

| | |
|---|-------|
| CHAPTER ONE: INTRODUCTION | 1 |
| STUDY OBJECTIVES | 1 |
| REASONS FOR DOING THIS STUDY | 1 |
| INTENDED AUDIENCE..... | 1 |
| SCOPE OF REPORT | 2 |
| INFORMATION SOURCES | 2 |
| ANALYST CREDENTIALS..... | 3 |
| RELATED BCC REPORTS | 3 |
| BCC ON-LINE SERVICES..... | 3 |
| DISCLAIMER | 4 |
| CHAPTER TWO: SUMMARY | 5 |
| SUMMARY | 5 |
| SUMMARY (CONTINUED) | 6 |
| <i>SUMMARY TABLE U.S. AMINO ACIDS MARKET SIZE, THROUGH</i> <i>2013 (\$ MILLIONS)</i> | 7 |
| <i>SUMMARY FIGURE U.S. AMINO ACIDS MARKET SIZE, 2005-2013</i> <i>(\$ MILLIONS)</i> | 7 |
| CHAPTER THREE: OVERVIEW OF AMINO ACIDS | 8 |
| <i>TABLE 1 THE PROTEIN AMINO ACIDS</i> | 8 |
| COMMERCIAL INTERESTS..... | 9 |
| <i>TABLE 2 MAJOR COMMERCIAL APPLICATIONS</i> | 9 |
| FEED FORTIFICATION | 9 |
| FOOD FLAVORING AGENTS | 10 |
| SPECIALTY USES..... | 10 |
| DIETARY NEEDS..... | 10 |
| <i>TABLE 3 THE “ESSENTIAL” AMINO ACIDS</i> | 11 |
| BIOLOGIC VALUE OF AMINO ACID MIXTURES | 11 |
| <i>TABLE 4 PROTEIN VALUE OF SELECTED FOODS</i> | 12 |
| RECOMMENDED DAILY ALLOWANCE..... | 12 |
| AMINO ACID METABOLISM | 13 |
| PROPERTIES | 13 |
| CHEMICAL STRUCTURE..... | 14 |
| <i>TABLE 5 CHEMICAL STRUCTURE OF AMINO ACIDS</i> | 14 |
| ISOLATION/ANALYSIS | 14 |
| MICROBIOLOGICAL ASSAY | 14 |
| CHROMATOGRAPHIC SEPARATION | 15 |
| PRODUCTION TECHNOLOGY | 15 |
| <i>TABLE 6 AMINO ACIDS BY PRODUCTION METHODS</i> | 15 |
| <i>TABLE 6 (CONTINUED)</i> | 16 |
| EXTRACTION | 16 |

| | |
|--|----|
| FERMENTATION..... | 17 |
| MICROBIOLOGICAL PROCESSES..... | 17 |
| TABLE 7 AMINO ACID PRODUCTION BY FERMENTATION..... | 18 |
| CHEMICAL D SYNTHESIS..... | 18 |
| ENZYMATIC CONVERSION..... | 19 |
| REGULATION..... | 19 |
| FEDERAL DRUG ADMINISTRATION (FDA)..... | 19 |
| U.S. Pharmacopoeia (U.S.P)..... | 20 |
| TABLE 8 U.S.P VERIFIED AMINO ACID PRODUCTS..... | 20 |
| The Bush Administration..... | 20 |
| | |
| CHAPTER FOUR: STRUCTURE OF THE INDUSTRY AND ITS | |
| COMPETITIVE ASPECTS..... | 21 |
| TABLE 9 MAJOR AMINO ACID PRODUCERS..... | 21 |
| TABLE 9 (CONTINUED)..... | 22 |
| FIGURE 1 SHARE OF GLOBAL AMINO ACIDS MARKET, 2008 (%)..... | 22 |
| FIGURE 1 (CONTINUED)..... | 23 |
| IMPORTANT STRATEGIES..... | 23 |
| MARKET SHARE..... | 23 |
| TABLE 10 LEADING PRODUCERS, BY TYPE, OF AMINO ACID..... | 24 |
| FIGURE 2 MARKET SHARE OF MAJOR PLAYERS, 2008 (%)..... | 25 |
| AJINOMOTO CO. | 25 |
| TABLE 11 NUMBER OF AJINOMOTO AFFILIATES PER CONTINENT..... | 26 |
| AJINOMOTO FOOD INGREDIENTS, LLC..... | 26 |
| AJINOMOTO AMINOSCIENCE, LLC..... | 26 |
| ANJINOMOTO HEARTLAND, LLC..... | 27 |
| ARCHER DANIELS MIDLAND CO. (ADM)..... | 27 |
| NOVUS INTERNATIONAL, INC. | 28 |
| SANOFI-AVENTIS..... | 29 |
| ADISSEO U.S.A..... | 29 |
| EVONIK..... | 30 |
| MONSANTO..... | 30 |
| KYOWA HAKKO KOGYO..... | 31 |
| NIPPON SODA..... | 31 |
| SHOWA DENKO K.K. | 31 |
| MITSUBISHI TANABE PHARMA..... | 32 |
| TANABE U.S.A INC. | 32 |
| ZHEJIANG CHEMICALS..... | 32 |
| DAESANG CORPORATION..... | 33 |
| CJ CORPORATION..... | 33 |
| MARKET FORCES..... | 33 |
| MARKET FORCES (CONTINUED)..... | 34 |
| | |
| CHAPTER FIVE: COMMERCIAL APPLICATIONS..... | 35 |
| TABLE 12 COMMERCIAL AMINO ACIDS BY USE..... | 35 |

| | |
|--|----|
| <i>TABLE 13 U.S. MARKET SIZE FOR AMINO ACIDS, THROUGH 2013</i> | |
| (\$ MILLIONS)..... | 36 |
| ANIMAL FEED SUPPLEMENTS | 36 |
| PHASE FEEDING | 37 |
| ANIMAL FEED REGULATION..... | 38 |
| International..... | 39 |
| TYPICAL ANIMAL FEED PRODUCT | 39 |
| Complete Protein Sources | 40 |
| New Amino Acid-Based Feed Products | 40 |
| AMINO ACID RESEARCH AND ANIMAL NUTRITION | 40 |
| Amino Acid Research and ... (Continued) | 41 |
| FIGURE 3 ANIMAL FEED SUPPLEMENTS' MARKET SHARE, 2008 (%)..... | 42 |
| CHAPTER SIX: METHIONINE | 43 |
| METHIONINE..... | 43 |
| METHIONINE APPLICATIONS AND CONSUMPTION PATTERNS..... | 44 |
| FIGURE 4 METHIONINE CONSUMPTION MARKET SHARES, 2008 | |
| (%)..... | 45 |
| METHIONINE CAPACITY AND MANUFACTURERS | 45 |
| FIGURE 5 WORLDWIDE METHIONINE MARKET SHARES, 2008 (%)..... | 46 |
| TABLE 14 MAJOR METHIONINE PRODUCTION CAPACITY | |
| WORLDWIDE BY COMPANY, 2008 (KILO TONS)..... | 47 |
| TABLE 15 METHIONINE MANUFACTURERS | 48 |
| TABLE 16 U.S. METHIONINE MARKET SIZE, THROUGH 2013 | |
| (\$ MILLIONS)..... | 48 |
| TABLE 17 U.S. METHIONINE MANUFACTURING CAPACITIES | |
| ANNUAL CAPACITY, 2008 (MILLION LBS.)..... | 49 |
| METHIONINE PRODUCT TYPES AND COMPARATIVE | |
| NUTRITIONAL VALUES | 50 |
| TABLE 18 PRODUCTION AND TRADE IN METHIONINE DOMESTIC | |
| CONSUMPTION: DL METHIONINE, THROUGH 2013 (MILLION | |
| LBS.)..... | 50 |
| TABLE 19 U.S. CONSUMPTION OF METHIONINE, THROUGH 2013 | |
| (MILLION LBS., 99% DL METHIONINE BASIS)..... | 51 |
| PRICE OF METHIONINE | 51 |
| TABLE 20 AVERAGE PRICE OF METHIONINE, 2008 (\$/LB)..... | 52 |
| METHIONINE PATENTS..... | 52 |
| PATENTS BY CATEGORY | 53 |
| TABLE 21 PRODUCT PATENTS BY PROCESS, 1998-2008..... | 53 |
| TABLE 22 U.S. PATENTS ASSIGNEES RELATED TO METHIONINE | |
| PRODUCTS, 1998-2008 | 54 |
| TABLE 23 U.S. PATENTS RELATED TO METHIONINE PRODUCTS | |
| BY YEAR, 1998-2008 | 54 |
| CHAPTER SEVEN: LYSINE | 55 |

| | |
|--|--------|
| LYSINE | 55 |
| LYSINE CAPACITY AND MANUFACTURERS | 56 |
| TABLE 24 LYSINE PRODUCTION CAPACITY, 2008 (KILO TONS)..... | 57 |
| CHINA AND FEED | 57 |
| FIGURE 6 MARKET SHARE FOR LEADING LYSINE PRODUCERS, 2008 (%)..... | 58 |
| VALUE OF U.S. LYSINE MARKET..... | 58 |
| TABLE 25 U.S. LYSINE MARKET SIZE, THROUGH 2013 (\$ MILLIONS)..... | 59 |
| TABLE 26 ANNUAL U.S. LYSINE MANUFACTURING CAPACITIES, 2008 (KILO TONS) | 59 |
| TABLE 27 PRICE OF LYSINE, THROUGH 2013 (98.5% L-LYSINE MONOHYDROCHLORIDE)..... | 60 |
| TABLE 28 PRODUCTION AND TRADE IN LYSINE, THROUGH 2013 (MILLION LBS., 98.5% L-LYSINE MONOHYDROCHLORIDE)..... | 60 |
| TABLE 29 U.S. CONSUMPTION OF LYSINE, THROUGH 2013 (MILLION LBS., 98.5% L-LYSINE MONOHYDROCHLORIDE)..... | 61 |
| LYSINE PATENTS..... | 61 |
| PATENTS BY CATEGORY | 62 |
| TABLE 30 PRODUCT PATENTS BY PROCESS, 1998–2008..... | 63 |
| TABLE 31 U.S. PATENTS ASSIGNEES RELATED TO LYSINE PRODUCTS, 1998-2008 | 63 |
| TABLE 31 (CONTINUED)..... | 64 |
| TABLE 32 U.S. PATENTS RELATED TO LYSINE PRODUCTS BY YEAR, 1998–2008..... | 64 |
| CHAPTER EIGHT: THREONINE..... | 65 |
| THREONINE | 65 |
| THREONINE APPLICATIONS AND CONSUMPTION PATTERNS | 66 |
| TABLE 33 THREONINE PRODUCTION CAPACITY, 2008 (KTONS)..... | 66 |
| FIGURE 7 MARKET SHARE FOR LEADING THREONINE PRODUCERS, 2008 (%) | 67 |
| THREONINE CAPACITY AND MANUFACTURERS | 67 |
| TABLE 34 THREONINE PRODUCERS | 68 |
| TABLE 35 U.S. THREONINE MARKET SIZE, THROUGH 2013 (\$ MILLIONS)..... | 68 |
| THREONINE PRICING | 68 |
| TABLE 36 PRICE OF THREONINE, THROUGH 2013..... | 69 |
| VALUE OF U.S. THREONINE MARKET..... | 69 |
| THREONINE PATENTS..... | 69 |
| PATENTS BY CATEGORY | 70 |
| TABLE 37 PRODUCT PATENTS BY PROCESS, 1998–2008..... | 70 |
| TABLE 38 U.S. PATENTS ASSIGNEES RELATED TO THREONINE PRODUCTS, 1998–2008..... | 71 |

| | |
|--|----|
| <i>TABLE 39 U.S. PATENTS RELATED TO THREONINE PRODUCTS BY YEAR, 1998-2008</i> | 71 |
| CHAPTER NINE: TRYPTOPHAN | 72 |
| TRYPTOPHAN..... | 72 |
| TRYPTOPHAN APPLICATIONS AND CONSUMPTION PATTERNS | 73 |
| <i>TABLE 40 TRYPTOPHAN PRODUCERS</i> | 73 |
| TRYPTOPHAN REGULATIONS..... | 73 |
| TRYPTOPHAN HEALTH APPLICATIONS..... | 74 |
| TRYPTOPHAN FAT FIGHTER | 75 |
| TRYPTOPHAN CAPACITY | 75 |
| PRICING | 75 |
| <i>TABLE 41 TRYPTOPHAN PRICES, 2008 (\$/KG)</i> | 76 |
| VALUE OF U.S. TRYPTOPHAN MARKET | 76 |
| <i>TABLE 42 U.S. VALUE OF TRYPTOPHAN IN ANIMAL FEED, THROUGH 2013 (\$ MILLIONS)</i> | 76 |
| TRYPTOPHAN PATENTS | 77 |
| PATENTS BY CATEGORY | 77 |
| <i>TABLE 43 PRODUCT PATENTS BY PROCESS, 1998-2008</i> | 78 |
| <i>TABLE 44 U.S. PATENTS ASSIGNEES RELATED TO L-TRYPTOPHAN PRODUCTS, 1998-2008</i> | 78 |
| <i>TABLE 45 U.S. PATENTS RELATED TO L-TRYPTOPHAN PRODUCTS BY YEAR, 1997-2008</i> | 79 |
| CHAPTER TEN: SUMMARY OF U.S. MARKET SIZE FOR ANIMAL FEED | |
| AMINO ACIDS..... | 80 |
| <i>TABLE 46 SUMMARY OF ANIMAL FEED AMINO ACIDS U.S. MARKET, THROUGH 2013 (\$ MILLIONS)</i> | 80 |
| <i>FIGURE 8 SUMMARY OF ANIMAL FEED AMINO ACIDS U.S. MARKET, 2005-2013 (\$ MILLIONS)</i> | 81 |
| CONSUMPTION OF METHIONINE, LYSINE, THREONINE AND TRYPTOPHAN IN FEEDSTUFFS | 81 |
| POULTRY FEEDS..... | 82 |
| <i>TABLE 47 POULTRY FEED COMPOSITIONS</i> | 82 |
| <i>TABLE 48 AMINO ACID FEED COMPOSITIONS (LB/TON)</i> | 83 |
| SWINE FEEDS | 83 |
| TECHNICAL FACTORS | 84 |
| PHYTASE..... | 84 |
| HIGH CORN OIL (HOC) | 84 |
| HYDROLYSATES | 84 |
| ANIMAL BY-PRODUCTS | 84 |
| DAIRY AND BEEF CATTLE, SHEEP, AQUACULTURE AND PET FOOD | 85 |
| DAIRY AND BEEF CATTLE FEEDS | 85 |
| SHEEP FEEDS | 85 |

| | |
|---|-----|
| AQUACULTURE | 85 |
| PET FOODS | 85 |
| TABLE 49 PET FOODS WITH ADDED AMINO ACIDS..... | 86 |
| CHAPTER ELEVEN: FOOD FLAVORING AGENTS..... | 87 |
| FIGURE 9 AMINO ACID FLAVORANTS WORLDWIDE MARKET | |
| SHARE, 2008 (%)..... | 87 |
| FIGURE 9 (CONTINUED) | 88 |
| PHENYLALANINE | 88 |
| PHENYLALANINE APPLICATIONS AND CONSUMPTION | |
| PATTERNS | 89 |
| Aspartame Artificial Sweeteners | 89 |
| Competitive Aspects of the Sweeteners Market..... | 89 |
| Aspartame-Sweetened Products | 89 |
| TABLE 50 SUGAR SUBSTITUTE PRICES 2008 (\$/100 COUNT BOX)..... | 90 |
| Diet Beverage Aspartame Use | 91 |
| Diet Candy Market..... | 91 |
| Aspartame and Coffee | 91 |
| Problems with Aspartame..... | 92 |
| PHENYLALANINE PHARMACEUTICAL USES..... | 92 |
| EUROPEAN ASPARTAME | 92 |
| PHENYLALANINE CAPACITY AND MANUFACTURERS..... | 92 |
| TABLE 51 PHENYLALANINE PRODUCERS..... | 93 |
| PHENYLALANINE PRICING | 93 |
| TABLE 52 PHENYLALANINE PRICES, 1980-2013 (\$/LB)..... | 94 |
| FIGURE 10 PHENYLALANINE PRICES, 1988-2013 (\$/LB)..... | 94 |
| VALUE OF U.S. PHENYLALANINE MARKET | 94 |
| TABLE 53 U.S. PHENYLALANINE MARKET SIZE, THROUGH 2013 | |
| (\$ MILLIONS)..... | 95 |
| PHENYLALANINE PATENTS | 95 |
| Patents by Category | 96 |
| TABLE 54 PRODUCT PATENTS BY PROCESS, 1998-2008..... | 97 |
| TABLE 55 U.S. PATENTS ASSIGNEES RELATED TO | |
| PHENYLALANINE PRODUCTS, 1998-2008..... | 97 |
| TABLE 55 (CONTINUED)..... | 98 |
| TABLE 56 U.S. PATENTS RELATED TO PHENYLALANINE | |
| PRODUCTS BY YEAR, 1998-2008..... | 99 |
| CHAPTER TWELVE: GLUTAMIC ACID | 100 |
| GLUTAMIC ACID PRODUCTION TECHNOLOGY | 100 |
| GLUTAMIC ACID APPLICATIONS AND CONSUMPTION | |
| PATTERNS | 101 |
| MSG REGULATION | 102 |
| CHINESE RESTAURANT SYNDROME..... | 102 |
| FASEB Report on MSG | 103 |

| | |
|--|-----|
| FDA Proposals for MSG | 104 |
| Dangers of MSG..... | 104 |
| Truth in Labeling Campaign (TLC)..... | 104 |
| GLUTAMIC ACID CAPACITY AND MANUFACTURERS..... | 105 |
| TABLE 57 GLUTAMIC ACID MANUFACTURERS..... | 105 |
| PRICING | 106 |
| VALUE OF U.S. GLUTAMIC ACID MARKET | 106 |
| TABLE 58 U.S. GLUTAMIC ACID MARKET SIZE, THROUGH 2013 (\$ MILLIONS)..... | 106 |
| GLUTAMIC ACID PATENTS | 106 |
| PATENTS BY CATEGORY | 107 |
| TABLE 59 PRODUCT PATENTS BY PROCESS, 1998–2008..... | 108 |
| TABLE 60 U.S. PATENTS ASSIGNEES RELATED TO GLUTAMIC ACID PRODUCTS, 1998–2008..... | 109 |
| TABLE 61 U.S. PATENTS RELATED TO GLUTAMIC ACID PRODUCTS BY YEAR, 1998–2008..... | 110 |
| CHAPTER THIRTEEN: CYSTEINE/CYSTINE | 111 |
| CYSTEINE/CYSTINE PRODUCTION TECHNOLOGY | 111 |
| CYSTEINE/CYSTINE CAPACITY AND MANUFACTURERS..... | 112 |
| TABLE 62 CYSTEINE PRODUCERS | 112 |
| CYSTEINE PRICING..... | 112 |
| VALUE OF U.S. CYSTEINE/CYSTINE MARKET | 112 |
| TABLE 63 U.S. CYSTEINE/CYSTINE MARKET SIZE, THROUGH 2013 (TONS/YEAR) | 113 |
| CYSTEINE/CYSTINE APPLICATIONS AND CONSUMPTION PATTERNS..... | 113 |
| CYSTEINE/CYSTINE PATENTS | 113 |
| CYSTEINE AND HIV | 114 |
| CYSTEINE AND COSMETICS | 115 |
| CYSTEINE AND NUTRACEUTICALS | 115 |
| Cysteine and Nutraceuticals (Continued) | 116 |
| PATENTS BY CATEGORY | 117 |
| TABLE 64 PRODUCT PATENTS BY PROCESS, 1998–2008..... | 118 |
| TABLE 65 U.S. PATENTS ASSIGNEES RELATED TO CYSTEINE PRODUCTS, 1998–2008..... | 119 |
| TABLE 66 U.S. PATENTS RELATED TO CYSTEINE PRODUCTS BY YEAR, 1998–2008..... | 119 |
| CHAPTER FOURTEEN: ASPARTIC ACID..... | 120 |
| ASPARTIC ACID PRODUCTION TECHNOLOGY..... | 120 |
| ASPARTIC ACID CAPACITY AND MANUFACTURERS | 120 |
| TABLE 67 ASPARTIC ACID MANUFACTURERS | 121 |
| ASPARTIC ACID PRICING | 121 |

| | |
|--|-----|
| <i>TABLE 68 U.S. ASPARTIC ACID MARKET SIZE, THROUGH 2013</i> <i>(\$ MILLIONS)</i> | 122 |
| <i>TABLE 69 ASPARTIC ACID PRICES, THROUGH 2008 (\$/LB)</i> | 122 |
| ASPARTIC ACID APPLICATIONS AND CONSUMPTION PATTERNS..... | 122 |
| ASPARTIC ACID COPOLYMERS..... | 122 |
| ASPARTIC ACID PATENT SUMMARIES..... | 123 |
| Patents by Category..... | 124 |
| <i>TABLE 70 PRODUCT PATENTS BY PROCESS, 1998–2008</i> | 124 |
| <i>TABLE 71 U.S. PATENTS ASSIGNEES RELATED TO ASPARTIC ACID</i> <i>PRODUCTS, 1998-2008</i> | 125 |
| <i>TABLE 72 U.S. PATENTS RELATED TO ASPARTIC ACID PRODUCTS</i> <i>BY YEAR, 1998–2008</i> | 125 |
| VALUE U.S. MARKET FOR FOOD FLAVORINGS..... | 126 |
| <i>TABLE 73 SUMMARY OF AMINO ACID FLAVORING AGENTS,</i> <i>THROUGH 2013 (\$ MILLIONS)</i> | 126 |
| <i>FIGURE 11 SUMMARY OF AMINO ACID FLAVORING AGENTS, 2007</i> <i>AND 2013 (\$ MILLIONS)</i> | 126 |
| CHAPTER FIFTEEN: SPECIALTY USES..... | 127 |
| PHARMACEUTICAL PRODUCTS..... | 127 |
| RESEARCH PURPOSES..... | 128 |
| CHEMICAL INTERMEDIATES..... | 129 |
| <i>TABLE 74 AMINO ACIDS FOR SPECIALTY USES</i> | 129 |
| CHAPTER SIXTEEN: GLYCINE..... | 130 |
| GLYCINE PRODUCTION TECHNOLOGY..... | 130 |
| GLYCINE PATENTS..... | 131 |
| GLYCINE PHARMACEUTICAL USES..... | 131 |
| GLYCINE FOOD APPLICATIONS..... | 131 |
| GLYCINE NON-FOOD APPLICATIONS..... | 132 |
| GLYCINE CAPACITY AND MANUFACTURERS..... | 132 |
| <i>TABLE 75 GLYCINE MANUFACTURERS</i> | 133 |
| GLYCINE PRICING..... | 133 |
| VALUE OF U.S. GLYCINE MARKET..... | 133 |
| <i>TABLE 76 U.S. GLYCINE MARKET PRICE, THROUGH 2013 (\$/LB)</i> | 133 |
| <i>FIGURE 12 U.S. GLYCINE MARKET SIZE, 2008 AND 2013</i> <i>(\$ MILLIONS)</i> | 134 |
| <i>TABLE 77 U.S. GLYCINE IMPORTS, 1999-2008</i> | 134 |
| CHAPTER SEVENTEEN: ALANINE..... | 135 |
| ALANINE PRODUCTION TECHNOLOGY..... | 135 |
| ALANINE APPLICATIONS AND CONSUMPTION PATTERNS..... | 136 |
| ALANINE PATENTS..... | 136 |
| PATENTS BY CATEGORY..... | 137 |

| | |
|--|-----|
| <i>TABLE 78 PRODUCT PATENTS BY PROCESS, 1998–2008</i> | 138 |
| <i>TABLE 79 U.S. PATENTS ASSIGNEES RELATED TO ALANINE PRODUCTS, 1998–2008</i> | 139 |
| <i>TABLE 79 (CONTINUED)</i> | 140 |
| <i>TABLE 80 U.S. PATENTS RELATED TO ALANINE PRODUCTS BY YEAR, 1998-2008</i> | 140 |
| ALANINE CAPACITY AND MANUFACTURERS | 140 |
| <i>TABLE 81 ALANINE MANUFACTURERS</i> | 140 |
| ALANINE PRICING..... | 141 |
| VALUE OF U.S. ALANINE MARKET | 141 |
| <i>TABLE 82 U.S. ALANINE MARKET SIZE, THROUGH 2013 (\$ MILLIONS)</i> | 141 |
| <i>FIGURE 13 U.S. ALANINE MARKET SIZE, 2008 AND 2013 (\$ MILLIONS)</i> | 141 |
| CHAPTER EIGHTEEN: ARGININE..... | 142 |
| ARGININE PATENTS..... | 142 |
| MEDICAL APPLICATIONS..... | 143 |
| Cancer Fighters | 143 |
| OTHER ARGININE PATENTS..... | 144 |
| PATENTS BY CATEGORY | 144 |
| <i>TABLE 83 PRODUCT PATENTS BY PROCESS, 1998–2008</i> | 144 |
| <i>TABLE 83 (CONTINUED)</i> | 145 |
| <i>TABLE 84 U.S. PATENTS ASSIGNEES RELATED TO ARGININE PRODUCTS, 1998–2008</i> | 146 |
| <i>TABLE 85 U.S. PATENTS RELATED TO ARGININE PRODUCTS BY YEAR, 1998-2008</i> | 146 |
| ARGININE CAPACITY AND MANUFACTURERS | 147 |
| <i>TABLE 86 ARGININE MANUFACTURERS</i> | 147 |
| ARGININE PRICING | 147 |
| VALUE OF U.S. ARGININE MARKET..... | 147 |
| <i>TABLE 87 U.S. ARGININE MARKET SIZE, THROUGH 2013 (\$ MILLIONS)</i> | 147 |
| <i>FIGURE 14 U.S. ARGININE MARKET SIZE, 2008 AND 2013 (\$ MILLIONS)</i> | 148 |
| CHAPTER NINETEEN: PROLINE..... | 149 |
| PROLINE TECHNOLOGY..... | 149 |
| PROLINE CAPACITY AND MANUFACTURERS | 150 |
| <i>TABLE 88 PROLINE MANUFACTURERS</i> | 150 |
| PROLINE PRICING | 150 |
| VALUE OF U.S. PROLINE MARKET..... | 150 |
| <i>TABLE 89 U.S. PROLINE MARKET SIZE, THROUGH 2013 (\$ MILLIONS)</i> | 151 |

| | |
|--|-----|
| <i>FIGURE 15 U.S. PROLINE MARKET SIZE, 2008 AND 2013</i> | |
| (\$ MILLIONS)..... | 151 |
| PROLINE PATENTS..... | 151 |
| PATENTS BY CATEGORY | 153 |
| <i>TABLE 90 PRODUCT PATENTS BY PROCESS, 1998-2008</i> | 153 |
| <i>TABLE 91 U.S. PATENTS ASSIGNEES RELATED TO PROLINE</i> | |
| <i>PRODUCTS, 1998–2008</i> | 154 |
| <i>TABLE 92 U.S. PATENTS RELATED TO PROLINE PRODUCTS BY</i> | |
| <i>YEAR, 1998–2008</i> | 154 |
| | |
| CHAPTER TWENTY: LEUCINE | 155 |
| LEUCINE PRODUCTION TECHNOLOGY..... | 155 |
| LEUCINE APPLICATIONS AND CONSUMPTION PATTERNS..... | 155 |
| LEUCINE CAPACITY AND MANUFACTURERS | 156 |
| <i>TABLE 93 LEUCINE MANUFACTURERS</i> | 156 |
| LEUCINE PRICING..... | 156 |
| <i>TABLE 94 U.S. LEUCINE PRICES (1 KG)</i> | 156 |
| VALUE OF U.S. LEUCINE MARKET | 157 |
| <i>TABLE 95 U.S. LEUCINE MARKET SIZE, THROUGH 2013</i> | |
| (\$ MILLIONS)..... | 157 |
| <i>FIGURE 16 U.S. LEUCINE MARKET SIZE, 2008 AND 2013</i> | |
| (\$ MILLIONS)..... | 157 |
| LEUCINE PATENTS..... | 157 |
| LEUCINE PATENTS (CONTINUED) | 158 |
| PATENTS BY CATEGORY | 159 |
| <i>TABLE 96 PRODUCT PATENTS BY PROCESS, 1998–2008</i> | 159 |
| <i>TABLE 97 U.S. PATENTS ASSIGNEES RELATED TO LEUCINE</i> | |
| <i>PRODUCTS, 1998–2008</i> | 159 |
| <i>TABLE 98 U.S. PATENTS RELATED TO LEUCINE PRODUCTS BY</i> | |
| <i>YEAR, 1998-2008</i> | 160 |
| | |
| CHAPTER TWENTY-ONE: VALINE..... | 161 |
| VALINE PRODUCTION TECHNOLOGY..... | 161 |
| VALINE APPLICATIONS AND CONSUMPTION PATTERNS..... | 161 |
| VALINE CAPACITY AND MANUFACTURERS | 162 |
| <i>TABLE 99 VALINE PRODUCERS</i> | 162 |
| VALINE PRICING..... | 162 |
| VALUE OF U.S. VALINE MARKET | 162 |
| <i>TABLE 100 U.S. VALINE MARKET SIZE, THROUGH 2013</i> | |
| (\$ MILLIONS)..... | 162 |
| <i>FIGURE 17 U.S. VALINE MARKET SIZE, 2008 AND 2013</i> | |
| (\$ MILLIONS)..... | 163 |
| VALINE PATENTS | 163 |
| PATENTS BY CATEGORY | 164 |
| <i>TABLE 101 PRODUCT PATENTS BY PROCESS, 1998–2008</i> | 164 |

| | |
|---|-----|
| <i>TABLE 102 U.S. PATENTS ASSIGNEES RELATED TO VALINE PRODUCTS, 1998–2008</i> | 164 |
| <i>TABLE 103 U.S. PATENTS RELATED TO VALINE PRODUCTS BY YEAR, 1998–2008</i> | 165 |
| CHAPTER TWENTY-TWO: TYROSINE | 166 |
| TYROSINE PRODUCTION TECHNOLOGY..... | 166 |
| TYROSINE APPLICATIONS AND CONSUMPTION PATTERNS..... | 166 |
| TYROSINE CAPACITY AND MANUFACTURERS | 167 |
| <i>TABLE 104 TYROSINE MANUFACTURERS</i> | 167 |
| TYROSINE PRICING..... | 168 |
| VALUE OF U.S. TYROSINE MARKET | 168 |
| <i>TABLE 105 U.S. TYROSINE MARKET SIZE, THROUGH 2013 (\$ MILLIONS)</i> | 168 |
| <i>FIGURE 18 U.S. TYROSINE MARKET SIZE, 2008 AND 2013 (\$ MILLIONS)</i> | 168 |
| TYROSINE PATENTS | 169 |
| PATENTS BY CATEGORY | 170 |
| <i>TABLE 106 PRODUCT PATENTS BY PROCESS, 1998–2008</i> | 170 |
| <i>TABLE 107 U.S. PATENTS ASSIGNEES RELATED TO TYROSINE PRODUCTS, 1998–2008</i> | 171 |
| <i>TABLE 108 U.S. PATENTS RELATED TO TYROSINE PRODUCTS BY YEAR, 1998–2008</i> | 172 |
| CHAPTER TWENTY-THREE: ISOLEUCINE..... | 173 |
| ISOLEUCINE PRODUCTION TECHNOLOGY | 173 |
| ISOLEUCINE APPLICATIONS AND CONSUMPTION PATTERNS | 174 |
| ISOLEUCINE CAPACITY AND MANUFACTURERS..... | 175 |
| <i>TABLE 109 ISOLEUCINE MANUFACTURERS</i> | 175 |
| ISOLEUCINE PRICING | 175 |
| VALUE OF U.S. ISOLEUCINE MARKET | 175 |
| <i>TABLE 110 U.S. ISOLEUCINE MARKET SIZE, THROUGH 2013 (\$ MILLIONS)</i> | 176 |
| <i>FIGURE 19 U.S. ISOLEUCINE MARKET SIZE, 2008 AND 2013 (\$ MILLIONS)</i> | 176 |
| ISOLEUCINE PATENTS | 176 |
| PATENTS BY CATEGORY | 177 |
| <i>TABLE 111 PRODUCT PATENTS BY PROCESS, 1998–2008</i> | 177 |
| <i>TABLE 112 U.S. PATENTS ASSIGNEES RELATED TO ISOLEUCINE PRODUCTS, 1998–2008</i> | 178 |
| <i>TABLE 113 U.S. PATENTS RELATED TO ISOLEUCINE PRODUCTS BY YEAR, 1999–2008</i> | 178 |
| CHAPTER TWENTY-FOUR: SERINE..... | 179 |
| SERINE PRODUCTION TECHNOLOGY..... | 179 |

| | |
|---|------------|
| SERINE APPLICATIONS AND CONSUMPTION PATTERNS..... | 180 |
| SERINE CAPACITY AND MANUFACTURERS | 180 |
| <i>TABLE 114 SERINE MANUFACTURERS</i> | <i>180</i> |
| SERINE PRICING..... | 180 |
| VALUE OF U.S. SERINE MARKET | 181 |
| <i>TABLE 115 U.S. SERINE MARKET SIZE, THROUGH 2013</i> <i>(\$ MILLIONS)</i> | <i>181</i> |
| <i>FIGURE 20 U.S. SERINE MARKET SIZE, 2008 AND 2013</i> <i>(\$ MILLIONS)</i> | <i>181</i> |
| SERINE PATENTS..... | 181 |
| PATENTS BY CATEGORY | 182 |
| <i>TABLE 116 PRODUCT PATENTS BY PROCESS, 1998-2008</i> | <i>182</i> |
| <i>TABLE 117 U.S. PATENTS ASSIGNEES RELATED TO SERINE</i> <i>PRODUCTS, 1998-2008</i> | <i>182</i> |
| <i>TABLE 117 (CONTINUED)</i> | <i>183</i> |
| <i>TABLE 118 U.S. PATENTS RELATED TO SERINE PRODUCTS BY</i> <i>YEAR, 1998-2008</i> | <i>183</i> |
| CHAPTER TWENTY-FIVE: ASPARAGINE..... | 184 |
| ASPARAGINE PRODUCTION TECHNOLOGY..... | 184 |
| ASPARAGINE APPLICATIONS AND CONSUMPTION PATTERNS..... | 184 |
| ASPARAGINE CAPACITY AND MANUFACTURERS..... | 185 |
| <i>TABLE 119 ASPARAGINE MANUFACTURERS</i> | <i>185</i> |
| ASPARAGINE PRICING..... | 185 |
| VALUE OF U.S. ASPARAGINE MARKET | 185 |
| <i>TABLE 120 U.S. ASPARAGINE MARKET SIZE, THROUGH 2013</i> <i>(\$ MILLIONS)</i> | <i>186</i> |
| <i>FIGURE 21 U.S. ASPARAGINE MARKET SIZE, 2008 AND 2013</i> <i>(\$ MILLIONS)</i> | <i>186</i> |
| ASPARAGINE PATENTS | 186 |
| PATENTS BY CATEGORY | 187 |
| <i>TABLE 121 PRODUCT PATENTS BY PROCESS, 1998-2008</i> | <i>188</i> |
| <i>TABLE 122 U.S. PATENTS ASSIGNEES RELATED TO ASPARAGINE</i> <i>PRODUCTS, 1998-2008</i> | <i>188</i> |
| <i>TABLE 123 U.S. PATENTS RELATED TO ASPARAGINE PRODUCTS</i> <i>BY YEAR, 1998-2008</i> | <i>189</i> |
| CHAPTER TWENTY-SIX: GLUTAMINE..... | 190 |
| GLUTAMINE PRODUCTION TECHNOLOGY..... | 190 |
| GLUTAMINE APPLICATIONS AND CONSUMPTION PATTERNS..... | 190 |
| GLUTAMINE CAPACITY AND MANUFACTURERS | 191 |
| <i>TABLE 124 GLUTAMINE MANUFACTURERS</i> | <i>191</i> |
| GLUTAMINE PRICING & CONSUMPTION | 192 |
| VALUE OF U.S. GLUTAMINE MARKET | 192 |

| | |
|---|-----|
| TABLE 125 U.S. GLUTAMINE MARKET SIZE, THROUGH 2013 (\$ MILLIONS)..... | 192 |
| FIGURE 22 U.S. GLUTAMINE MARKET SIZE, 2008 AND 2013 (\$ MILLIONS)..... | 192 |
| GLUTAMINE PATENTS..... | 193 |
| PATENTS BY CATEGORY | 194 |
| TABLE 126 PRODUCT PATENTS BY PROCESS, 1998–2008..... | 194 |
| TABLE 127 U.S. PATENTS ASSIGNEES RELATED TO GLUTAMINE PRODUCTS, 1998–2008..... | 195 |
| TABLE 128 U.S. PATENTS RELATED TO GLUTAMINE PRODUCTS BY YEAR, 1998–2007..... | 196 |
| CHAPTER TWENTY-SEVEN: HISTIDINE | 197 |
| HISTIDINE PRODUCTION TECHNOLOGY | 197 |
| HISTIDINE APPLICATIONS | 197 |
| HISTIDINE CAPACITY AND MANUFACTURERS | 198 |
| TABLE 129 HISTIDINE MANUFACTURERS | 198 |
| HISTIDINE PRICING | 198 |
| VALUE OF U.S. HISTIDINE MARKET..... | 199 |
| TABLE 130 U.S. HISTIDINE MARKET SIZE, THROUGH 2013 (\$ MILLIONS)..... | 199 |
| FIGURE 23 U.S. HISTIDINE MARKET SIZE, 2008 AND 2013 (\$ MILLIONS)..... | 199 |
| HISTIDINE PATENTS..... | 199 |
| HISTIDINE PATENTS (CONTINUED) | 200 |
| PATENTS BY CATEGORY | 201 |
| TABLE 131 PRODUCT PATENTS BY PROCESS, 1998–2008..... | 201 |
| TABLE 132 U.S. PATENTS ASSIGNEES RELATED TO HISTIDINE PRODUCTS, 1998–2008..... | 202 |
| TABLE 133 U.S. PATENTS RELATED TO HISTIDINE PRODUCTS BY YEAR, 1998–2008..... | 202 |
| CHAPTER TWENTY-EIGHT: SPECIALTY AMINO ACIDS..... | 203 |
| TABLE 134 SUMMARY OF SPECIALTY AMINO ACIDS, THROUGH 2013 (\$ MILLIONS)..... | 203 |
| OTHER SPECIALTY USES OF AMINO ACIDS | 204 |
| COSMETICS AND AMINO ACIDS | 204 |
| PHOTOGRAPHY AND AMINO ACIDS..... | 205 |
| DETERGENT AND AMINO ACIDS | 206 |
| Detergent and Amino Acids (Continued)..... | 207 |
| AMINO ACID HEALTH APPLICATIONS | 208 |
| Amino Acid Health ... (Continued) | 209 |
| APPENDIX I: ANCILLARY COMPANIES | 210 |
| TABLE 135 CELL CULTURE REAGENTS/AMINO ACIDS SUPPLIERS..... | 210 |

| | |
|---|------------|
| <i>TABLE 136 AMINO ACID STANDARDS SUPPLIERS PROVIDING PROTEIN CHEMISTRY REAGENTS AND AMINO ACID ANALYSIS</i> | <i>211</i> |
| <i>TABLE 137 AMINO ACID ANALYZERS SUPPLIERS PROVIDING INSTRUMENTATION AND LAB EQUIPMENT</i> | <i>211</i> |
| <i>TABLE 138 AMINO ACID ANALYSIS SUPPLIERS PROVIDING CUSTOM SERVICES FOR BIOCHEMISTRY AND PROTEIN CHEMISTRY-RELATED SERVICES</i> | <i>212</i> |
| <i>TABLE 139 AMINO ACID POLYMER SYNTHESIS SUPPLIERS PROVIDING CUSTOM SERVICES AND BIOCHEMISTRY/PROTEIN CHEMISTRY-RELATED SERVICES</i> | <i>212</i> |
| <i>TABLE 140 AMINO ACIDS SUPPLIERS OF RADIOCHEMICALS AND LABELED COMPOUNDS.....</i> | <i>212</i> |
| APPENDIX II: MEXICAN AMINO ACID SUPPLIERS | 213 |
| DEGUSSA MEXICO, S.A. DE C.V..... | 213 |
| WARNER JENKINSON, S.A. DE C.V..... | 213 |
| CRODA MEXICO, S.A. DE C.V..... | 213 |
| CIA. QUIMICA INDUSTRIAL NEUMANN S.A. DE C.V..... | 213 |
| GARDHAL, S.A. | 214 |
| HELM DE MEXICO, S.A..... | 214 |
| QUIMICA U.S.P. DE MEXICO S.A. DE C.V..... | 214 |
| ABASTECEDORA DE PRODUCTOS VALLEJO, S.A. DE C.V. | 214 |
| ALQUIMIA MEXICANA, S. DE R.L..... | 215 |
| CIPO, S.A. DE C.V..... | 215 |
| HERVI, S.A. DE C.V..... | 215 |
| RETECMA, S.A. DE C.V. | 215 |
| PRODUCTOS QUIMICOS MONTERREY, S.A. | 216 |
| HELM DE MEXICO, S.A..... | 216 |
| SULFATOS Y DERIVADOS, S.A. DE C.V. | 216 |
| INFORMATICA COSMOS, S.A. DE C.V. | 216 |