

Fermented Beverage Production

SECOND EDITION



Edited by

Andrew G. H. Lea

and

John R. Piggott

Contents

1	Production of Fermentable Extracts from Cereals and Fruits	1
	<i>A. Paterson, J. S. Swanston, and J. R. Piggott</i>	
	INTRODUCTION	1
	Structure of Cereals	2
	<i>Grain Development</i>	2
	<i>The Cereal Endosperm</i>	3
	Cereal Storage Polymers	3
	<i>Starch</i>	3
	<i>Amylose</i>	4
	<i>Amylopectins</i>	4
	<i>Starch Granules</i>	4
	<i>Starch Lipids</i>	5
	<i>Storage Proteins</i>	6
	<i>Cereal Lipids</i>	7
	Cereal Cell Walls	8
	<i>Basic Structure</i>	8
	<i>Glucans and Celluloses</i>	9
	<i>Hemicelluloses</i>	9
	MALTING	11
	Outline of Barley Malting	11
	<i>Changes in Barley Cell-Wall Components During Malting</i>	12
	<i>Changes in Endosperm Proteins</i>	13
	<i>Changes in Starch</i>	13
	Depolymerization Activities During Mashing	14
	<i>The Biochemistry of Mashing</i>	14
	<i>Depolymerization of Starch Polymers</i>	14
	<i>Cell-Wall Degradation</i>	16
	<i>Protein and Nucleic Acid Solubilization and Breakdown</i>	16
	<i>Lipid Extraction During Mashing</i>	16
	Continued Activities During Distillery Fermentation	17
	<i>Degradation of Branched Dextrins</i>	17
	<i>Formation of Ethyl Carbamate</i>	17
	Multiple Parallel Fermentation	17

	Fruits as Raw Materials	18
	<i>Fruit Juices and Their Composition</i>	18
	<i>Fruit Pulping</i>	19
	<i>Implications of Processing Certain Fruits</i>	21
	REFERENCES	23
2	Alcoholic Beverage Fermentations	25
	<i>D.R. Berry and J.C. Slaughter</i>	
	YEAST	25
	PHYSIOLOGY OF YEAST GROWTH	26
	Nutritional Requirements	26
	Carbohydrate Utilization	27
	<i>Uptake of Glucose</i>	27
	<i>Glucose and the Uptake of Maltose</i>	28
	<i>Glucose and the Uptake of Sucrose</i>	29
	Utilization of Nitrogen Sources	29
	Ethanol Fermentation	30
	PRODUCTION OF FLAVOR COMPOUNDS	33
	Higher Alcohols	34
	Organic Acids	34
	Esters	35
	Carbonyl Compounds	36
	Maio-lactic Fermentation	37
	Sulphur Compounds	37
	REFERENCES	38
3	Beers: Recent Technological Innovations in Brewing	41
	<i>D. Iserentant</i>	
	INTRODUCTION	41
	THE TRADITIONAL BREWING PROCESS	41
	Raw Materials	41
	Wort Production	43
	Wort Fermentation and Maturation	44
	NEW TECHNOLOGICAL EVOLUTIONS	45
	Raw Materials	45
	Wort Production	48
	Fermentation and Maturation	49
	NEW PRODUCTS: LOW ALCOHOL BEER, ALCOHOL-FREE BEER, AND ICE BEER ..	51
	Low-Alcohol Beer and Alcohol-Free Beer	51
	<i>Physical Removal of Ethanol</i>	52
	<i>Adaptation of the Traditional Process</i>	52
	Ice Beer	53
	CONCLUSION	54
	REFERENCES	54
4	Cidermaking	59
	<i>Andrew G.H. Lea and Jean-François Drilleu</i>	
	HISTORY AND DEFINITION	59

RAW MATERIALS	62
Cider Apples	62
Milling and Pressing	65
Juice Additions	68
FERMENTATION	69
Yeast Selection	69
Malo-lactic Fermentation	72
Sulfite Binding	73
Cider Color	75
Cider Flavor	76
POST-FERMENTATION OPERATIONS	79
Racking and Storage	79
Storage Disorders	80
Flavor Disorders	82
CONCLUSION	84
REFERENCES	84
5 White Wines	89
<i>Andrew Ewart</i>	
WINE STYLES AND GRAPE VARIETIES	89
Dry, White, Floral and Fruity Wines	89
Medium-Dry, White, Floral and Fruity Wines	89
Dry, White, Full-Bodied Wines	90
Sweet, White Table Wines	90
IMPROVED PLANTING MATERIAL	91
THE VINEYARD AND HARVEST	91
The Vineyard	91
Harvest	92
PREFERMENTATION TREATMENTS	96
YEAST AND FERMENTATION CONTROL	98
POSTFERMENTATION OPERATIONS	101
REFERENCES	105
6 Red Wines	107
<i>Roger Boulton</i>	
STYLES OF RED TABLE WINES	107
GRAPE MATURITY AND HARVESTING	108
PREFERMENTATION OPTIONS	109
JUICE, SKIN AND SEED CONTACTING	110
Maceration Prior to Fermentation	111
Conventional Maceration	111
Maceration After the Fermentation	112
Carbonic Maceration	112
Color and Component Extraction During Conventional Maceration	113
The Role of Copigmentation	114
The Rates of Component Extraction	116
Extraction From Seeds	120

The Use of Temperature and Contacting Time To Enhance Extraction	122
The Choice of Time to Press	122
THE ETHANOL FERMENTATION	123
Must Preparation	123
Yeast Inoculation	125
Fermentation Temperature	125
Concurrent Malo-Lactic Fermentation	126
Prediction of Fermentation Behavior	126
Fermentation Problems	127
Heat Evolution	128
Gas Evolution	128
MALO-LACTIC FERMENTATION	129
Malo-Lactic Bacteria	129
Bacterial Nutrition	130
Immobilized Bacteria	130
POST-FERMENTATION HANDLING OF WINES	130
AGING	131
Aging Reactions	131
Cooperage Considerations	132
Microbial Control During Aging	132
Evaporative Losses	132
PREPARATION FOR BOTTLING	133
REFERENCES	134

7 Sparkling Wines	139
<i>Patricia Howe</i>	
INTRODUCTION	139
BASE WINES	140
CARBONATION	140
Levels and Terms	140
Quantification of Carbonation	142
Methods of Carbonation	142
SECONDARY FERMENTATION BY YEAST	143
Selection of Yeast and Conditioning	143
Fermentation Temperature	143
Culturing Techniques	144
Inoculum Size	144
Agglomerating Ability	144
Enclosed or Encapsulated Yeast	144
The Sugar Source for the Carbonating Fermentation	144
The Vessel Used for the Carbonating Fermentation	145
YEAST LEES AGING	145
Overview of Lees Aging Reactions	145
Non-Enzymic Effects on Composition of the Wine with Lees Contact	147
Excretion of Amino Acids	147
Autolysis and Enzymatic Activity	147
METHOD OF CLARIFICATION	148
No Clarification	148
Riddling and Disgorging	148
Filtration	149

THE FINAL PACKAGE	149
SWEETENING	149
AGING OF SPARKLING WINES IN THE ABSENCE OF YEAST—	
EFFECT OF HEAT AND LIGHT	150
General Sensory Effects of Heat	150
Heat and the Formation of Ethyl Carbamate	150
Heat and Maillard Reaction Products	150
Heat and Changes in Ester Composition	151
Heat and Oxidation	151
Heat, Internal Pressure, and Bottle Seal	151
Heat and Protein Instabilities	151
Light	151
FOAM AND BUBBLES	152
Bubbles	152
Foam	152
CONCLUSION	153
REFERENCES	153

8 Fortified Wines: Sherry, Port and Madeira 157

H. P. Reader and M. Dominguez

INTRODUCTION	157
Definition and Scope	157
Origins and Current Status of Fortified Wines	158
Outline of the Basic Processes	158
ALCOHOLIC FERMENTATION	159
FORTIFICATION SPIRIT	166
SHERRY	166
Definition	166
Viticulture	167
<i>Climate and Soil</i>	167
<i>Vineyards and Grape Varieties</i>	167
<i>Vintage</i>	168
Vinification	169
<i>Pressing</i>	169
<i>Fermentation and Fortification</i>	169
Styles of Wine	170
Aging and Maturation	170
<i>Cellars</i>	171
<i>The Solera System</i>	171
<i>Aging Under Flor</i>	171
<i>Maturation without Flor</i>	173
Sweetening and Color Wines	174
Commercial Styles of Sherry	176
Final Processing	176
PORT	177
Regulation	177
Geographical Origin	177
Viticulture	178
Vintage	179
Vinification	179

Basic Styles of Wine	182
Aging and Maturation	182
Blending	184
Commercial Styles of Port	185
<i>Wood Aged Styles</i>	185
<i>Bottle Aged Styles</i>	185
Processing	185
MADEIRA	186
Regulation and Geographical Origin	186
Viticulture	186
Vintage	187
Vinification	187
Aging and Maturation	188
Blending	188
Commercial Styles of Madeira	188
Processing	189
QUALITY ASPECTS	189
Ethyl Carbamate	189
Microbial Spoilage	189
ACKNOWLEDGEMENT	190
REFERENCES	190
9 From Vine to Cognac	195
<i>R. Cantagrel and B. Galy</i>	
INTRODUCTION	195
THE GEOLOGY AND THE 'CRU' (GROWTH AREA)	195
THE VINE VARIETIES	196
THE WINEMAKING	197
Treatment of the Grapes in the First 5 Minutes	198
From the Harvest to the Fermentation Vat	198
The Fermentation	199
THE CHARENTE DISTILLATION	202
THE AGING OF COGNAC	202
BLENDING: AN IMPORTANT STEP IN THE PROCESS OF COGNAC PRODUCTION ..	209
The Development of the Chemical Equilibrium During Blending and Reduction	209
Production of the Blend	210
Notions of Age	210
Commercial Denominations	210
CONCLUSION	211
REFERENCES	211
10 Armagnac and Wine-Spirits	213
<i>A. Bertrand</i>	
ARMAGNAC	213
Historical Background	213
Appellation Areas, Soils, Climate, Vine Stocks	214
Vinification	215

Distillation and Regulations	215
<i>The Continuous Armagnac Still (Figure 10-2)</i>	216
<i>Two-Stage Pot Stills</i>	218
Analysis	218
<i>Traditional Analyses</i>	219
<i>Gas Chromatography</i>	219
<i>High-Pressure Liquid Chromatography (HPLC)</i>	219
<i>Sensory Analyses</i>	219
<i>Analysis of Principal Ions in Armagnac Spirits</i>	222
<i>Carbonyl Compounds in Wine Spirits</i>	223
Aging and Merchandizing Preparation	226
WINE-SPIRITS	229
Regulations	229
<i>Wine-spirits</i>	229
<i>Brandy</i>	230
<i>Distillation</i>	230
<i>Wine Rectifiers (Mariller, 1925)</i>	230
<i>Indirect Rectifiers</i>	230
<i>Batch Rectification for the Production of Wine-Spirits or Distillates (Figure 10-16)</i>	230
Composition of Brandies	231
Aging and Merchandising Preparation	231
ETHYL CARBAMATE IN WINE SPIRITS	231
Role of the Distillation Process	232
Role of the Vine Cultivar	233
Search for a Precursor in the Case of 22 A Baco Wine	234
<i>Catalytic Role of Copper</i>	234
<i>Role of Light</i>	234
<i>Hydrocyanic Acid</i>	234
Use of Ion Exchange Resins to Reduce EC Content	235
CONCLUSION	236
ACKNOWLEDGEMENTS	236
REFERENCES	237
11 Whiskies	239
<i>J.R. Piggott and J.M. Conner</i>	
INTRODUCTION	239
MATERIALS	240
MILLING, COOKING, AND MASHING	241
Malt Whisky	241
Grain Whisky	242
FERMENTATION	242
DISTILLATION	244
Batch Distillation	244
Continuous Distillation	246
By-Products	248
MATURATION	248
Current Practice	249

<i>Cask Type</i>	250
<i>Warehousing</i>	251
Sensory Changes During Maturation	252
Chemical Changes During Maturation	252
<i>Extraction of Wood Components</i>	253
<i>Reactions Involving Distillate Components</i>	253
<i>Solution Changes That Affect the Release of Aroma-Compounds</i>	254
BLENDING	255
FILTRATION	255
RAW MATERIAL AND PRODUCT ANALYSES	256
Sensory Assessment	256
Raw Materials	256
<i>Cereals</i>	256
<i>Yeast</i>	257
<i>Water</i>	257
Mashing and Fermentation	257
Distillation	257
Maturation	258
REFERENCES	259

12 Rum	263
<i>Denis A. Nicol</i>	
INTRODUCTION	263
THE HISTORY OF RUM	263
THE ORIGIN OF THE WORD 'RUM'	265
CANE JUICE PRODUCTION	265
MOLASSES	266
MOLASSES HANDLING	267
CANE JUICE	269
DIFFERENT TYPES OF MOLASSES	269
YEASTS	269
YEAST PROPAGATION	269
FERMENTATION	270
FERMENTATION EFFICIENCIES	271
DISTILLATION	272
POT DISTILLED RUM	273
HIGH ESTER RUMS	275
COLUMN DISTILLATION	276
INVENTORY CONTROL AND MANAGEMENT	277
THE AGING OF RUM—MATURATION	278
THE AROMA AND FLAVOR OF RUM	278
EFFLUENT DISPOSAL	279
QUALITY	279
Quality—Molasses	280
Water, Yeast and Fermentation (IOB, Methods of Analysis, 1997)	280
Quality—Water (IOB, Methods of Analyses, 1997)	280
Quality—Yeast	280
Quality—Yeast	281

Quality—Plant Hygiene	281
Quality—Distillation	281
Quality—Casks	281
Quality—Effluent	282
Quality—Bottled Rums	283
SUMMARY AND CONCLUSION	286
REFERENCES	287
13 Vodka, Gin and Other Flavored Spirits	289
<i>R.I. Aylott</i>	
INTRODUCTION	289
Vodka	289
Gin	290
Other Flavored Spirits	290
DEFINITIONS AND REGULATIONS	290
Neutral Alcohol	291
Vodka	291
Gin	291
Other Flavored Spirits	292
BRANDS, MARKETS AND VOLUMES	293
Vodka	293
Gin	294
Other Flavored Spirits	294
VODKA, GIN AND FLAVORED SPIRIT PRODUCTION	295
Neutral Alcohol	295
Vodka	296
Gin	297
<i>Materials for Gin Production</i>	297
<i>Gin Distillation</i>	298
<i>Compounded Gin Production</i>	299
<i>Flavored Gins</i>	299
<i>Other Juniper-Based Drinks</i>	299
Other Flavored Spirits	301
Packaging and Distribution	301
ANALYSIS	302
Alcohol	302
Water	304
Flavor	304
Brand Authenticity Analysis	306
ACKNOWLEDGEMENTS	307
REFERENCES	307
14 Liqueurs & Speciality Products	309
<i>David W. Clutton</i>	
INTRODUCTION	309
STATISTICS	310
Pre-mixed drinks	312
LEGAL DEFINITIONS	313

COMPOSITION	314
CREAM LIQUEURS	315
COCKTAILS	316
SUMMARY	317
APPENDIX	318
REFERENCES	334
15 Cachaça, Pisco and Tequila	335
<i>J.B. Faria, Eduardo Loyola, Mercedes G. López, and Jean Pierre Dufour</i>	
CACHAÇA: THE BRAZILIAN SUGAR CANE SPIRIT	335
Historical Background	335
Cachaça Regulations	336
Raw Material	336
<i>Sugar Cane Juice Extraction</i>	336
<i>Must Preparation</i>	336
Fermentation	337
<i>The Yeast</i>	337
<i>The Fermentation Process</i>	337
<i>Sugar Cane Wine Composition</i>	338
Distillation	338
<i>Discontinuous and Semi-Continuous Systems</i>	338
<i>Continuous Distillation</i>	339
<i>Distillate Composition</i>	341
Aging	341
Some Aspects Related to Quality of Cachaça	342
<i>Sulphur Compounds and the Sensorial Quality of Cachaça</i>	342
<i>Inappropriate Handling and Industrial Practices</i>	344
<i>Sugar Addition and Legal Regulations</i>	346
<i>New Detected Contamination</i>	346
<i>Cachaça Production and Market</i>	346
Conclusions	346
PISCO	346
Introduction	346
Production Zone	347
Vinification in the Pisco Industry	348
Distillation	349
<i>Distillation Method</i>	350
Chemical Composition of Pisco	351
Production and Consumption	353
TEQUILA	353
Introduction	353
Materials	355
Tequila Elaboration	355
Harvesting, Cooking and Mashing	355
Fermentation	357
Distillation	357
Maturation	357
Flavor Chemistry	358

REFERENCES	360
16 Filtration and Stabilization of Beers	365
<i>G.J. Freeman and M.T. McKechnie</i>	
BACKGROUND TO BEER STABILITY	365
THE IMPORTANCE OF OXYGEN	366
COLD CONDITIONING	367
CONVENTIONAL POWDER FILTRATION	368
STABILIZATION WITH PROCESSING AIDS	373
Tannic Acid	374
Silicas	375
Polyvinylpyrrolidinone (PVPP)	376
Nylon	377
Bentonite	378
Activated Carbon	378
Enzymes	378
DILUTION OF HIGH-GRAVITY BEERS	378
PASTEURIZATION	379
Introduction	379
Theory	379
Equipment and Process Conditions	379
<i>Effect Upon Beer Quality</i>	381
COLD STERILIZATION OF BEER	381
Sheet Filters	382
Enzinger Pulp Filters	382
Cartridge (Membrane) Filters	383
Ceramic Candles	384
GAS ADJUSTMENT	384
CASK ALES	385
BEER RECOVERY	385
Centrifuges	386
Vacuum Filters	386
Filter Presses	387
Alcohol Evaporation Systems	387
Crossflow Membrane Filtration	388
THE FUTURE	389
ACKNOWLEDGEMENTS	389
REFERENCES	390
17 Flavor Chemistry	393
<i>V.C. Cole and A.C. Noble</i>	
INTRODUCTION	393
RAW MATERIALS	393
Wine Derives Flavor from Grapes	393
Beer, Whisky, and Gin Derive Flavor from Grain	396
Flavor Additives: Hops in Beer	397
Raw Materials in the Flavor of Gin, Vodka, and Whisky	397
Other Raw Materials: Fruits in Wine and Brandies	398

FERMENTATION	399
Yeast Strain	399
Temperature	400
Oxygen Effect	400
Barrel Fermentation	400
Malo-lactic Fermentation	400
Lees Contact (<i>sur lies</i>)	401
Sulfur Compounds	401
DISTILLATION	401
Thermally Induced Chemical Reactions	402
Still Type	403
CONTRIBUTION OF AGING TO FLAVOR	403
Reactions During Aging	403
<i>Oxidation</i>	403
<i>Esterification and Hydrolysis</i>	404
Evaporation	405
Effects of Oak Aging	405
<i>Compounds Extracted from Oak</i>	405
<i>French versus American Oak</i>	406
<i>New versus Used Barrels</i>	407
<i>Cooperage Techniques</i>	407
CONCLUSION	407
REFERENCES	408
Index	413