S. Gulf Coast.....	72
5.6 Cost of Production Estimate for: Fatty Alcohols (Synthetic) Process: Modified Oxo Process in China	74
5.7 Cost of Production Estimate for: Fatty Alcohols (Synthetic) Process: Modified Oxo Process in Malaysia	75
5.8 Cost of Production Estimate for: Fatty Alcohols (Synthetic) Process: Modified Oxo Process in Northwest Europe	76
5.9 Cost of Production Estimate for: Fatty Alcohols (Synthetic) Process: Modified Oxo Process in the U.S. Gulf Coast.....	77
5.10 Cost of Production Estimate for: Detergent Range Alcohols Process: Ziegler Alfol Process in China	79
5.11 Cost of Production Estimate for: Detergent Range Alcohols Process: Ziegler Alfol Process in Malaysia	80
5.12 Cost of Production Estimate for: Detergent Range Alcohols Process: Ziegler Alfol Process in Northwest Europe	81
5.13 Cost of Production Estimate for: Detergent Range Alcohols Process: Ziegler Alfol Process in the U.S. Gulf Coast	82
5.14 Cost of Production Estimate for: Fatty Alcohols (Natural) Process: Fatty Acid Route (Lump) in China	84
5.15 Cost of Production Estimate for: Fatty Alcohols (Natural) Process: Fatty Acid Route (Lump) in Malaysia	85

5.16	Cost of Production Estimate for: Fatty Alcohols (Natural) Process: Fatty Acid Route (Lump) in Northwest Europe	86
5.17	Cost of Production Estimate for: Fatty Alcohols (Natural) Process: Fatty Acid Route (Lump) in the U.S. Gulf Coast	87
5.18	Cost of Production Estimate for: Fatty Alcohols (Natural) Process: Methyl Ester Route in China	89
5.19	Cost of Production Estimate for: Fatty Alcohols (Natural) Process: Methyl Ester Route in Malaysia.....	90
5.20	Cost of Production Estimate for: Fatty Alcohols (Natural) Process: Methyl Ester Route in Northwest Europe.....	91
5.21	Cost of Production Estimate for: Fatty Alcohols (Natural) Process: Methyl Ester Route in the U.S. Gulf Coast.....	92
5.22	Summary of Economics for Production of Synthetic Detergent Alcohols	93
5.23	Summary of Economics for Production of Natural Detergent Alcohols.....	94
5.24	Overall Summary of Economics for Production of Detergent Range Alcohols	95
6.1	Global Fatty Alcohol Demand.....	100
6.2	Global Fatty Alcohol Supply, Demand, and Trade	102
6.3	Capacities of Fatty Alcohol in North America in 2014	103
6.4	North America Fatty Alcohol Supply, Demand, and Trade	104
6.5	Capacities of Fatty Alcohol in Europe in 2014	105
6.6	Western European Fatty Alcohol Supply, Demand, and Trade	106
6.7	Capacities of Fatty Alcohol in Southeast Asia in 2014.....	107
6.8	Southeast Asia Fatty Alcohol Supply, Demand, and Trade	108
6.9	Capacities of Fatty Alcohol in Rest of the World in 2014	109
6.10	Rest of the World Fatty Alcohol Supply, Demand, and Trade	110

Nexant Thinking™ PERP PROGRAM



www.nexantthinking.com

The NexantThinking™ Process Evaluation/Research Planning (PERP) program is recognized globally as the industry standard source for information relevant to the chemical process and refining industries. PERP reports are available as a subscription program or on a single report basis.

Contact Details:

New York: Marcos Nogueira Cesar, Vice President, Global Products, E&CA: Nexant Thinking™
Phone: + 1-914-609-0324, e-mail: mcesar@nexant.com

New York: Heidi Junker Coleman, Global Programs Support Manager
Phone: + 1-914-609-0381, e-mail: hcoleman@nexant.com

Nexant, Inc. (www.nexant.com) is a leading management consultancy to the global energy, chemical, and related industries. For over 38 years, Nexant has helped clients increase business value through assistance in all aspects of business strategy, including business intelligence, project feasibility and implementation, operational improvement, portfolio planning, and growth through M&A activities. Nexant has its main offices in San Francisco (California), White Plains (New York), and London (UK), and satellite offices worldwide.

Copyright © by Nexant Inc. 2014. All Rights Reserved.