## **Contents**

	A Few Words of Thanks ix	1.6.8	Storing Malt and Maintaining Malt
	Preface xi		Stores 91
		1.7	Malting Losses 92
		1.7.1	Losses During Steeping 93
1	The Technology of	1.7.2	Losses During Respiration and Germination 93
	Malting 1	1.7.3	Calculating Malting Losses 94
1.1	Malting Barley 1	1.8	The Properties of Malt 95
1.1.1	The Morphology of Barley 2	1.8.1	External Characteristics 95
1.1.2	The Chemical Composition of Barley 2	1.8.2	Mechanical Analysis 95
1.1.3	Determining and Evaluating the	1.8.3	Physico-Chemical Analysis 96
	Properties of Barley 6	1.9	Malt from Other Grains 98
1.2	Preparing Barley for Malting 9	1.9.1	Wheat Malt 98
1.2.1	Receiving Barley in Bulk 9	1.9.2	Malt from Alternative Cereals 100
1.2.2	Conveyor Systems 9	1.9.2	Pseudocereals 103
1.2.3	Cleaning and Sorting Barley 10	1.9.3	Specialty Malts 103
1.2.4	Preparing and Storing Barley 13	1.9.4	- •
1.2.5	Artificial Drying of Barley 16	1.9.5	Micromalting 106
1.2.6	Plant Diseases and Animal Pests		
	Affecting Barley 18	2	The Technology of Wort
1.2.7	Changes in the Weight of Barley During		Production 109
	Storage 19	2.1	Raw Materials for the Brewing
1.3	Steeping the Barley 19		Process 109
1.3.1	Moisture Uptake in the Barley	2.1.1	Malt 109
	Kernel 19	2.1.2	Adjuncts: Alternatives to Malt 109
1.3.2	Supplying Oxygen to the Steeping	2.1.3	Brewing Liquor 111
	Grain 20	2.1.4	Hops 124
1.3.3	Cleaning the Barley 21	2.1.5	Adding Hops to the Wort 139
1.3.4	Water Consumption 21	2.2	Milling the Malt 148
1.3.5	Steeping Equipment 22	2.2.1	Monitoring Grist Quality 150
1.3.6	Steeping Technology 25	2.2.2	Mill Designs 150
1.4	Germination 28	2.2.3	Properties and Composition
1.4.1	The Theory of Germination 28		of the Grist 158
1.4.2	The Practice of Germination 36	2.2.4	The Arrangement of the Milling
1.5	Various Malting Systems 41		Area 159
1.5.1	Floor Malting 41	2.3	Wort Production 159
1.5.2	Pneumatic Malting Systems 45	2.3.1	The Theory of Mashing 159
1.5.3	Germination Vessels in Pneumatic	2.3.2	Mashing Techniques 168
	Malting Systems 49	2.3.3	Mashing Regimes 174
1.5.4	The Finished Green Malt 65	2.3.4	Particular Issues with Mashing 185
1.6	Kilning the Green Malt 66	2.3.5	Monitoring the Mashing Process 186
1.6.1	The Processes Involved in Kilning 66	2.4	Extracting the Wort (Lautering) 188
1.6.2	Kilns 72	2.4.1	Operations During Lautering 188
1.6.3	Kilning Techniques 79	2.4.2	The Lauter Tun 189
1.6.4	Monitoring and Automating	2.4.3	The Lautering Process with a Lauter
	Kilning – Kiln Maintenance 87		Tun 192
1.6.5	Energy-Saving Measures 88	2.4.4	Lautering with a Conventional Mash
1.6.6	Additional Tasks Associated with		Filter 202
	Kilning 89	2.4.5	Membrane Compression Filters 203
1.6.7	Handling of Malt After Kilning 90	2.4.6	The Thin-bed Filter 205

2.4.7	A Comparison of Thin-bed Mash Filtration and the Modern Lauter	3.1.1 3.1.2	Yeast Morphology 263 The Chemical Composition of
	Tun 207		Yeast 264
2.4.8	The Strainmaster 207	3.1.3	Yeast Enzymes 264
2.4.9	Continuous Lautering Methods 208	3.1.4	Yeast Reproduction 265
2.4.10	The Wort Collection Vessel 209	3.1.5	Yeast Genetics 266
2.5	Boiling and Hopping the Wort 209	3.1.6	Genetic Manipulation of Yeast 266
2.5.1	Wort Kettles 210	3.1.7	Yeast Autolysis 268
2.5.2	Physical Processes During Wort	3.2	Yeast Metabolism 268
	Boiling 215	3.2.1	Carbohydrate Metabolism 269
2.5.3	Coagulation of Protein 216	3.2.2	Protein Metabolism 271
2.5.4	Hopping the Wort 219	3.2.3	Lipid Metabolism 272
2.5.5	Aroma Compounds in Wort 226	3.2.4	Mineral Metabolism 273
2.5.6	Technical and Energy Aspects of	3.2.5	Vitamins 274
	Modern Wort Boiling Systems 229	3.2.6	Metabolites and Their Significance for
2.5.7	Casting Out the Wort 236		Beer Quality 274
2.5.8	The Cast-out Wort 237	3.3	Bottom-fermenting Yeast in Brewing
2.5.9	Cleaning the Brewhouse		Operations 279
	Equipment 237	3.3.1	Yeast Strain Selection 279
2.5.10	Automating the Wort Boiling	3.3.2	Culturing Pure Strains of Brewing
	Process 239	3.3.2	Yeasts 279
2.5.11	Options for Recovering Residual	3.3.3	Yeast Degeneration and Loss of Typical
	Extract 239	3.3.3	Characteristics 281
2.5.12	Spent Grain 241	3.3.4	Harvesting Yeast 282
2.5.13	Safety and Consistency in the	3.3.5	Cleaning the Yeast 283
	Brewhouse Production 241	3.3.6	
2.6	Brewhouse Yield 242		Yeast Storage 284
2.6.1	Calculation of Brewhouse Yield 242	3.3.7	Shipping Yeast – Dry Yeast 285
2.6.2	Assessing Brewhouse Yield 244	3.3.8	The Physiological Condition
2.6.3	Conclusions on the Topic of Brewhouse	2.4	of the Yeast 285
	Yield 246	3.4	Beer Production with
2.7	Wort Chilling and Elimination of Break		Bottom-fermenting Yeast 286
	Material 246	3.4.1	Fermentation Rooms or Cellars 286
2.7.1	Chilling the Wort 247	3.4.2	Fermentation Vessels 287
2.7.2	Oxygen Uptake in the Wort 247	3.4.3	Pitching the Yeast 294
2.7.3	Elimination of Hot and Cold Break	3.4.4	Conducting Fermentation 297
2.7.0	Material 247	3.4.5	Primary Fermentation 298
2.7.4	Other Processes 249	3.4.6	Degree of Attenuation 301
2.7.5	Wort Chilling and Cold Wort	3.4.7	Maturation Levels of the Green
2.7.0	Handling 249		Beer 304
2.7.6	Operations with a Coolship and a	3.4.8	Changes in the Wort During
2.7.0	Baudelot (Falling Film) Chiller or a		Fermentation 304
	Closed Chiller 249	3.4.9	Recovery of Carbon Dioxide Produced
2.7.7	Closed Wort Chilling Systems 251		During Fermentation 307
2.8	Cold Wort Yield 260	3.5	Maturation and Lagering 309
	Data Collected for Cold Wort	3.5.1	The Lager Cellar 310
2.8.1		3.5.2	Lager Vessels 311
202	Yield 260 Calculation of Cold Wort Yield 260	3.5.3	The Maturation Process 312
2.8.2		3.6	Modern Fermentation and Lagering
2.8.3	Overall Yield in Wort Production	0.0	Methods in Beer Production 321
	(Overall Brewhouse Yield – OBY) 261	3.6.1	Methods of Operation for Fermenting in
		5.0.1	Tanks and Larger Vessels 321
3	The Technology of	3.6.2	Utilization of Intermediate Storage
_	Fermentation 263	0.0.4	Tanks and Implementation of a Green
3.1	Brewing Yeast 263		Beer Centrifuge 326
U.1	DICWING ICASE 200		Deer Celiffinge J20

3.6.3	Methods for Accelerating Fermentation and Maturation 327	5.3.5 5.3.6	Capping the Bottles 383 Oxygen Uptake During Bottling 383
3.6.4	Continuous Fermentation Processes 335	5.4	"Sterile Filling" and the Pasteurization of Beer 387
3.6.5	Classic CCTs Employed in a	5.4.1	"Sterile Filling" 387
	Continuous-flow Process 336	5.4.2	Pasteurization of Beer 391
3.6.6	Hopping Beer on the Cold Side 336	5.5	The Layout of a Bottling Plant 393
4	Beer Filtration 339	6	Beer Losses 395
4.1	The Theory of Filtration 339	6.1	Factors Affecting Beer Losses 395
4.2	Filtration Technology 341	6.1.1	Wort Losses 396
4.2.1	Pulp Filtration 341	6.1.2	True Beer Losses 397
4.2.2	Diatomaceous Earth Filtration 342	6.2	Calculating Beer Losses 399
4.2.3	Sheet Filters 349	6.2.1	Calculation of Volumetric Losses 399
4.2.4	Membrane Filtration 350	6.2.2	Calculation of Surpluses and
4.2.5	Centrifuges 351		Deficits 400
4.3	Combined Clarification Processes 353	6.2.3	Calculating the Quantity of Wort and
4.4	Options for Replacing Diatomaceous Earth as a Filter Medium 353		Beer Obtained from 100 kg of Malt 400
4.4.1	Combining a Centrifuge with a Pulp Filter 353	6.2.4	Calculating the Extract Losses from the Cast-out Wort and/or from Malt
4.4.2	Combining a Fine Clarification		Grist 400
1.1.2	Centrifuge and a Horizontal Filter 354	6.2.5	The Economic Aspects of Recovering
4.4.3	Multi-step Microfiltration 354		Beer 401
4.4.4	Filter Sheets 354		
4.4.5	The Use of Synthetic Extrudates 355	7	The Finished Beer 405
4.4.6	Crossflow Microfiltration 355	7.1	The Composition of Beer 405
4.4.7	Concluding Remarks on Modern	7.1.1	Extract in Beer 405
	Filtration Systems 359	7.1.2	Volatile Compounds 406
4.5	Filtration – Auxiliary Equipment and	7.2	The Classification of Beer 407
	Monitoring Devices 359	7.3	Properties of Beer 407
4.5.1	Auxiliary Equipment 360	7.3.1	General Characteristics 407
4.5.2	Devices for Monitoring Filtration 360	7.3.2	The Redox Potential of Beer 407
4.6	Beginning and Ending a Filtration	7.3.3	Beer Color 408
	Run 361	7.4	The Aroma of Beer 408
4.7	Tank Bottoms 362	7.4.1	Characteristics of Beer Aroma 409
4.8	Compressed Air 363	7.4.2	Factors Influencing Flavor 410
		7.4.3	Off-flavors in Beer 411
_	D   1 D   065	7.5	Beer Foam 414
5	Packaging Beer 365	7.5.1	The Theory of Foam Formation 414
5.1	Beer Storage After Filtration 365	7.5.2	Technological Influences on the
5.2	Filling Barrels and Casks 365		Properties of Beer Foam 415
5.2.1	Barrels and Casks 365	7.6	Factors Affecting the Physico-chemical
5.2.2	Cleaning Barrels and Casks 366		Properties of Beer and Their
5.2.3	Filling Casks and Barrels 367		Stabilization 418
5.2.4	Improvements in Filling and Dispensing	7.6.1	The Composition of Colloidal
	from Conventional Casks 368		Turbidity 418
5.2.5	Cleaning and Filling Kegs 368	7.6.2	The Formation of Colloidal
5.2.6	Filling and Storage Areas 371		Turbidity 419
5.3	Bottling and Canning 371	7.6.3	Technological Measures to Improve
5.3.1	The Containers 371		Colloidal Stability 419
5.3.2	Cleaning Bottles 374	7.6.4	The Stabilization of Beer 419
5.3.3	Bottling 377	7.6.5	The Flavor Stability of Beer 428
5.3.4	Cleaning and "Sterilizing" Filling	7.6.6	Methods for Monitoring and Predicting
	Machines 382		Flavor Stability 434

viii

8.3.5

Changes in Wort During Top

Fermentation 473

Index 501