

Index

a

- AAS (atomic absorption spectrometry) 447, 466, 467
- abscisic acid (ABA) 46, 52, 54
- accelerated fermentation 219
 - under carbon dioxide pressure 217, 218
- Accum, Frederic 32
- acetaldehyde 131, 132, 211
 - as flavor attribute 680, 682
 - as off-flavor 267
- acetaldehyde dehydrogenase 132
- acetate (acetyl-CoA) 134
- acetic acid 252, 483, 484, 688
 - in bottom-fermented beer 359
 - as off-flavor 267
- acetic acid bacteria 478
- Acetobacter* 268
- Acetobacter pasteurianus* 477
- acetogenesis 638
- α -aceto-hydroxybutyrate 132
- acetoin 359, 484
- acetolactate 128
- 2-acetolactate 132, 133, 417
- α -acetolactate 132
- acetyl-CoA 131, 132, 134, 207
- acetyl-CoA synthetase 132
- 2-acetyl-pyrazine 285
- 2-acetyl-pyridine 385
- 2-acetyl-pyrrole 383, 385, 386
- 2-acetyl-pyrroline 177
- 2-acetyltetrahydropyridine 177
- 2-acetyl-thiazole 385, 386
- 4-acetyl-thiazole 385
- 2-acetyl-thiazoline 385
- acid-caustic titration 449, 450
- acidic cleaning agents 599
 - for keg cleaning 618
- acidic/sour flavor attribute 680, 687, 688
- acidification phase, of lambic beer production 252
- acidity 108, 109
- acid malt 164
- acidogenesis 638
- acrosipre length 153
- activated-carbon filtration 112
- activated-sludge plant 635, 636
- active chlorine 601, 612, 618
- active noise abatement 672
- active transport 126
- adaptive control algorithms 543, 544
- additive cleaning substances 598
- adenosine diphosphate-glucose 49
- ADF (apparent degree of fermentation) 444
- adhumulone 87
- adjunct mashing 176–181
- Advant OCS 551
- aerated waste water ponds 637
- aeration
 - during fermentation 214
 - in fermentation 209
 - of water 112
- aerobic metabolism 131
- aerobic waste water treatment 635–637, 668
 - combined with anaerobic waste water treatment 640
- Africa
 - beer markets 506, 509
 - top brewers 512
- after-bitterness, assessing 680, 690
- agarose gels 232, 234
- agrarian societies, beer and 2–5
- AI (aniline index) 422, 423
- air, beer transport with 419
- air pollution. *see also* emissions
 - control regulations 675
- albumins 50, 51

- alcohol acyltransferase 134
- alcohol chilling test 457
- alcohol dehydrogenase 131
- alcohol-free beers 235–240
 - biological methods 238–240
 - bioreactors (immobilized yeast fermentation) 240
 - combination physical-biological processes 240
 - dialysis 238
 - interrupted fermentation (batch processing) 239
 - physical methods 236–238
 - production techniques 236–240
 - reverse osmosis 237, 238
 - thermal dealcoholization 236, 237
- alcoholic flavor attribute 680, 688
- alcohols
 - aliphatic 210
 - aromatic 210
 - as cleaning additives 598
 - formation of higher 132, 133
 - oxidations of 402
- aldehydes 132, 211
 - aldol condensation of 402
 - in bottom-fermented beer 359
 - for disinfection 600–602
 - staling process and 399
 - Strecker 187, 239, 408, 423
- alehouses
 - identification of 21
 - licensing of 22
- ales 23, 248–250, 504, 505, 507
 - bitter 248
 - in Britain 21, 22
 - British pale 28
 - British sea power and 22, 23
 - brown 249
 - cask-conditioned 248–250
 - dispensing 348
 - India pale 249
 - Irish 249
 - mild 248
 - ‘normal’ 249
 - old 249
 - pale 248
 - ‘real’ 249
 - Scottish 249
 - types of 25
 - types of English 248, 249
- aleurone cells, cell death of 54
- aleurone layer 44, 45, 51, 153, 154
 - wheat 47
- Alexis barley 404, 406
- ale yeast 121–123
- algorithms
 - advanced 543–545
 - classic 542–545
- aliphatic alcohols 210
- alkaline cleaning agents 597, 598, 609
 - aluminum and 612
 - in bottle-washing machines 616
 - for keg cleaning 618
 - temperature and 613
- alkalinity 109, 111
- allergens, plant food 52
- α -acids
 - bitter flavor and 690
 - cohumulone fraction of 368
 - determination of 461
 - in hops 87, 91, 97, 99
 - lightstruck flavor and 426, 428
- Alster 258
- Alsterwasser 258
- alt beer 223, 224
- Altbier 259
- Althammer, A. 6
- Altbierbowle (Altbier punch) 258
- Alt-Schuss (Alt-Shot) 258, 259
- alu 2
- aluminum, cleaning 597, 612
- Alzheimer’s disease 517
- amaranth (*Amaranthus cruentus*, *A. hypochondriacus*, *A. caudatus*) 56, 57, 69
 - for gluten-free beer 246
- amaretto, beer and 259
- AmBev 511
- American lager 28
- American Society of Brewing Chemists (ASBC) 437, 439
- American Society of Brewing Chemists units 161
- Amici, Giovanni Battista 31
- amino acids 525
 - concentration in beer 453
 - foam and 362
 - formation of *N*-heterocycles from 385
 - in grains 51
 - metabolism of by yeast 139
 - removal from wort 128, 129
 - Strecker’s degradation of 402
- α -amino compounds 408
- 1-amino-1-desoxy 408
- ammonia 448
- ammonia cooling systems 671
- ammonia sulfate 457
- amylase 31, 54, 55, 170
- α -amylase 60, 170, 173, 180, 247, 411, 447

- β-amylase 170, 173, 180, 181
- α-amylase/trypsin inhibitors 51
- α-amylolysis 160, 161
- amyololysis 160, 161, 171, 458
- amylopectin 49, 64, 170, 173
- amyloplasts 46, 49
- amylose 49
- anabolic processes 46–53
 - regulation of grain filling 52, 53
 - starch formation 47–50
 - storage proteins 50–52
- anaerobic metabolism 131
- anaerobic waste water treatment 637–639, 668
 - combined with aerobic waste water treatment 640
- analysis, methods for analyzing hop and hop products 92
- analytics. *see* quality control
- Anheuser-Busch 36, 511
- aniline index (AI) 422, 423
- anion exchanger 114, 115
- annual capacity, of malting plant 560
- anthocyanogens 89, 373, 374, 379, 380
 - analysis of total 447
 - solubility of 380
 - value of 380
- antifreeze proteins 53
- antimicrobial properties of beer 524
- antioxidants
 - applied to beer-based mixed drinks 269
 - in beer 518
 - comparative effects 374
- AOX (absorbable organic halogen substances) problem 666, 667
- apparent degree of fermentation (ADF) 444
- apparent density 440
- apparent extract 441
- apparent specific density 440, 441
- apparent specific gravity 443
- Apple Radler 264, 265
- applied gauge pressure, calculating 344–346
- arabinoxylans 45, 46
- arginine 160
- Arnhold, Max and Georg 30
- aroma 361
- aroma hops 89, 94, 95
- aroma profile, of alcohol-free beer 237, 238
- aroma substances in hops 88, 89, 371
- aromatic alcohols 210
- aromatic compounds, staling and changes in 402, 403
- arteries, beer and protection of 522
- articulated-arm robot 583
- artificial sweeteners, in beer-based mixed drinks 261, 262
- ASBC (American Society of Brewing Chemists) 437, 439
- ascorbic acid, applied to beer-based mixed drinks 269
- Asia/Pacific
 - beer markets 506, 509
 - malt and 502
 - top brewers 512
- asset management systems 552
- astringency, assessing 680, 690
- atherosclerosis, beer and 516–519
- atomic absorption spectrometry (AAS) 447, 466, 467
- attenuation 31
- A-type amyloplasts 49
- Aubry test 151
- Aureobasidium* 477
- Australia
 - beer market 509, 510
 - malting barley varieties 500
- Austria
 - beer market 506
 - dietetic beer in 241
- automated yeast propagation 138, 139
- automatic reel changing feature, on pressure-sensitive labelers 333, 334
- automation 531–553
 - control strategies 542–549
 - information technologies 551, 552
 - measurement technology 533–542
 - objectives of 531
 - overview 531–533
 - PCS 550, 551
- availability, calculating 707
- Avena fatua* 60
- b**
- Babylonian beer 6
- Bacillus* spp. 602
- back-of-label coding/dating 337
- bacteria. *see also individual species*
 - acetic acid 478
 - beer-spoilage 481–484
 - capsular slime-forming acidic acid 477
 - diacetyl and 215
 - lactic acid 478
- balanced alkalinity 109
- ballast resistors 655
- Balling, Carl Josef Napoleon 31
- Balling formula 442, 443
- bar cooling 342
- bar counter 343

- Baretz, Leonhard 33
- Barke barley 406
- barley adjunct, mashing with 177, 179
- barley flakes 177
- barley (*Hordeum vulgare*) 3, 14, 43, 59, 60
 - acreage and production of 59
 - amino acids 51
 - brewing 147
 - as brewing cereal 17
 - catabolic processes in 53
 - cleaning 149, 150
 - conversion to malt 560, 561
 - DMS and 387
 - endosperm 45, 46
 - genome 44
 - grain ripening 48
 - intake of 149–163
 - malting varieties 500
 - organoleptic stability and variety of 404
 - pre-cleaning 149
 - six-row 498
 - starch content 46
 - starch granules 50
 - steeping 150, 151
 - storage of 149–163, 555
 - two-row 498
 - varieties of 147
 - world market in 498–501
- barley malts, gelatinization temperatures of 172
- barley wine 688
- barrels, cleaning 617, 618
- base, inspecting 316, 318
- basis regulation 495
- batch archiving 552
- Bauer, M. 32
- Bavaria 19
 - beer export 29
 - lager beer and 25–27
- Bavarian lager 28
- Bavarian Purity Law (Reinheitgebot) 26, 55, 90, 97, 119, 241
 - hot holding and 186
- Baverstock, James 31
- Bavarian Purity Law (Reinheitgebot) 260
- B complex vitamins 525, 526
- beauty, beer and 525, 526
- beer 22. *see also* beer-based mixed drinks; *individual types*
 - alcohol and 521
 - antimicrobial properties of 524
 - archaeological evidence for 2
 - assessing flavor of 676–679
 - cancer and 521, 522
 - defined 1, 26
 - effect of addition of hops on character of 94
 - enriched with xanthohumol 97
 - global production of 505, 506
 - health benefits of 515–528
 - with hop flavor 94–97
 - polyphenol contents in 376
 - production process 531–533
 - role in early societies 5
 - styles of 27
- beer additives 15, 32
- beer bar 343
 - dispensing direct from 346, 348
 - dispensing from above 346, 347
 - dispensing from below 346, 347
- beer-based mixed drinks 257–273
 - antioxidant application 269
 - assessment by German Agricultural Society 264–266
 - constituent beer 260
 - development of 258, 259
 - filling 272
 - filtration 271, 272
 - flavorings and juices 263
 - food acids 262, 263
 - ingredients and mixing formulations 260–263
 - microbiology of 268
 - mixing 270, 271
 - off-flavors 266–268
 - packaging 272
 - pasteurization 269, 270
 - preservation of 269, 270
 - production equipment 273
 - quality control of 263–268
 - sensory assessment of 264
 - sweetening 261, 262
 - water quality 261
 - wet chemical analysis of 263, 264
- beer bath 526
- beer belly 527
- beer-bread 4, 5
- beer color 212, 360, 361
- beer consumption 497, 503, 506
- beer dispensing. *see* draft beer system
- beer-dispensing tanks 350
- beer foam 361–366. *see also* gushing
 - basis of 362
 - beer filtration 365
 - cold break removal 364
 - influence of brewing water 362
 - influence of foam stability 362
 - influence of gas 362

- influence of hop products 363
- influence of malt 363
- influence of malt filtration 363
- main fermentation 364
- precocious indicators for foam image 365
- storage conditions 364
- wort boiling and 363, 364
- Beer-Lambert law 444, 445
- beer lines 342
- beer markets 505–510
 - Africa 509
 - America 507, 508
 - Asia 507, 509
 - Australia and Pacific 507, 509, 510
 - Europe 507, 508
 - profitability 510
- beer miracles 10
- beer pests 478
 - detection of 484–489
- beer pumps 346–348
- Beer Quality Acceptance Panel 695
 - training for 696, 697
- beer recovery, from yeast 221
- beer-spoilage bacteria 481–484
- beer staling
 - cohumulones and 369, 370
 - flavor attributes of 687, 688
- beer-strainers 6
- beer styles 503–505, 507
- beer taxes 23, 27, 497
- Belgian lambic beer 250–253
- Belgian wheat beer 69
- bentonite 232, 271
- beor* 2, 21
- Berliner Weisse 235, 253, 254, 258, 259
 - foreign yeast in 481
 - production method 254
- berries, in brewing 43
- Berthelot, P. 31
- Berzelius, J. 31
- β -acids 87, 426, 428, 461
- β -fraction 461
- beverage parts 351
- biguanides 600, 601
- biochemical basics, of anaerobic waste water treatment 637–639
- biofilms 478, 479
- biogas 637, 648, 669
- biogenic amines 525
- biological acidification 411, 412
- biological degradation, of waste water 624, 666
- biological methods, of alcohol-free beer production 238–240
- biological oxygen demand (BOD) 623–625, 627, 629, 635, 667, 668
- biomass 669
- bioreactors 240
- biotin 127, 130
- Bismarck 259
- bitter 676
- bitter acids of hops 87, 88, 525
- bitter ale 248
- bittering hops 89, 94, 95
- bitterness, assessing 680, 689, 690
- bitter principles, yield of 97, 98
- bitter substances 366–370
 - aging and appraisal of 409
 - cohumulone and 368
 - precipitation of, during fermentation 212
- bitter units 222, 446
- black beer 6
- black malt 60
- black rice 56, 57
- blood alcohol levels, beer and 521
- blow-off 648
- blue maize 56, 57
- Bock beer 237, 688
- Bockbierbowle (Bock punch) 259
- BOD (biological oxygen demand) 623–625, 627, 629, 635, 667, 668
 - in aerobic waste water treatment 636
- body, assessing 680, 688, 689
- boiled wort color 162, 163
- boiler house, heat requirements 647, 648
- boiling. *see* wort boiling
- Bolivia, brewing in 36
- Boorde, Andrew 22
- Botec 551
- bottle-cleaning machine 614–616
- bottled beer 505, 507
 - metal ions in 389, 390
- bottle infeed and discharge 307, 308
- bottle jetting 310
- bottle pockets and bottle transport 308
- bottle rinsing machines, heat requirements 646
- bottles, inspecting 316, 318
- bottle washer 305–313
 - components 307–311
- bottling hall 419, 420
- bottling line 305–319
 - bottle washer 305–313
 - inspection and monitoring units 313–319
- bottling plant 565
- bottling waste water 625, 630
- bottom fermentation 19, 26, 55, 119, 216–219

- bottom-fermented beer 222
 - composition of finished 359, 360
 - qualities of 360
- bottom-fermented lager beer, concentration of staling components in 405
- bottom-fermenting yeasts 121, 122, 207, 479, 480
 - determination of foreign yeasts in 488, 489
- bouza* 7
- Boyle, Robert 12
- bragot 21
- brain lesions, alcohol and 519
- bran 47
- branched amylopectins 49
- branching enzymes 49
- branding in global brewing industry 511, 513
- brands, top 20 brands worldwide 513
- brassatores* 13
- Braumat 551
- Brautechnische Analysenmethoden von MEBAK* 438
- braxatores* 13
- Brazil
 - beer market 506, 509, 510
 - brewing in 36
 - as malt importer 501
- BRC (British Retail Consortium) 493, 494, 496
- bread, as staple food 18, 19
- bread wheat
 - genome 44
- bread wheat (*Triticum aestivum*) 14
- breakthrough 155
- Brettanomyces* 252, 255, 480, 481
- Brettanomyces anomalus* 481
- Brettanomyces bruxellensis* 69, 123
- Brettanomyces lambicus* 69, 123
- brewers, world's top 510, 511
- Brewers' Academy of the United States 33
- Brewers Gold hops 368
- brewers guilds 13, 14
- brewery planning 562–576. *see also*
 - malthouse planning
 - capacity calculations 564
 - documentation and specifications 575, 576
 - investment costs 573–575
 - machinery dimensioning 562, 563
 - new plant costs 574
 - required land area 569–572
 - showcase brewery characteristics 562
 - utilities and power supply 568, 569
 - wort/beer losses 563
- brewhouse 431, 563, 564
 - development of reductions in 413, 414
 - DMS and 388, 389
 - as electric power consumer 654
 - heat requirements 644, 645
 - technical approval of 703, 704
 - waste water 625, 630
- brewing
 - industrialization of 21–25
 - internationalization of 33–36
 - legislative restrictions on 19
 - modules of 4
 - prerequisites for 3
 - science of 30–33
- Brewing Convention of Japan 437, 439
- brewing curriculum 33
- brewing ordinances 14
- brewing privilege 11–13
- brewing sciences 32, 33
- brewmaxx 551
- brew size 564
- brew water 105–117
 - beer foam and 362
 - quality criteria 108–111
 - water hardness 105–107
 - water treatment 110–117
- bright beer tank 418–420, 566, 567
 - cleaning 607, 609, 610
- British Retail Consortium (BRC) 493, 494, 496
- bromoacetic acid 602
- brown ale 249
- Brown Bavarian lager 28
- brown bottles, lightstruck flavor and 424, 425
- brown butt-beer 23
- Brownian motion 401
- brush 45
- B-type amyloplasts 49
- Buchner, Eduard 120
- buckwheat (*Fagopyrum esculentum*) 56, 57, 70, 246
- Budweiser 511
- building costs, new brewery 574
- Bull, John 23
- business management 491
- butanediol 252
- 2,3-butanediol 132
- 2,3-butanedione (diacetyl) 132, 133, 686
- Buttes, Henry 22
- butyric acid 210, 483
- n*-butyric acid 686
- butyric flavor attribute 680, 686

C

- Cab 259
- caelia/cereia* 8
- Cagniard-Latour, C. 31
- cake filtration 225, 226
- calcium
 - flocculation and 123
 - gushing and 390
 - as yeast nutrient 129, 130
- calcium alginate 240
- calcium carbonate 112
- calcium chloride 110
- calcium hardness of water 105, 106
- calcium hydrogen carbonate 108
- calcium ions 108, 109
 - molar mass and conversion factors for 109
- calcium oxalate
 - precipitation of 390–392
 - turbidity and 431
- calcium pectate 240
- calcium silicate 597
- calcium sulfate 110
- calcofluor 460, 462
- calibration curve 443
- callose 50
- caloric value of beer, determination of 466
- camera inspection technology 319
- Caminant barley 404, 406
- Canadian beer market 508, 510
- cancer, beer and 521, 522
- Candida* 252
- cans 277, 278, 505, 507
 - filling 296–300
 - in plastic carrier multipacks 593, 594
- Canterbury Tales, The* (Chaucer) 21
- capacitive level sensor 535
- capacity
 - of brewery 563
 - of malting plant 557–561
- capillary gas chromatography 91
- caprylic acid 237
- caramelized flavor 680, 685, 687, 688
- caramel malts 163, 175, 224, 685
- carbohydrate metabolism 131, 132
- carbohydrates
 - in beer 523
 - usable 466
 - in waste water 623
 - as yeast nutrients 127, 128
- carbonate hardness 105, 106, 110
- carbon balance, in waste water treatment 639, 640
- carbon dioxide
 - accelerated fermentation under carbon dioxide pressure 217, 218
 - in beer 525
 - beer foam and 361, 362
 - beer pumps and 348
 - beer transport and 419
 - calculating applied gauge pressure 344–346
 - as cooling agent 671, 672
 - degassing from yeast 141, 142
 - in draft beer system 339–341
 - in draft beer systems 350
 - emission of fermentation 671
 - in fermentation 209, 212
 - filling and 283, 284
 - measurement of 453, 454
 - micro-split at inner bottle surface as source for 394
 - oxygen content and 283
 - plastic bottles and permeability of 280
 - reaction with sodium hydroxide 609
 - titration curve 450
- carbon dioxide extraction, fractionating 372
- carbon dioxide gas alert units 356
- carbon dioxide lines, in draft beer system 343
- carbon dioxide recovery 221, 569
- carbonic acid 106, 632
 - neutralization of 632–634
- carbonyl compounds, staling process and 399–404
- carbonyl groups, oxidative degradation of 402
- carbonyls 423
- cardboard flavor 404
- cardiovascular benefits of beer drinking 516
- Carlsberg 511
- Carlsberg flasks 137, 140
- Carlsberg test 461
- Carlsberg 1 yeast 120
- Carlsberg 2 yeast 120
- carpronic acid 483
- Cartesian robots 583
- caryophyllene 683
- caryopsis 44
- cask-conditioned ale 248–250
 - production methods 249, 250
- catabolic pathway 132
- catabolic processes 53–55
- catechin factors in malt extract 404, 406
- cation exchanger 114, 115
- catty flavor 404
- caustic potash 597

- caustic soaker bath and spray 615
- CBV (conductometric bittering value) 91
- CCD (charge-coupled display) 319
- CCV (cylindroconical vessel) 217, 220
- celiac sprue 52, 244, 468
- cellar beer 222
- cellar mold 477
- cell membrane 124–126
- cellulose 45, 50, 230
- cell wall
 - flocculation and 123
 - yeast 124, 125
- Celosia* 69
- Celts, brewing and 8, 9
- Cerabar M flansch 537
- cereals 55–70
 - acreage and production of brewing 59
 - amaranth 56, 57, 69
 - barley (*see* barley)
 - black rice 56, 57
 - blue maize 56, 57
 - buckwheat 56, 57, 70
 - DNA content 44
 - domestication of 43
 - einkorn 56, 57, 67
 - emmer 56, 57, 67
 - grain structure 44–46
 - kamut 56, 57
 - maize 63, 64
 - millets 61–63
 - oats 56, 57, 60, 61
 - proso millet 56, 57, 62, 63
 - pseudo- 69, 70
 - quinoa 56, 57, 70
 - rice 64
 - rye 56, 57, 65
 - sorghum 56, 57, 65, 66
 - as source for alcoholic drinks 3, 4
 - spelt 56, 57, 66, 67
 - triticale 56, 57, 68
 - tritodeum 56, 57, 68
 - wheat 56, 57, 68, 69
- certification 491–496
 - to ISO standards 495
 - legal requirements 495
 - management systems and business management 491
 - management systems standards 491–494
 - principles and similarities 494
 - through HACCP 496
 - through IFS and BRC 496
- cervesia* 8
- cervisarii* 13
- CFA (continuous flow analysis) 461, 462
- charcoal, gushing and 392, 393
- charcoal filtration 199
- charge-coupled display (CCD) 319
- Charlemagne 11, 13
- Chaucer, Geoffrey 21
- checklist of in-house measures of waste water 632
- cheesy flavor attribute 680, 686
- chemical/mechanical cleaning 353
- chemical oxygen demand (COD) 199, 623–625, 627, 630, 636, 666, 667
- chemicals
 - in bottle-washing machine 616, 617
 - causing gushing 394, 395
- chemiluminescence detector 463
- chicha* 70
- chill haze 428, 430, 433
- China
 - beer market 506, 509
 - brewing in 3
 - hops in 10
- chitin 125
- chit malt 164
- chloride 111, 448
- chloride ions, ratio to sulfate ions 689
- chlorine 447, 598, 600–602, 666
- chlorine dioxide 447, 455, 600, 601
- chloroacetic acid 602, 667
- chloroform 666
- CHP (combined heat and power) 657
- Christian Middle Ages, brewing in 9–16
- chromatographic analysis 461–464
- chrome-nickel-steel, cleaning 611, 612
- chromosomes 126
- chymotrypsin 51
- Cicero 8
- CIES (Comité International d'Enterprises à Succursales) 493
- CIP. *see* cleaning in place (CIP)
- cis*-acting element 52
- cities, brewing and 13
 - rise and decline of central European 18–20
- citric acid 267, 598
- Citrobacter* 681
- Citrobacter freundii* 252
- Cladosporium* 477
- Clara 259
- clarification, of beer 213
- Clark electrodes 455
- Clark sensor 538
- cleaning 595–599. *see also* cleaning in place (CIP)
 - barrels 617, 618

- cleaning agents 596–599
- disinfection 600–603
- draft beer system 353, 354
- foam 619
- glass bottles 613–617
- goal of 595
- loss 603
- material compatibility 611–613
- methods 603–611
- PET bottles 617
- stack 603
- work safety and environmental protection 620
- cleaning agents
 - acidic 598, 599
 - alkaline 597, 598
- cleaning in place (CIP) 596
 - centralized CIP station 605
 - for closed cleaning circuit 608, 609
 - combined 605–611
 - heat requirements 646, 647
 - measurement record 612
 - non-recovery 603, 604
 - for open cleaning circuit 608
 - program variants 610
 - recovery tank 604, 605
 - reduction of water usage and 665
- climatic zone 658
- closed cleaning circuits 608, 609
- closed-loop control 533, 542, 543
- Clostridium* spp. 602
- closure inspection 317, 318
- clove/4-VG flavor attribute 680, 684
- coagulable nitrogen 187, 188
- coagulation, of fractions of nitrogenous compounds 452
- coal, as fuel source for brewing 20, 24, 648
- Cocculus indicus* (fishberry) 32
- COD (chemical oxygen demand) 199, 623–625, 627, 630, 636, 666, 667
- code detection 319
- coefficient of performance (COP) 659, 660
- cofactors 130
- cognitive function, beer drinking and 516, 517
- cohumulones 87
 - beer aging and 369, 370
 - bitter quality and 368
 - foam stability and 369
- cola
 - beer and 258, 264
 - wheat beer and 259
- Colabier (cola-beer) 259
- Colahefe 259
- Colaweizen 259
- cold break removal 364, 414
- cold fermentation
 - with conventional storage 216, 217
 - with integrated maturation at 12 °C 218, 219
 - with programmed maturation at 20 °C 219, 220
 - with well-directed maturation in cylindroconical vessel 217
- cold room, draft beer system 340
- cold storage 215
- cold supply 657–662
 - cold production 659–661
 - cooling requirements 657, 658
 - goals for optimal 661, 662
- cold trub 201, 202
- cold-water zone, in bottle-cleaning machine 615, 616
- colloidal silica 232
- colloidal stability of beer 213, 428–432
 - raw materials and auxiliary materials and 431
 - turbidity composition 430
 - turbidity formation 430, 431
- color
 - beer 212, 360, 361
 - of malt 162, 163
 - photometric measurement of 445, 446
- colorless bottles, lightstruck flavor and 424, 425
- color malt 175
- color spectrometers 319
- Columbia, beer market in 509
- combined CIP cleaning method 605–611
- combined heat and power (CHP) 657
- combined packers 582, 583
- Combrune, Michael 24, 31
- combustion method, of determining nitrogenous compounds 451
- compensator tap 345
- competitive ELISA 468
- complexing agents 598
- complexometric titration 450
- compressed air 569, 662, 663
 - waste heat from 650, 651
- compressor number, calculated 659–661
- computerized beer dispensing 349, 350
- concentrate (retentate) 117
- concentration, beer and improved 523, 524
- conductivity 449
 - measurement of 537
- conductometric bittering value (CBV) 91
- conductometric values (CVs) 91

- congress mash, analyses of 458
 - consumer protection 495
 - consumer research 700, 701
 - consumption data, malthouse 561, 562
 - contaminants 437, 438, 479
 - contamination 595
 - reduction of 4
 - continuous flow analysis (CFA) 461, 462
 - continuous packer 580–582
 - control strategies 542–549
 - advanced algorithms 543–545
 - classic algorithms 542, 543
 - control of lauter tun 545–550
 - conversion
 - of barley to malt 560, 561
 - of water hardness units 107
 - cooling agents, emissions of 671, 672
 - Coors 511
 - COP (coefficient of performance) 659, 660
 - copper
 - cleaning 612
 - contributing to beer taste 690
 - turbidity and 430
 - yeast fermentation and 129, 130
 - copper adjuncts 176
 - copper kettles 17, 18
 - Coriolis-type mass flow meters 537, 538
 - corn adjuncts, mashing with 177, 179
 - corn grits 58
 - corn syrup 261
 - coumaric acid 135
 - counter-flow cleaning 618
 - Crabtree effect 120, 126, 129, 131
 - cropped yeast 415
 - cross-flow filtration 230, 231, 233, 234
 - cross-flow microfiltration 116
 - crown cork 35, 36
 - crowners 303, 304
 - crushed cell layer 46
 - Cryptococcus* 252
 - crystal malt 163, 175, 224, 685
 - cultivation, of yeast strains 136–138
 - curing 557
 - CVs (conductometric values) 91
 - cylindroconical vessel (CCV) 217, 220
 - cytolysis 158–160, 171
 - cytoplasm 124, 126
 - Czech Republic 506
- d**
- daily quality control 469–473
 - dark beers 175, 222
 - color of 360
 - residual alkalinity for 109
 - dark malt
 - in alt beer 224
 - drying of 156
 - pH 163
 - date coding 337
 - DCS (distributed control system) 550, 551
 - dead-end filtration 230
 - DEAE-cellulose 240
 - trans-2-trans-4-decadienal 400
 - n*-decanal 400
 - decanoic acid 210
 - n*-decanoic acid 686
 - trans-2-decenal 400
 - decoction method 169, 175
 - deferrization 110
 - defoamers 597, 598, 618
 - degassing 648
 - degradation tests 624
 - degree of fermentation 444
 - dehydrin 52
 - dehydrohumulinic acid 424, 426
 - Dekkera* spp. 123
 - demanganization 110, 111
 - dementia, beer and 516, 517
 - density, extract and 441
 - density analysis 440, 441
 - deoxynivalenol 438
 - 6-deoxytetrahydro- β -acids 428
 - depth filtration 226
 - dermatitis herpetiformis 244
 - descriptive analysis 693
 - desiccation 46, 52
 - Detergent and Cleanser Law 666
 - dextrinizing units 447
 - dextrins 123, 127, 446, 466
 - diacetyl (2,3-butanedione)
 - in bottom-fermented beer 359
 - as flavor attribute 680, 686
 - formation of 132, 133
 - in lambic beer 252
 - off-flavors and 211
 - potential 215
 - dialysis, in alcohol-free beer production 238
 - diastatic malt 164
 - diastatic power 450, 451
 - diauxie 161
 - dicarbonyl α -compound 408
 - 2–6-dichlorophenol 267
 - diesel 258
 - dietetic beer 235, 240–242
 - production methods 241, 242
 - Difference Panel 695
 - training for 696
 - difference tests 693

- diffusion 126
- diffusion channels 126
- dihydrohumulone 427
- cis*-dihydro-iso-humulone 427
- trans*-dihydro-iso-humulone 427
- dimethyl disulfide 682
- 2,3-dimethyl-pyrazine 385
- 2,5-dimethyl-pyrazine 385
- 2,6-dimethyl-pyrazine 385
- 2-ET-3,5-dimethyl-pyrazine 385
- 2-ET-3,6-dimethyl-pyrazine 385
- dimethylsulfide. *see* DMS (dimethylsulfide)
- dimethylsulfoxide (DMSO) 386
- dimethyl trisulfide 682
- DIN EN ISO 9000 438, 492
- DIN EN ISO 9001 491, 492
- DIN EN ISO 9004 492
- DIN EN ISO 14001 492
- DIN EN ISO 17025 494
- DIN EN ISO 22000 492, 493
- DIN Standard 8777 189, 703
- DIN Standard 8782 705, 706
- DIN Standard 8783 705
- DIN Standard 8784 705
- directional difference test 693
- discrimination ability 699
- disinfecting 600–603. *see also* cleaning
 - disinfecting substances 601
 - for draft beer systems 353, 354
 - goal of 595
 - head section 311
- dispensing 346–350
 - from above the beer bar 346, 347
 - beer-dispensing tanks 350
 - with beer pumps 346–348
 - computerized 349, 350
 - direct from beer bar 346, 348
 - with pre-mixed gas 348, 349
 - types of 346
 - from underneath beer bar 346, 347
 - use of gas blenders 349
- dispensing head 352
- dispensing tap 349
- dispersators 598
- dispersing mill 167
- dispersion agents 599
- dissolved organic carbon (DOC) 623, 627
- dissolved oxygen 538
- distillation method, for sulfur dioxide 467, 468
- distributed control system (DCS) 550, 551
- DMS (dimethylsulfide)
 - barley and malt and 387
 - brewhouse 388, 389
 - fermentation and 211
 - formation of 386, 387
 - in lambic beer 252
 - malt cleaner 388
 - temperature and 387
 - withering and kilning and 387, 388
 - wort boiling and 187–189
- DMS (dimethylsulfide)/cooked vegetable flavor attribute 680–682
- DMS (dimethylsulfide) precursor 155, 161, 187–189, 386, 388, 409
- DMSO (dimethylsulfoxide) 386
- DNA content, of cereals 44
- DOC (dissolved organic carbon) 623, 627
- documentation and specifications, new
 - brewery 575, 576
- n*-dodecanal 400
- dormancy of barley 151
- Dortmunder beer 222, 360
- dosing 541
- double-end bottle washing machine 306, 313, 614
- downstream products 93
 - addition of 99, 100
- Dr. Pepper 259
- draft beer system 339–357
 - applied gauge pressure calculation 344–346
 - beer bars/bar counter requirements 343
 - beer line requirements 342
 - beer quality in 339–346
 - carbon dioxide content 339–341
 - carbon dioxide line requirements 343
 - cold room 340
 - design of 341–346
 - dispensing 346–350
 - foamhead 341
 - gas-pressurized parts 350, 351
 - glass-washing equipment 343, 344
 - hygiene requirements 352–355
 - keg-tapping equipment 351, 352
 - pouring beer 341
 - refrigeration requirements 342
 - room requirements 341, 342
 - safety precautions 356
 - temperature 339
 - testing 355, 356
 - time on tap 339
- draught beer 505, 507
- Dreckiges 259
- Drecksack 259
- Dreher, Anton 30
- drive system 654
- drought, grain filling and 52, 53

- dry milling 165, 167
- dull flavor 687, 688
- Dumas, determination of nitrogenous compounds according to 451
- duo-trio test 693
- dust emissions 672
- Dutch brewing 20, 21
- dynamic low-pressure boiling 192–195
- dynamic viscosity 457
- e**
- EBC (European Brewery Convention) 159, 437
- EBC Analytica* 438, 440, 461
- EBC/ASBC 447
- EBC bitterness units 95, 96, 222
- EBC color units 212, 360
- EBC turbidity units 411, 456, 540
- ECD (electron capture detector) 463
- Ecotherm 190
- EDTA 598
- efficiency tests, reporting 706, 707
- Egypt, brewing in 6, 7
- Ehrlich mechanism 132
- einkorn (*Triticum monococcum* L.) 3, 56, 57, 67
- elderly, alcohol abuse in 520
- electrical energy 643. *see also* power supply
- electron capture detector (ECD) 463
- electronic density meter 441
- electronic level-controlled filling systems 292–296
 - Sensomatic VPL-PET 295, 296
 - Sensomatic VPVI 294, 295
- electronic spin resonance spectroscopy (ESR) 469
- electronic volumetric filling systems 296–300
 - Volumetric VOC 296, 297–300
 - Volumetric VODM-PET 296, 297, 300, 301
- ELISA (enzyme-linked immunosorbent assay) 462, 468, 469
- emblems
 - brewers 15, 16
 - guild 14
- embryo 44, 45
- emissions 670–673
 - cooling agents 671
 - defined 670
 - dust 672
 - fermentation carbon dioxide 670
 - gaseous 670–672
 - noise 672, 673
 - sewage disposal plant 669, 670
- emmer (*Triticum dicoccum*) 7, 56, 57, 67
- Emsgold, Pils and 259
- end degradation 624
- endoplasmic reticulum 124, 126
- endosperm 44, 45
 - starchy 45, 46
 - wheat 47
- energy 643–663, 668–670
 - cold supply 657–662
 - compressed air supply 662, 663
 - conservation of 669
 - heat requirement of brewery 643–651
 - power supply 651–657
 - renewable 669, 670
- English ales 21, 22, 28, 248, 249
- English degree of water hardness 107
- English infusion mashing method 248
- English pale ale 28
- Enterobacter* 268
- Enterobacter aerogenes* 252
- Enterobacter cloacai* 252
- Enterobacter* phase, of lambic beer production 251, 252
- environmental factors, in grain filling regulation 52, 53
- environmental management systems 492
- environmental protection 665–675
 - cleaning and 620
 - emissions 670–673
 - energy 668–670
 - legal basis of 673, 674
 - waste 673, 674
 - waste water 665–668
- environmental regulations 673, 674
- enzymatic analyses 464–466
- enzyme digestibility 49
- enzyme-linked immunosorbent assay (ELISA) 462, 468, 469
- enzymes
 - in barley germination 153
 - barley malt 171
 - malt 161, 162
 - modification of grain for gluten-free beer by 245
- enzymological studies 31
- Epic of Gilgamesh* 5
- epoxides 89
- equalizing tanks, aeration of waste water 634, 635
- equipment, technical approval of 703–707
- ergosterol 125, 129
- Escherichia coli* 355
- ESR (electronic spin resonance spectroscopy) 469

- Essay on Brewing* (Combrune) 31
- Esterel 147
- ester fractions, in hops 372
- esters 134
- in alcohol-free beer 237
 - in bottom-fermented beer 359
 - fermentation and 210
 - flavor and 683
 - formation of 134
 - in hops 89
 - lightstruck flavor and 423
 - in wheat beer 174
- estery/fruity flavor attribute 680, 682, 683
- ethanol 209, 210
- content analysis 441–443
 - determination of 465
 - formation of 131
- ethyl acetate 210, 252, 682
- ethyl alcohol, foam and 362
- ethylcaproate 210
- ethylcaprylate 210
- ethylene vinyl alcohol polymer (EVOH) 279
- ethyl fenchol 267
- ethyl lactate 252
- ethyl mercaptan 267
- ethyl *n*-butyrate 683
- ethyl *n*-hexanoate 682, 683
- ethyl *n*-octanoate 683
- Études sur la Bière* (Pasteur) 32
- EurepGAP (Good Agricultural Practices) 493
- Europe
- beer consumption in 503, 506
 - beer markets in 506–508
 - brewing in 33
 - hop farms 502
 - malt and 502
 - malting barley varieties 500
 - top brewers 512
- European Brewery Convention. *see under* EBC
- European Sankey ‘S’ system 351
- eutrophication 667
- evacuation 285–287
- evaporation 186–189
- flash 194, 197
 - thin film 199, 200
 - vacuum 197, 198
- evaporation condensers 659
- evaporation efficiency 187
- EVOH (ethylene vinyl alcohol polymer) 279
- cis-3-exanal 400
- exhaust emission heat exchanger 648
- export beers 222, 360
- external boilers 192, 193
- extinction 444
- extract
- analysis of 440–444
 - apparent 441
 - density and 441
 - measuring losses 704
 - real 441, 442
- extremely high rice addition, mashing with 180, 181
- f**
- facilitated diffusion 126
- famines, brewing and 14, 15
- FAN (free amino nitrogen) 152, 160, 211, 453
- analysis of 446
 - in dark beers 175
 - in raw grain worts 63
- FAO (Food and Agriculture Organization) 58
- farnesene 88
- fatty acids
- auto-oxidation of 402
 - in fermentation 210
 - as flavor attribute 680, 685, 686
 - in hops 89
 - thermal degradation of 405
 - as vitamin 130
 - yeast management and 129
- Fenton reaction 687
- fermentation 4, 207–215. *see also* bottom fermentation; top fermentation
- accelerated 217–219
 - aeration 209
 - appearance during 213
 - beer color and 212
 - beer foam and 364
 - carbon dioxide content 212
 - changes during 209–213
 - changes in composition of nitrogen compounds 211
 - changes in redox properties of beer 212
 - characteristics 564
 - clarification and colloidal stabilization and 213
 - cold 216–219
 - control of 214
 - degree of 444
 - discovery of 119, 120
 - fermenters 214, 215
 - flavor stability and 417, 418
 - flowchart of 208
 - goals of 213

- immobilized yeast 240
- interrupted 238, 239
- metabolic pathways 131–135
- parameters 213, 214
- pH drop and 211, 212
- pitching 207, 208
- precipitation of bitter substances and polyphenols 212
- pressureless warm 217, 218
- science of 31, 32
- topping-up 209
- turbidity and 432
- fermentation cellar
 - design of 657, 658
 - waste water and 625, 630
- fermentation pathway 120
- fermentation tank 531–534
 - cleaning 607–610
- fermenters 214, 215
- fermentum* 12
- Fertile Crescent 3, 43
- ferula acid 89
- ferulic acid 135
- festival beers 222
- fiber, beer as source of 523–525
- Ficaria* 12
- FID (flame ionization detector) 463
- filling 275–319
 - of beer-based mixed drinks 272
 - bottle washer 305–313
 - bottling line parts 305–319
 - cans 277, 278
 - carbon dioxide content 283, 284
 - crowners 303, 304
 - electronic level-controlled systems 292–296
 - electronic volumetric systems 296–300
 - evacuation 285–287
 - filling phase 288, 289
 - filling pressure 284
 - flavor stability and 420–422
 - flushing with ring-bowl or pure gas 287, 288
 - fobbing 301–303
 - framework conditions 281–285
 - gases and 282–284
 - glass bottles 275–277
 - hot 270
 - inspection and monitoring units 313–319
 - kegs 280, 281
 - mechanical level-controlled systems 290–292
 - oxygen content 282, 283
 - packaging choice 275–281
 - plastic bottles 278–280
 - pressurization 284, 288
 - process steps 285–290
 - screw-cappers 304
 - settling and sniffing 290
 - temperature and 285
 - volumetric VODM-PET 300, 301
- filling area, electric power requirement in 654, 655
- filling lines, technical approval of 704–706
- filling station 531, 532, 534
- fill-level inspection 316, 317
- film thickness, in shrink-wrap packaging 590
- filter 531, 532
- filter media, gushing and 392
- filtration 566
 - of beer-based mixed drinks 271, 272
 - beer foam and 365
 - cake 225, 226
 - characteristics 566, 567
 - cross-flow 230, 231, 233, 234
 - dead-end 230
 - depth 226
 - filter aids for pre-coating 230
 - flavor stability and 418–420
 - kieselguhr 226–228, 233
 - kieselguhr pre-coating 230
 - mash 413, 431
 - measurements when transported with air 419
 - membrane 230, 231
 - processes 115–117
 - purpose of 225
 - record of in filter line 233
 - surface 226
 - techniques 226–231
 - turbidity and 432
 - variables influencing 231
- filtration and stabilization plant design 232–234
- filtration cellar, waste water COD concentrations 630
- final beer testing 700
- finger millet (*Eleusine caracana* (L.) Gaertn.) 62
- fixed-bed reactors 240
- flakes 58
 - barley 177
- flame AAS 467
- flame ionization detector (FID) 463
- flame photometric detector (FPD) 463
- flash evaporation ‘Varioboil’ 197, 199
- flash pasteurization 270, 422, 646, 661

- flavanols 377, 378
- flavor assessment 676–679, 699, 700
 - attendance requirements 678
 - final beer testing 700
 - in-process sample testing 699, 700
 - overall impression 678, 679
 - technique 677
- flavor attributes 679–690
 - acetaldehyde 680, 682
 - acidic/sour 680, 687, 688
 - after-bitterness 680, 690
 - alcoholic 680, 688
 - astringency 680, 690
 - bitterness 680, 689, 690
 - body 680, 688, 689
 - butyric 680, 686
 - caramelized 680, 685
 - cheesy 680, 686
 - clove/4-VG 680, 684
 - diacetyl 680, 686
 - dimethylsulfide/cooked vegetable 680–682
 - estery/fruity 680, 682, 683
 - fatty acid 680, 685, 686
 - floral 680, 684
 - fresh grass 680, 684
 - grainy/straw 680, 685
 - hoppy 680, 683, 684
 - hydrogen sulfide/mercaptan 680, 681
 - malty 680, 685
 - metallic 680, 690
 - oxidized 680, 687
 - procedures for illustrating 680
 - roasted 680, 685
 - solvent 680, 682
 - spicy 680, 684
 - sulfur dioxide 679, 680
 - sweetness 680, 689
 - yeasty 680, 686
- flavorings, in beer-based mixed drinks 263
- flavor profile and rating test 693
- flavor profiling 693, 700
- flavor stability 399–423
 - analytical control of 422, 423
 - barley variety and 404
 - changes in aromatic compounds and 402, 403
 - fermentation and maturation and 417, 418
 - filling and 420–422
 - filtration and 418–420
 - flotation and 414, 416
 - germination and 404–409
 - hot break removal and 414, 415
 - indicator substances 403, 404
 - malt quality and 409
 - mash filtration and 413
 - preserving organoleptic stability and 404–423
 - reasons for beer aging 401, 402
 - staling processes 399, 400
 - wort boiling and 413
 - wort preparation and 409–413
 - yeast handling and 414–417
- flavor wheel 681, 683
- Flieger 259
- floculation 123
- floor area, calculation of malthouse 558, 559
- floral flavor attribute 680, 684
- flotation 414, 416
- flow injection analysis 462
- flow measurement 536–538
- flue gas, neutralization with 634
- fluorescence detector 462
- flushing
 - with pure gas 287, 288
 - with ring-bowl 287, 288
- foam 98, 341
 - retention of 455, 456
- foam cleaning 619
- foam image 365
- foam-positive malts 363
- foam stability 433
 - cohumulone and 369
- fobbing 301–303
- foiling 326, 327
- folic acid 519
- fonio millet (*Digitaria exilis*) 62
- food acids, in beer-based mixed drinks 262, 263
- food adulteration 32
- Food and Agriculture Organization (FAO) 58
- food hygiene regulation 495
- food safety standards 492, 493
- forcing test 456, 457
- foreign bodies, inspecting for 316
- foreign substances, inspecting for 316
- foreign yeasts 480, 481
 - determination of 485–489
- formaldehyde 151
- formalin test 457
- formazin 456
- formic acid, in bottom-fermented beer 359
- forward-scatter detectors 540
- fossil fuel combustion emissions 670
- fouling 117
- 4-VG flavor attribute 680, 684

- foxtail millet (*Setaria italica* (L.) P. Beauv.)
 - 44, 61, 62
- FPD (flame photometric detector) 463
- frambozen lambic beer 251–253
- frame filter 27
- France
 - beer market 506
 - malting companies 501, 503
- Franck, Hans 16
- Franconian breweries 28, 29
- free aggressive carbon dioxide 111
- free amino nitrogen. *see* FAN (free amino nitrogen)
- free diffusion 126
- French degree of water hardness 107
- French paradox 517
- fresh and aged test 694, 695
- fresh grass flavor attribute 680, 684
- fresh hop aroma 683
- freshness, cleanness, crispness of flavor 687, 688
- friabilimeter 159, 459
- Friabilimeter Calibration Network 459
- Frohberg yeast strain 120
- front-of-label coding/dating 337
- fructose 127, 483
- fruit beers 504
- fruit lambic beers 250–253
 - production method 252, 253
- Fuchs, J. 31
- fuels 648
- full packs, space requirements of 567
- fumes 671
- fumigation 411, 412
- fuminosin 438
- fungi, gushing and 394
- furan 383, 408
- furaneol 689
- 2-furfural 381, 423
- furfural derivatives 381
- furfuryl alcohol 381
- Fusarium culmorum* 394, 477
- Fusarium graminearum* 394, 477
- Fusarium* spp. 151
- fuzzy control algorithms 543–545
- fuzzy controllers 533
- fuzzy PID control loop 545
- fuzzy set theory 543
- g**
 - GA (gibberellic acid) 54, 153, 154
 - α -galactosidase 122
 - Galant 379, 381
 - galvanic-amperometric sensors 539
 - γ rays 319
 - gantry robots 582, 583
 - gas, as heat source 648
 - gas blenders 349
 - gas chromatography (GC) 91, 463, 464
 - gas chromatography-mass spectroscopy (GC-MS) 91
 - Gaseosa 259
 - gaseous emissions 670–672
 - gases
 - in bottom-fermented beer 359, 360
 - extractor devices 311
 - filling and 282–284
 - plastic bottle permeability to 279, 280
 - gas flashing during mashing 411, 412
 - gas-pressurized parts, of draft beer systems 350, 351
 - Gay-Lussac, Joseph Louis 31, 119
 - GC (gas chromatography) 91, 463, 464
 - GC-MS (gas chromatography-mass spectroscopy) 91
 - gelatinization 49, 170, 172
 - gelatinization temperature (GT) 170, 172
 - of adjunct 176–178
 - geraniol 88
 - germ 46
 - wheat 47
 - German Agricultural Society 264–266
 - German degree of water hardness 107
 - German Purity Law 98
 - German slider ‘A’ system 352
 - Germany
 - beer market 506, 508, 510
 - brewing in 9, 27–30
 - dietetic beer in 241
 - hop farms 502
 - germination 53, 152–155, 405–409
 - germination box design 554, 555
 - infection with mold spores during 390
 - kilning 407–409
 - malt quality 409
 - process scheme 557–559
 - withering 405–407
 - germination/kilning floor design 557, 558
 - Gespritztes 259
 - Gestreiftes 259
 - geuze beer 5, 481
 - GFSI (Global Food Safety Initiative) 493
 - gibberellic acid (GA) 54, 153, 154
 - gibberellin hormones 153
 - glass bottles 275–277
 - cleaning 613–617
 - lightstruck flavor and 424, 425

- glass splinters, detection of 317
- glass-washing equipment 343, 344
 - glass cleaning system 343, 344
 - glass-washing machines 344
 - two-sink installation 343
- glassy kernels 459
- gliadins 52
- Global Food Safety Initiative (GFSI) 493
- globoid bodies 45
- globulins 50
- β -glucan 61, 158–160, 177, 465
- β -1-6-glucan 125
- endo- β -glucanase 158
- glucanases 54
- β -glucanases 60, 177
- β -1-3-glucane 125
- β -glucan gel 231
- (1-3, 1-4)- β -D-glucans 50
- α -glucans
 - reaction with polyphenols 379
 - turbidity and 430
- β -glucans
 - analysis of 462
 - beer foam and 363
 - metabolism of 46
 - reaction with polyphenols 379
 - turbidity and 430
 - viscosity and 457
- α -glucan tarnishing 173
- gluconate 598
- Gluconobacter* 268
- Gluconobacter frateurii* 477
- glucoronoarabinoxylans 50
- glucose 58, 689
 - aerobic and anaerobic fate of 131, 132
 - as yeast nutrient 127, 128
- glucose syrup 261, 262
- glucosidases 55
- α -1-4-glucosyl starch chains 49
- gluten 437
 - determination of 468, 469
- gluten-free beer 244–246
 - conventional ‘gluten-containing’ raw material 245
 - production methods 244–246
 - sources of gluten-free sugars and starch 245, 246
- glutenins 52
- gluten-sensitive enteropathy 52
- glycerol 211, 689
- glycogen 126, 128
- glycols 598
- glycolysis 209
- glycoproteins 170, 362
- Golgi apparatus 124, 126
- Good Agricultural Practices 493
- Good Manufacturing Practice 493
- Goodwin, Henry 24
- grading of malt 460
- grain combustors 648
- grain enlargement 46, 47
- grain filling 47
 - regulation of 52, 53
- grain ripening, timeline of processes 48
- grains
 - bred for gluten-free beer 245
 - ensuring supply of 14, 15
 - rich in carbohydrates 246
 - spent 673
- grain starches 49
- grain starch modification 4
- grain structure 44–46
- grainy/straw flavor attribute 680, 685
- graphite tube AAS 467
- grass seeds, in brewing 43
- gravity figure 440
- Great Britain
 - ales in 21–23, 28, 248, 249
 - beer market 506, 508, 510
 - growth in brewing industry 30
- Greeks, brewing and 7, 8
- green bottles, lightstruck flavor and 424, 425
- green malt, infection of 390
- grinding technology 165–168
- gripper cups/heads 579–584
- grist load 564
- grits 58
- Groll, Josef 30
- gross tank space (GTS) 562
- gruit* 11, 12, 20
- GT (gelatinization temperature) 170, 172
 - of adjunct 176–178
- GTS (gross tank space) 562
- gueuze beers 250–253
 - production methods 251, 252
- guild emblems 14
- guilds, brewing 8, 13, 14
- Guinness 259
- Guinness, Arthur 25
- gushing 389–395, 461
 - chemical components causing 394, 395
 - determination of induced by raw materials 389
 - filter media 392
 - malt-induced 392–394

- metal ions in bottled beer 389, 390
- precipitation of calcium oxalate crystals 390–392

h

- HACCP (Hazard Analysis of Critical Control Points) 493, 496
- Haffmans formula 454
- Hafnia alvei* 252
- Haithabu 11, 16
- Hall, John 22
- Hallertauer hops 377
- Hallertauer Magnum hops 368
- Hallertau Hersbruck hops 368
- Hallertau Magnum hops 377
- Hallertau Tradition hops 377
- halogenated acetic acids 667
- halogenated carboxylic acids 600, 602
- halogenated hydrocarbons 666
- Hamburg, as brewing center 16, 17
- hammer mills 165, 167
- hand assessment 460
- Hanseatic League, brewing and 16–18
- Hansen, C. E. 32
- Hansenula* 252
- happir* 5
- Harden, Arthur 120
- hardness, water 105–107
- hard resins 87
- Hassall, Arthur Hill 32
- HAT vapor condensers 650
- Hazard Analysis of Critical Control Points (HACCP) 493, 496
- hazardous substances 674
- haze 373, 377, 428, 430, 433
- health benefits of beer 515–528
- hearing, sense of 676
- heart attack, beer and 515, 516, 518
- heat
 - combined heat and power 657
 - grain filling and 52, 53
 - malthouse system 561, 562
 - recovery possibilities 648–651
 - staling and 405, 406
- heat carrier systems 647, 648
- heating plant 568
- heat requirements of brewery 643–651
 - boiler house 647, 648
 - bottle rinsing machines 646
 - brewhouse 644, 645
 - heat consumers 644–647
 - heat recovery possibilities 648–651
 - keg cleaning 646
 - optimization possibilities 648
 - pasteurization, CIP 646, 647
 - room heating and system losses 647
 - service warm water 645, 646
- heat supply 656
- heat transfer date coding 337
- Heineken 511
- Helicobacter pylori* infection, beer and 522, 524
- hemicelluloses 45
- hemp 10, 11
- Henry-Dalton formula 453, 454
- Henry's law 283
- herbal additives 12
- Hermstädt, S. 31
- N-heterocycles 381–386
 - in malting process 383
 - mashing conditions and 383
 - presence of 381, 382
 - structures of 385
 - of wort 384
 - wort boiling 386
- O-heterocycles 381, 383
- S-heterocycles 381
- heterofermentative beers 235
- hexagram, brewing and 15, 16
- hexahydro-iso- α -acids 426
- trans*-hexahydro-iso-humulones 427
- n*-hexanal 400
- trans*-2-hexanal 400
- hexanoic acid 210
- 1-hexanol 64
- hexose 209
- higher alcohols
 - in bottom-fermented beer 359
 - formation of 132, 133
- high-frequency inspection technology 319
- high-gravity beer 237
- high original wort
 - beer production methods for 247, 248
 - brewing with 246–248
- high-performance liquid chromatography (HPLC)
 - analysis of bitter substances in hops 366–368
 - hop addition and 91
 - quality control and 462, 463
- high-performance reactors 636
- high-temperature wort boiling 192, 194
- histidine 160
- history of brewing 1–36
 - advent of lager 25–36
 - agrarian societies 2–5
 - Celts and Germans 8, 9
 - Christian Middle Ages 9–16

- Dutch brewing 20, 21
 - Hanseatic League 16–18
 - Hellenistic period 7, 8
 - hopped beer 16–21
 - industrialization of brewing 21–25
 - Mesopotamia and Egypt 5–7
 - homocysteine 519
 - homofermentative beers 235
 - homogeneity, of malt kernels 460
 - hop addition 91–94
 - hop aroma 97
 - hop extracts 371, 541
 - Hopf, G. 32
 - hop gardens 17
 - hopped beer 6
 - central European cities and 18–20
 - Dutch brewing and 20, 21
 - Hanseatic League 16–18
 - hop pellets 371, 541
 - nitrate reduction and addition of 93
 - hopping technology 91–100
 - addition of ‘downstream products’ 99, 100
 - beer enriched with xanthohumol 97
 - beer with hop flavor 94–97
 - foam 98
 - hop addition 91–94
 - microbiology 99
 - yield of bitter principles 97, 98
 - hop polyphenols 374–378
 - hop products
 - beer foam and 363, 366
 - classification of 90
 - global use of 502, 503, 505
 - hoppy 680, 683, 684
 - hops (*Humulus lupulus*) 85–100
 - analytics 91
 - aroma substances in 88, 89, 371
 - bitter acids 87, 88
 - bitter substances in 366–370, 461
 - cohumulone contents in 370
 - components 87–89
 - cultivation of 85–87
 - ester fractions in 372
 - first use in brewing 10, 11
 - global market 501, 502
 - global use of 502, 503, 505
 - harvesting 86, 87
 - main hop-growing areas 504
 - polyphenolic-related reactions and 379
 - polyphenols in 89, 375
 - storage of 100
 - as tithe 11
 - top hop companies 505
 - trading networks for 24
 - hordeins 52
 - Hordeum chilense* 68
 - hordine 156
 - horizontal integration 552
 - horizontal leaf filter 227–229
 - hot break 431
 - hot break removal 414, 415
 - hot date stamping 337
 - hot filling 270
 - hot holding 186
 - hotmelt labeling 327–332
 - with pre-cut labeling 328–330
 - reel-fed 330, 331
 - hot-water zone, in bottle-cleaning machine 615, 616
 - HPCL (high-performance liquid chromatography) 91, 462, 463
 - hull 44, 45
 - humulene 683
 - humulone 87
 - hupulones 426
 - hydrochloric acid 446, 447, 598
 - hydrocinnamic acid 89
 - hydrogels 432
 - hydrogen carbonate ions 108
 - hydrogen peroxide 598, 601
 - hydrogen sulfide 211
 - hydrogen sulfide/mercaptan, as flavor
 - attribute 680, 681
 - hydrohumulones 426
 - hydrolases 54, 55, 162
 - hydrolysis 53–55, 638
 - hydrometer 31, 441
 - hydrophile 395
 - hydrophobins 437
 - hydrophone 395
 - hydrosulfide 267
 - hydroxybenzoic acids 89, 377, 378
 - hydroxycinnamic acids 377, 378
 - hydroxymethylfurfural 381, 386, 446
 - hygiene requirements
 - cleaning and disinfecting procedures 353, 354
 - in draft beer systems 352–355
 - problem areas 354, 355
 - hygiene target 352
 - hygiene testing 355
 - hypertension, beer and 519
 - hypochlorite 612
- i**
- ICP-OES (inductively coupled plasma optical emission spectrometry) 466, 467

- IFS (International Food Standard) 438, 493, 496
- immissions 670
- immobilized yeast fermentation 240
- immunoassays 468
- Imperial stout 223
- InBev 511
- India pale ale 249
- indicator substances, for organoleptic beer stability 404, 405
- indirect beer pests 478, 487
- indirect beer spoilage bacteria 482
- indirect kilning 24
- indole 381
- inductively coupled plasma optical emission spectrometry (ICP-OES) 466, 467
- inductive sensor 537
- industrialization of brewing 21–25
 - lager beer and German 29
- information technologies 551–553
- infrared inspection technology 319
- infusion method, of mashing 169
- in-house measures of waste water 631–634
- inkjet date coding 337
- in-line inspection machine 313–315
- in-line measurement 541, 542
- inliner, in beer-dispensing tanks 350
- inorganic contamination 595
- inorganic substances, removal from water 110, 111
- inositol 130
- in-process sample testing 699, 700
- inspection 313–319
 - machine types 313–316
 - reliability of 319
 - tasks 316–318
 - technology 318, 319
- Institute of Brewing and Distilling 437, 439
- Institute of Brewing (London) 33
- intelligence, beer and 518
- Interbrew 511
- intermediate-spray, in bottle-cleaning machine 615
- intermittent packers 579, 580
- internal boilers 189–192
 - layout of 190
 - optimized ‘Stromboli’ 190, 191
 - optimized ‘Subjet’ 190–192
- International Food Standard (IFS) 438, 493, 496
- International Organization for Standardization 693
- International Organization of Legal Metrology 442
- interrupted fermentation method 238, 239
- invertase 31
- invert sugar 261, 262
- investment costs, brewery 573–575
- iodine
 - mash and 173
 - photometric iodine reaction 446
- iodometric titration 450, 451
- ion balance 107
- ion chromatography 447
- ion exchange 113–115
- ions, determination of 447, 448
- Ireland
 - beer market 506
 - brewing in 9, 10, 24, 25
 - Irish ale 249
- Iris* 12
- iron
 - in brew water 111
 - gushing and 389–391
 - measurement of 448
 - as off-flavor 267
 - turbidity and 430
 - as yeast nutrient 129, 130
- ISFET pH measurement sensor 536
- iso- α -acid homologs 369
- iso- α -acids 91, 93, 98, 99, 365, 424, 446, 689, 690
 - lightstruck flavor and 426
- iso-acids, lightstruck flavor and 429
- iso-adhumulones 368–370
- iso-amyl acetate 210, 682, 683, 689
- iso-amyl alcohol 132, 688
- iso-butanal 420
- iso-butanol 132, 688
- iso-butyl acetate 210, 683
- iso-cohumulones 369
- iso-extract 93, 95–97
 - calculating dosage of 99, 100
- iso-glucose 261
- iso-humulones 368–370, 402, 424, 427
- isoleucine 132
- isomaltol 383
- cis, trans*-isomers 369, 370
- isooctane 446
- iso-pellets 95, 96
- ISO standards, certification according to 495
- isothermal mashing process 458
- trans*-iso-umulone 427
- iso-valeric acid 210, 686
- iso-xanthohumol 379

j

- Japan
 - beer market 506, 509, 510
 - brewing in 36
 - as malt importer 501
- Jefferson, Thomas 31
- jet spray heads 606, 607
- Joseph and his Brothers* (Mann) 3
- juices, in beer-based mixed drinks 263
- jump-mash process 239

k

- KAC (knowledge-based analytical controller) 545, 546, 548–550
- Kaiser, Cajetan 33
- kamut 56, 57
- kegging lines 577
- kegging plant 567
- kegs 280, 281
 - cleaning 617, 618, 646
- keg-tapping equipment 351, 352
- ketoacid 132
- α -ketoacid 215
- ketones 211
- α -ketones 408
- kettle extracts 93
- kettle hop aroma 683, 684
- kidney stones, beer and risk of developing 522, 523
- kieselguhr filtration 226–228, 233, 566
 - beer foam and 365
 - flavor stability and 418
 - gushing and 392, 393
 - horizontal leaf filter 227–229
 - metal candle leaf filter 229
 - plate and frame filter 227
 - waste from 674
- kieselguhr-free filtration methods 566
- kieselsoils 232
- kilning 8, 155, 156
 - diagram 561
 - DMS and 387, 388
 - influence on flavor stability 407–409
 - planning for 557
- kilning tower design 557, 558
- kinematic viscosity 457
- Kjeldahl, determination of nitrogenous compounds according to 451, 452
- Kjeldahl nitrogen (TKN) 627
- Klebsiella* 268
- Klebsiella aerogenes* 252
- Klencke, H. 32
- Klevi, Lesli 524
- Kloeckera apiculata* 252

- Kloeckera* spp. 69
- knowledge-based analytical controller (KAC) 545, 546, 548–550
- knowledge-based controllers 533
- Koch, Robert 120
- Kolbach index 160, 387
- Kölsch beer 224
- kräusen 208, 254
- kräusenring 213
- Krefelder 258, 259
- kriek lambic beer 251, 252
- Kulmbach 30
- Kützing, F. 31

l

- labeling 321–337
 - date coding and identification 337
 - foiling 326, 327
 - hotmelt 327–332
 - machine construction 321–324
 - options 322
 - pressure-sensitive 332–334
 - roll on/shrink on 331, 332
 - sleeving 334–336
 - tamper-evident sealing 327, 332
 - wet-glue 324–327
- labels
 - bottle-washing machines and 616, 617
 - inspecting position/type 318
 - removal of 309
- lactic acid 180, 252, 483, 688
- lactic acid bacteria 478
- Lactobacillus* 69, 239, 252, 268, 687
- Lactobacillus amylolyticus* 99, 480
- Lactobacillus backii* 483
- Lactobacillus brevis* 479, 483
- Lactobacillus brevisimilis* 483
- Lactobacillus buchneri* 483
- Lactobacillus casei* 479, 483
- Lactobacillus coryniformis* 483
- Lactobacillus lindneri* 479, 483
- Lactococcus* 268
- lager beer 222
 - dispensing 348
 - popularity of 503, 504, 507
 - rise of 25–27
 - spread of lager brewing 27–30
 - types of 28
- lager yeast 121–123
- lambic beer 5, 235, 250–253
 - foreign yeast in 481
 - fruit 252, 253
 - production methods 251, 252
- land area requirements, brewery 569–572

- lanosterol 129
 - laser date coding 337
 - lautering 181–186
 - grinding and 165
 - lauter tun (*see* lauter tun)
 - mash filter 182, 184, 186
 - strainmaster 186
 - lauter tun 167, 168, 182–186, 531, 532, 534
 - advanced control of 545–550
 - controller structure 548
 - control results 548–550
 - description of 545–547
 - mash transfer to 411
 - process characteristics 547, 548
 - Lavoisier, A. 31
 - leak tests 355
 - LEA (late embryogenesis abundant) genes 52
 - leathery/whiskey flavor 687, 688
 - lectin hypothesis 123
 - legislation
 - of beer 14
 - consumer protection 495
 - environmental regulations 675
 - quality control and 438
 - lemonade
 - beer and 258, 259, 264
 - Pils and 258
 - Leuconostoc* 268
 - Levant nut 32
 - level measurement 534, 535
 - Lg foam tester 456
 - lichenase 465
 - Liebig, J. 31
 - life expectancy, beer and 516
 - light
 - beer-based mixed drinks and 272
 - cans and protection from 278
 - glass bottles and protection from 277
 - lighting 655, 656
 - light (lite) beers 109, 240
 - lightstruck flavor 277, 399, 423–428, 681
 - lignin 45, 430
 - lime softening 112, 113
 - limit dextrinase 173
 - limit monitors 541
 - linalool 88, 97
 - lining materials, cleaning agents and 613
 - lipases 54
 - lipids, oxidation of 402
 - lipoxygenases 405
 - Liquicap FMI 51 535
 - load management, of electrical power supply 656, 657
 - load values, of waste water 626, 627
 - London, brewing in 23
 - Long, J. 31
 - Long saccharometer 31
 - loop reactors 240
 - loss cleaning and disinfecting 603
 - lotus effect 141
 - low-carb beers 240, 241
 - low-pressure boiling 194, 196
 - low-temperature vapro condensers 649, 650
 - Lundin fractions 453
 - lupolone 100
 - lupuline 378
 - lupulin gland 87, 88
 - lupulones 87
 - lysine 69, 160
- m**
- machine configurations
 - for non-returnables 578, 579
 - for returnables 577, 578
 - machine drive 310, 311
 - machinery dimensioning 562, 563
 - magnesium
 - in beer 526
 - gushing and 390
 - as yeast nutrient 129, 130
 - magnesium hardness of water 105, 106
 - magnesium hydrogen carbonate 108
 - magnesium hydroxide 112
 - magnesium ions 108, 109
 - magnesium sulfate precipitation 452
 - Maillard products
 - high-temperature wort boiling and 194, 195
 - kilning and 407, 408
 - mashing process and 410
 - thiobarbituric acid index and 161, 446
 - wort boiling and 189, 193–195
 - Maillard reactions
 - color and flavor production and 155
 - in mash 168
 - melanoidins and 175
 - wort boiling and 187
 - maize grits 63
 - maize syrup 58
 - maize (*Zea mays*) 43, 63, 64
 - acreage and production of 59
 - aleurone layer 45
 - amino acids in 51
 - for gluten-free beer 246
 - molecular diversity in 53
 - protein and starch in 47

- starch content 46
- starch granules 50
- malt 5
 - acid 164
 - beer foam and 363, 366
 - caramel 163
 - chit 164
 - color of 162, 163
 - conversion from barley 556
 - dark 156, 163, 224
 - diastatic 164
 - DMS and 387
 - enzymes 161, 162
 - flavor stability and quality of 409
 - global production 501–503
 - for gluten-free beer 246
 - grading 460
 - Hanseatic League trade in 17
 - quality of 157, 158, 704
 - roasted 164
 - smoked 164
 - sorghum 164
 - special 163, 164
 - storage of 555
 - top malting companies 503
 - trading networks for 24
 - wheat 164
 - world market 498–501
- Malta 505, 507
- maltase process 174, 175
- maltase rest 174, 175
- malt cleaner 388
- Malteurop Group 501, 503
- malthouse planning 555–559. *see also*
 - brewery planning
 - barley and malt storage 555
 - calculation example for malting plant 560
 - consumption data 561, 562
 - floor area calculation 561
 - germination 555
 - kilning 556
 - steeping 556
 - steeping, germination and kilning tower design 557
- malthouse waste water 625
- malt-induced gushing 392–394
- malting 4, 147–164
 - barley cleaning 149, 150
 - barley intake and storage 149–163
 - brewing barley 147, 148
 - cleaning, storage, and polishing of malt 156, 157
 - germination and 53, 54, 152–155
 - kilning 155, 156
 - malt quality 157, 158
 - malt yield 157
 - *N*-heterocycles in 383
 - quality criteria of barley malt 157–163
 - steeping 150, 151
 - volume and mass change during 157
- malting losses 560
- malt mill 531, 532
- malt milling 409, 410
 - turbidity and 431
- maltol 381, 383, 689
- maltooxazine 385
- maltose 58, 127, 209, 440, 689
- maltose rest 239
- maltotriose 58, 127, 209, 689
- maltoxazine pyrroline 381
- malt polyphenols 373, 374
- malt replacements 176–181
- malt silos 531, 532, 534, 564
- maltster's guilds 14
- malt treatment 564
- malty flavor attribute 680, 685
- Malzbier 242
- management systems 491
 - standards 491–494
- manganese 129, 130, 448
- manganometric titration 450
- Mann, Thomas 3
- mannoproteins 125
- manufacturing cultures 479, 480
- marketing strategies 24
- Märzen beers 222, 360
- mash filter 167, 182, 184, 186
- mash filtration 413
 - influence on beer foam 363
 - turbidity and 431
- mashing 168–181
 - adjunct 176–181
 - American infusion method 35
 - with barley adjunct 177, 179
 - biological acidification 411
 - with corn adjuncts 177, 179
 - dark beer varieties 175, 176
 - with extremely high rice addition 180, 181
 - flavor stability and 410–413
 - maltase process 174
 - mashing parameters 169–173
 - *N*-heterocycles and 383
 - oxygen during 411–413
 - with sorghum adjunct 181, 182
 - step-mashing process 173, 174
 - temperature during 410, 411
 - turbidity and 431

- with very high rice adjunct addition 177–180
- mash pH 704
- mash tun 531, 532, 534
- mash tun adjuncts 176
- mass balance 442
- mass selective detector 463
- mass spectrometers 319
- material compatibility, cleaning and 611–613
- maturation 214, 215–220, 565
 - characteristics 565
 - flavor stability and 417, 418
- Mazout 258
- MBT (3-methyl-2-butene-1-thiol) 424–426
- mealiness, measuring 459
- measurement technology 533–542. *see also* photometric measurements
 - conductivity measurement 537
 - dosing 541
 - flow measurement 536–538
 - ‘in-line’ measurement 541, 542
 - level measurement 534, 535
 - limit monitors 541
 - oxygen measurement 538, 539
 - pH value measurement 536
 - pressure measurement 536, 537
 - temperature measurement 534, 535
 - turbidity measurement 539, 540
- measuring devices 31
- MEBAK (Mittleuropäische Brautechnische Analysenkommission)
 - analytical methods 437, 438
 - boiling system guidelines 190
 - malt quality analyses 157, 159
 - on quality of beer-based mixed drinks 263, 264
- Mecafill VKPV 292
- mechanical level-controlled filling systems 290–292
- Megasphaera* 268, 478, 479, 481
- Megasphaera cerevisiae* 483, 484
- melanoidins
 - flavor and 408
 - foam stability and 362
 - formation of 382, 408
 - kilning and 155
 - redox potential and 360
 - staling process and 401, 402
 - turbidity and 430
- melibiase 122
- membrane filtration 230
- membrane processes 115–117
- memory effect 335
- mercaptans
 - carbonyl formation and 403
 - as flavor attribute 386, 680, 681
 - lightstruck flavor and 211, 424
- Merkur hops 368
- Merlin thin film evaporator 199, 200
- Mesopotamia, brewing in 5, 6
- metabolic pathways 131–135
 - carbohydrate 131, 132
 - formation of esters 134
 - formation of higher alcohols 132, 133
 - formation of sulfur dioxide 135
 - formation of vicinal diketones 132, 133
 - phenolic compounds 134, 135
- metabolism of cereals 46–55
 - anabolic processes 46–53
 - catabolic processes 53–55
- metal candle leaf filter 229
- metal ions in bottled beer 389–391
- metallic flavor attribute 680, 690
- metals, beer and removal of 524, 525
- methane 670
- methanogenesis 638
- methional 400
- methionine 130
- Methods of Analysis* (ASBC; Institute of Brewing and Distilling; Brewery Convention of Japan) 439
- methylbutanal 404
- 3-methylbutanal 420
- 2-methylbutanol 132
- 2-methyl-1-butanol 210
- 3-methyl-1-butanol 210
- 3-methyl-2-butene-1-thiol (MBT) 424–426
- 3-methyl-2-buten-1-thiol 681
- methylene chloride 666
- S-methyl esters 682
- 5-methylfurfural 400
- 3-methyl-3-mercaptoputylformiate 404
- S-methylmethionine (DMS precursor) 188–190, 682
- methylpropanal 404
- 2-methyl-1-propanol 210
- 2-methyl-pyrazine 383, 385, 386
- 3-methylthio-1-propanol 211
- Mexican beer market 506, 508, 510
- MIAC (model identification adaptive control) 543, 544
- microbiology 31, 32, 477–489
 - of beer-based mixed drinks 268
 - detection of beer pests 484–489
 - foreign yeasts 480, 481
 - hop 99
 - manufacturing cultures 479, 480

- microorganisms
 - beer-spoilage bacteria 481–484
 - brewery microflora 477–479
 - disinfecting 600–603
 - preventing growth of 151
- microscope 31
- microtiter plates 468
- mild ale 248
- Miller 511
- millets (*Panicum miliaceum*, *Setaria italica*)
 - 61–63
 - acreage and production of 59
 - amino acids 51
 - for gluten-free beer 246
- mineral deposits, removing 599
- minerals
 - in beer 525, 526, 527
 - as yeast nutrients 129, 130
- mitochondria 124, 126, 127
- Mitteleuropäische Brautechnische
Analysenkommission. *see* MEBAK
- mixed gas, dispensing beer with 348, 349
- mixing, of beer-based mixed drinks 270,
271
- mixing tanks, aeration of waste water in
634, 635
- mobile CIP systems 609–611
- model identification adaptive control (MIAC)
543, 544
- model reference adaptive control (MRAC)
543, 544
- modification of malt kernels 460
- modular labeling system 321, 323
- Mohren 259
- molasses 58
- mold amylases 4
- mold fungi 477, 478
- mold spores, infection of green malt by 390
- molecular diversity 53
- Molson 511
- monasteries, brewing and 9–12
- Moniliella* 477
- mono bromoacetic acid 667
- Moorwasser 259
- Morgenstern system 113
- mPas, milli Pascal seconds (unit of viscosity)
457
- MRAC (model reference adaptive control)
543, 544
- multidimensional GC-MS 91
- multipacks
 - paperboard 592, 593
 - with plastic carrier 593, 594
- Munich, lager brewing in 27–30
- Munich beer 222
- munu* 5
- m* value 105, 106, 107, 111, 113
- mycotoxins 437, 438, 462, 468
- myocardial infarction, beer and 515, 516,
518
- myrcene 88, 187
- Myrica gale* 12
- n**
- Nährbier 235, 242
- nanofiltration 116
- Narziss, L. 555
- National Institute of Health 518
- National Institute on Alcohol Abuse and
Alcoholism 518
- NBB medium, for detection of beer pests
484, 485
- NDMA (*N*-nitrosodimethylamine) 156, 525
- near-IR absorption 442, 443
- near-IR transmission spectroscopy 451
- near ‘real’ beer 246
- neck finish, inspecting 316, 318
- neger 259
- nephelometric turbidity units (NTU) 456
- Netherlands 506
- net tank space (NTS) 562
- neutral cleaning agents 597
- neutralization, of waste water 632–634, 668
- niacin 526
- Nigerian beer market 509
- ninhydrin 446
- nitrate
 - in beer 377, 525
 - in brew water 111
 - determination of 448
 - reduction in water 111
 - in wort 93
- nitric acid 598, 599, 612, 618
- nitrite 448
- nitrogen
 - beer dispensing and 349
 - beer foam and 362
 - sources for yeast 128, 129
 - using during mashing 411
 - in waste water 623, 627
- nitrogenous compounds
 - changes in composition of 211
 - determination of 451–453
 - fractions of 452, 453
- nitrosamines 156
- N*-nitrosoamine 437
- N*-nitrosodimethylamine (NDMA) 156, 525
- noble hop aroma 683

- noise emission 672
 - regulations 673
- trans-2-nonadienal 400
- trans-2-cis-6-nonadienal 400
- n*-nonal 400
- γ -nonalactone 64
- non-alcohol beers 504, 505, 507
- non-biological stability, measurement of 456, 457
- noncarbonate hardness of water 105, 106, 110, 111
- (*E*)-2-nonenal 404
- trans*-2-nonenal 687
- non-ionic surfactants 598
- non-recovery CIP cleaning method 603, 604
- non-returnables, machine configurations for 578, 579
- ‘normal’ ale 249
- North America
 - beer consumption in 506
 - beer markets 506, 508
 - malt and 502
 - malting barley varieties 500
 - top brewers 512
- nozzle head, in CIP system 609, 610
- NTA 598
- NTS (net tank space) 561
- NTU (nephelometric turbidity units) 456
- nucleus (cell) 124, 126
- Nugget hops 368
- nursing tissue 44
- nutriceutical 526
- o**
- oat malt 164
- oats (*Avena* spp.) 14, 56, 57, 60, 61
 - acreage and production of 59
 - as brewing grain 15, 19
 - proteins in 51
 - starch content 46
- obligate beer pests 478, 487
- obligate beer spoilage bacteria 482
- ochratoxin A 438
- n*-octanoic acid 686
- octaolic acid 210
- OECD screening test 624
- OEE (overall equipment efficiency) 706, 707
- off-flavors in beer-based mixed drinks 266–268
- oil 648
- old ale 249
- Omnigrad TR 45 535
- one-step cleaners 609
- one-step wort cooling 649, 650
- opaque beer 62, 65
- open cleaning circuits 608
- open-loop control 533, 542
- operational load analysis 656
- Operational Performance Indicators 706
- opium 32
- OPP (oriented polypropylene) 324
- optical oxygen sensors 539
- optimized internal boiler
 - Stromboli 190, 191
 - Subjet 190–192
- optodes 455
- organic contamination 595
- organic loads, in waste water 627
- organic substances, removal of problematic 112
- organoleptic stability
 - indicator substances 404, 405
 - measurements to preserve 404–423
- oriented polypropylene (OPP) 324
- original gravity 442
- ortho-phosphate 627
- Oryza glaberrima* Steud. 64
- Oryza japonica* 64
- Osiris 6
- osteoporosis, beer and 526, 527
- overall equipment efficiency (OEE) 706, 707
- oxalic acid 392
- oxazole 381, 385, 408
- oxidation reactions, staling and 399, 402
- oxidation/UV irradiation, combination processes using 112
- oxidized flavor attribute 680, 687
- oxidizing cleaning agents 600, 613
- oxidizing cleaning booster 598
- oxidoreductases 162
- oxygen
 - aerobic waste water treatment and 635
 - in beer 212
 - beer foam and 362
 - filling and 282, 283, 420, 421, 423
 - germination and 407
 - mashing process and 411–413
 - measurement of 454, 455, 538, 539
 - plastic bottles and permeability of 280
 - regulation of 648
 - staling and 402, 403, 405, 406
 - for steeping 150, 151
 - as yeast nutrient 129, 139
- ozone, measurement of 447
- p**
- packaging 275–281, 505, 507, 534, 577–594
 - of beer-based mixed drinks 272

- cans 277, 278
- glass bottles 275–277
- kegs 280, 281
- packing into packs open at top 578–584
- paperboard multipacks 592, 593
- plastic bottles 278–280
- plastic carrier multipacks 593, 594
- selecting machine configuration 577, 578
- shrink-wrap 587–591
- wrap-around 584–587
- packs open at top 578–584
- machine design 578–582
- robot technology 582–584
- Painter, W. 35, 36
- paired comparison test 693, 695
- pale ale 248
- Pale American lager 28
- pale beer 222
- pale malt 224
- drying of 155, 156
- pH 163
- TBN 161, 162
- pantothenate 130
- pantothenic acid 489, 526
- paperboard multipacks 592, 593
- papery/cardboard flavor 687, 688
- Parkinson's disease, beer and 517
- Partigyle system 255
- passive noise abatement 673
- Pasteur, Louis 31, 32, 119, 120
- pasteurization 422
- of alcohol-free beer 240
- of beer-based mixed drinks 268–270
- flash 270, 422, 646, 661
- heat requirements 646
- microflora and 477
- pathothenate agar 489
- Payen, A. 31
- PCS (process control system) 533, 550, 551
- pearl millet (*Pennisetum glaucum* (L.) R. Br.) 61
- peas 246
- peat, as heat source 20
- Pectinatus* 478, 479, 481
- Pectinatus cerevisiophilus* 484
- Pectinatus frisingensis* 484
- Pediococcus* 69, 99, 252, 254, 268
- Pediococcus Clausenii* 483
- Pediococcus damnosus* 479, 483
- Pediococcus inopinatus* 483
- Penn, William 33
- PEN (polyethylene naphthalate) bottles 278, 280, 422
- 2,3-pentandione 211
- 2,3-pentanediol 132
- 2,3-pentanedione 132, 133, 686
- pentosans 362, 430
- PE (population equivalent) 629
- pepsin 31
- peptidases 54
- Pepys, Samuel 22
- perforation date coding 337
- performance, beer and better 523, 524
- performance efficiency, calculating 707
- pericarp 44, 45
- periplasm 124, 125
- perlite 230
- gushing and 392, 393
- permanent haze 428
- permease 128
- permeate 115
- Peronospora* warning service 86
- peroxidases 405
- peroxyacetic acid 601, 602, 618
- Perzoz, J. 31
- pesticides, hop cultivation and 86
- PET (polyethylene terephthalate) bottles 278, 279. *see also* plastic bottles
- for beer-based mixed drinks 272
- cleaning 617
- hotmelt labeling of 327, 328
- machine configurations for 577, 578
- in paperboard multipacks 593
- percent of market 505, 507
- in plastic carrier multipacks 593
- pressure-sensitive labeling of 332, 333
- reel-fed hotmelt labeling of 330, 331
- screw-cappers for 304
- shrink-sleeve process and 336
- staling and 421, 422
- washing 306, 307
- pH
- acidic/sour flavor and 687
- anaerobic waste water treatment and 639
- of barley malt enzymes in mash 171
- of brew water 111, 113
- during fermentation 209–212
- influence of mash pH on flavor stability 411, 412
- of malt 163
- of mash 383, 704
- measurement of 448, 449, 536
- taste and 361
- of waste water 632–634, 639
- phenolic compounds 134
- phenylacetaldehyde 404
- β -phenylacetate 210
- phenylethanal 420

- phenylethanol 132
- 2-phenylethanol 688
- 2-phenyl-1-ethanol 210
- 2-phenylethyl acetate 683
- phosphatases 168
- phosphate 448, 598
 - acidic-acting primary converted to basic-acting secondary 108
 - in waste water 627, 667
- phospholipids 125
- phosphoric acid 598, 599, 612, 618
- phosphorus 130, 623
- phosphorus molybdenum acid precipitation, of nitrogenous compound fractions 452, 453
- photodetectors 540
- photometric iodine reaction 446
- photometric measurements 444–448
 - α -amylases 447
 - bitter units 446
 - of color 445, 446
 - free amino nitrogen 446
 - ions 447, 448
 - photometric iodine reaction 446
 - thiobarbituric acid index 446, 447
 - total polyphenols and anthocyanogens 447
- physical methods, of alcohol-free beer production 236–238
- physiology and toxicology 515–528
 - beauty benefits of beer 525, 526
 - beer and alcohol 521
 - beer and bacteria 524
 - beer and cancer 521, 522
 - beer and concentration, performance, and reaction time 523, 524
 - beer and kidney stones 522, 523
 - beer and protection of stomach and arteries 522
 - beer and removal of metals 524, 525
 - beer as clean food 525
 - beer as sports drink 523
 - beer belly 527
 - beer prescription 527, 528
 - beneficial minerals in beer 526, 527
 - health benefits of beer 515–521
- Pichia* 252
- picric acid 32
- picric acid plus citric acid test 457
- picrotoxin 32
- PID controllers 533, 542, 543
- Pilsner malt, friabilimeter results 459
- Pilsner (Pilsener, Pils) 222
 - absorption spectrum of 445
 - color 360
 - dispensing 348
 - Emsgold and 259
 - introduction of 30
 - lemonade and 258
 - residual alkalinity for 109
- pipelines, cleaning 610
- pirrazoline 408
- pitching 207, 208
- planning efficiency, calculating 707
- plant food allergens 52
- plastic bottles 278–280. *see also* PET (polyethylene terephthalate) bottles
 - PEN 278, 280, 422
 - staling and 421, 422
- plastic carrier multipacks 593, 594
- plastic screw caps 304
- plate and frame filter 227
- PLC (programmable logic controller) 550
- pleasure, alcohol consumption and 520
- Pliny 8, 12, 525
- plumule 46
- Poland, beer market 506, 508
- polarographic-amperometric sensors 538
- polarographic sensor 455
- pollutant load
 - brewery side products 631
 - waste water 625, 626, 628
- polyamide 279
- polycarbonates 598
- polyethylene naphthalate (PEN) bottles 278, 280, 422
- polyethylene terephthalate (PET) bottles. *see* PET (polyethylene terephthalate) bottles
- polypeptides, turbidity and 430
- polyphenols 89
 - analysis of total 447
 - in beer production 371–381
 - defined 373
 - foam and 362
 - health benefits of 437
 - hop 374–378
 - malt 373, 374
 - origin of 373–378
 - oxidation of 168
 - polyphenolic-related reactions during brewing 379, 380
 - precipitation of, during fermentation 212
 - reaction path during brewing 380
 - redox potential and 360
 - staling process and 401, 402
 - turbidity and 430
 - value of anthocyanogens 380

- polysaccharides, turbidity and 430
- polyvinylpyrrolidone (PVPP) 89, 365, 432
 - for anthocyanogens 381
 - removal of polyphenol by 374
- polyvinylpyrrolidone (PVPP) 232–234, 240
- population equivalent (PE) 629
- porter 235, 254, 255
 - foreign yeast in 481
 - introduction of 23–25
 - production method 255
- post-fermentation treatment of yeast 140
- Postgate, John 32
- posthumulone 87
- potassium
 - in beer 526
 - determination of 447, 448
 - to prevent microbial growth during steeping 151
 - as yeast nutrient 129, 130
- potassium dichromate 448
- potassium permanganate 151
- potato starch granules 50
- potential beer pests 478, 487
- potential beer spoilage bacteria 482
- potential diacetyl 215
- potentiometer 455
- potentiostatic sensors 539
- Potsdamer 258
- Powell, Jonathan 527
- power factor correction 653
- power supply 568, 651–657
 - combined heat and power 657
 - drive system 654
 - electric power consumption 653–656
 - external 652, 653
 - heat supply 656
 - lighting 655, 656
 - malthouse 560, 561
 - measurement at release point 652
 - optimization of 656, 657
 - requirement figures 651, 652
 - requirement for compressed air production 662
 - supply contracts 653
- pre-coating 226
 - filter aids for 230
 - methods 230
- preference tests 693
- prehumulone 87
- Preliminary Beer Law 90
- Preliminary Purity Law 93
- prenylflavonoids 378
- prepared cleaners 597
- preserving agents 269
- pre-soak with pre-spray, in bottle-cleaning machine 615
- pressure, measurement of 536, 537
- pressureless warm fermentation 217, 218
- pressure-sensitive labeling (PSL) 332–334
- pressurization 288
- Prewmaister, Jorg 16
- primary degradation 624
- principles and similarities 494
- proanthocyanidins 377, 378, 406
 - colloidal stability and 428
 - turbidity and 89, 433
- proantocianidine 432
- process bus 551
- process control system (PCS) 533, 550, 551
- production planning, flexible 552
- production process 531–533
- professionalism 12–16
- Profile Panel 695
 - training for 698, 699
- profitability, in global beer markets 510
- programmable logic controller (PLC) 550
- prohibition, in United States 36
- prolamin box (P-box) 52
- prolamines 50
- prolamins 51, 52
- 1-propanol 210, 688
- n*-propanol 132
- properties and quality 359–395
 - aroma substances in hops 371
 - beer color 360, 361
 - beer foam 361–366
 - bitter substances in hops 366–370
 - composition of finished, bottom-fermented beer 359, 360
 - DMS 386–389
 - gushing 389–395
 - *N*-heterocycles 381–386
 - polyphenols in beer production 371–381
 - qualities of bottom-fermented beer 360
 - rate of 707
 - redox potential 360
 - taste 361
- propionic acid 483, 484
- proso millet malt 246
- proso millet (*Panicum miliaceum*) 56, 57, 62, 63
- proteases 54, 60
- proteinases 417, 418
- protein-carbohydrate bodies 45
- protein coagulation, in wort boiling 187

- protein electrophoresis 460
- proteins
 - barley 46
 - cell membrane 125
 - reactions with polyphenols 379
 - starch 49
 - storage 50–52
 - turbidity and 231, 232
 - waste water 623
 - wheat 46
- proteolysis 160, 171, 175, 458
- Proud, Robert 35
- Provisional Beer Law 55, 58, 97
- prozyanidine 406
- pseudocereals 69, 70
- pseudomycels 481
- PSL (pressure-sensitive labeling) 332, 333
- puranone 383
- pure gas flushing 287, 288
- purines 130
- purity laws 14, 26
- p* values 106, 107, 111, 113
- PVPP. *see* polyvinylpyrrolidone (PVPP); polyvinylpyrrolidone (PVPP)
- pycnometer 441
- γ-pyranone 408
- pyrazine 175, 383, 385, 408
- pyrazole 383
- pyridoxine 130, 526
- pyrimidines 130
- pyrrodine 408
- pyrrol 381, 408
- pyrrole 383
- pyrroline 383
- pyrrolizine 385
- pyruvate 120, 131, 132
- pyruvate decarboxylase 131
- pyruvate dehydrogenase 131, 132
- pyruvic acid 483, 484
- Python beer line 351
- Python water cooling system 342
- q**
 - QACs (quaternary ammonium compounds) 600–602
 - quality. *see* properties and quality
 - Quality and Security 438
 - quality assurance 700
 - quality control 437–473, 700
 - AAS and ICP-OES 466, 467
 - acid-caustic titration 449, 450
 - α-amylases 447
 - analyses 439–469
 - bitter units 446
 - carbon dioxide measurement 453, 454
 - chlorine dioxide measurement 455
 - chromatographic analyses 461–464
 - color 445, 446
 - complexometric titration 450
 - conductivity 449
 - congress mash 458
 - continuous flavor analysis 461
 - daily 469–473
 - density, extract, alcohol content, original gravity, and degree of fermentation 440–444
 - determination of caloric value of beer 466
 - determination of nitrogenous compounds 451–453
 - diastatic power 450, 451
 - electronic spin resonance spectroscopy 469
 - ELISHA 468, 469
 - enzymatic analyses 464–466
 - free amino nitrogen 446
 - friabilimeter 459
 - grading 460
 - gushing 461
 - hand assessment 460
 - head retention 455, 456
 - homogeneity and modification 460
 - hop bitter substances 461
 - ions 447, 448
 - manganometric titration 450
 - overview 437–439
 - oxygen measurement 454, 455
 - pH measurements 448, 449
 - photometric iodine reaction 446
 - photometric measurements 444–448
 - protein electrophoresis 460
 - spent grain analysis 459
 - sulfur dioxide 467, 468
 - thiobarbituric acid index 446, 447
 - titration methods 449–451
 - total polyphenols and anthocyanogens 447
 - turbidity and nonbiological stability 456, 457
 - viscosity 457, 458
 - quality management systems 492, 494
 - quaternary ammonium compounds (QACs) 600–602
 - quinoa (*Chenopodium quinoa*) 56, 57, 70, 246
- r**
 - radiation inspection technology 319
 - radicle 46
 - Radler 258, 271, 272

- raffinose 122
 - raffinose test 122
 - raspberry
 - Berliner Weisse and 253, 259
 - lambic beer and 252, 253
 - raw materials, influence on colloidal stability 431
 - RDF (real degree of fermentation) 444
 - reaction time, beer and 523, 524
 - ‘real’ ale 249
 - real degree of fermentation (RDF) 444
 - real extract 441, 442, 689
 - recipe-controlled processes 551, 552
 - recirculating cleaning 353, 354
 - recovery beer, diacetyl and 686
 - recovery tank CIP cleaning method 604, 605
 - Recycling and Waste Management Act 673
 - redox potential 360
 - redox properties, changes in 212
 - redox reactions, staling process and 399–402
 - reduction capacity, polyphenols and 375
 - reductones 360
 - reel-fed hotmelt labeling 330, 331
 - refermentation phase, of gueuze beer production 252
 - refrigeration plant 568
 - refrigeration requirements, for draft beer system 342
 - refrigeration system. *see also* cold supply
 - waste heat from 651
 - Regina 259
 - regulations
 - air pollution control 670
 - environmental 670, 671
 - food safety 32
 - noise emission 672
 - Regulation 178/2002 495
 - Regulation 852/2004 495
 - waste management 673
 - water balance 673
 - reliability of inspection 319
 - religion, brewing and 5, 6, 10
 - renewable energy 669, 670
 - Renewable Energy Source Act 670
 - repeatability (*r*) 439
 - reproducibility (*R*) 439
 - residual alkalinity 109, 111
 - residual draining, in bottle-cleaning machine 614
 - residual liquid inspection 316, 318
 - restriction pressure 345
 - returnable glass bottles 577
 - returnables, machine configurations for 577, 578
 - returned empties, space requirements of 567
 - reverse osmosis
 - in alcohol-free beer production 237, 238
 - brew water treatment and 115–117
 - for vapor condensate 199
 - rho-iso- α -acids 93
 - trans*-rho-iso-humulones 427
 - rH value 212
 - ribes flavor 404
 - riboflavin 526
 - ribosomes 124, 126
 - rice adjuncts 177–181
 - rice grits 58
 - rice (*Oryza sativa*) 43, 44, 64
 - acreage and production of 59
 - aleurone layer 45
 - for gluten-free beer 246
 - proteins in 47, 51
 - starch granules 50
 - starch in 47, 50
 - Richardson, John 31
 - right of precinct 13
 - ring-bowl flushing 287, 288
 - roasted flavor attribute 680, 685
 - roasted malt 164, 175
 - roasted malt beer 224
 - robot technology, for packaging 582–584
 - roller mills 165, 167
 - roll on/shrink on labeling 331, 332
 - Romans, brewing and 7, 8
 - room heating 647
 - rooms in draft beer system 340–342
 - rotary fillers 290
 - rotary inspection machine 314, 315
 - rotary labelers 321, 323
 - for hotmelt labeling 330
 - rotary packers 580–582
 - Russ 259
 - Russia 501
 - beer market 506, 508, 510
 - Russ’n Mass 258
 - rye malt 164
 - rye (*Secale cereale*) 65
 - acreage and production of 59
 - amino acids 51
 - as dominant grain 14
 - properties of 56, 57
- s**
- saacharose 261
 - Saatz yeast strain 120

- SAB Miller 511
- saccharification 247, 446
- saccharometer 31
- Saccharomyces* 69, 119, 120, 121
- Saccharomyces bayanus* 207, 252
- Saccharomyces carlsbergensis* 121, 479, 480
- Saccharomyces cerevisiae* 207, 222, 252, 479, 480
- var. *bayanus* 480
 - var. *diastaticus* 480
 - var. *pastorianus* 480
- Saccharomyces dairensis* 252
- Saccharomyces globosus* 252
- Saccharomyces inusitatus* 252
- Saccharomyces pastorianus* 121
- Saccharomyces* phase, of lambic beer production 252
- Saccharomyces uvarum* 252
- var. *carlsbergensis* 207
- safety precautions, draft beer systems 356
- Saladin boxes 152
- Saladin tithe 21
- salty 676
- sandwich ELISA 468
- saturation pressure 344
- sauergut cultures 480
- SBR (sequencing batch reactor) processes 635–637
- scaling 117
- SCARA (Selective Compliance Assembly Robot Arm) 582, 583
- Schmutiges 259
- Schmutz 259
- SchoKo 194–196
- Schönfeld test 151
- Schussbier 259
- Schwan, Theodor 119
- Schwann, Theodor 31
- Schwarz, Anton 33
- Schweinebier 259
- Scotland, brewing in 24
- Scottish ale 249
- screw-cappers 304
- scurvy 22
- scutellum 44–46, 153
- wheat 47
- sealing materials, cleaning agents and 613
- seasonal beers 504
- secalins 52
- seed coat 44, 45
- semipermeable membrane 115
- senses 675, 676
- Sensomatic VPL-PET 295, 296
- Sensomatic VPVI 294, 295
- sensors 552, 553
- sensory evaluation 675–701
- of beer-based mixed drinks 264, 265
 - building sensory capability 695–699
 - consumer research 700, 701
 - environment for 691, 692
 - final beer testing 700
 - five senses 675, 676
 - flavor attributes 679, 690
 - how to assess beer flavor 676–679
 - in-process sample testing 699, 700
 - manual 692
 - panel leader 691, 692
 - panel motivation 692
 - performance monitoring 699
 - selection, training, and validation of panelists 694, 695
 - sensory tests 693, 694
- sensory fatigue 678
- sequencing batch reactor (SBR) processes 635–637
- sequestering agents 598
- serpin superfamily 51
- service warm water 645, 646
- sesquiterpene hydrocarbons 89
- settling 290
- sewage disposal plant 670
- air emissions from 671, 672
- shekar* 6
- shikaru* 6
- shock cooling 432
- short-grain millet 61–63
- Shot'Malzbier 258
- shrink-sleeve process 334, 336
- shrink-wrap packaging 587–591
- sicera* 6, 21
- side scatter detectors 540
- sidewall, inspecting 316, 318
- Siebel, John E. 33, 35
- sight 676
- signpost formations 480
- sikaru* 6
- silica 233, 271
- silica gel 240
- silicates 597
- silicon 527
- silo capacity 561
- simulation tests 624
- single-end bottle washing machine 306, 312
- Sinner's Circle 305
- sintered glass 240
- six-row barley 498
- sixteenth-century price revolution 18

- sleeving 334–336
 - shrink-sleeve 334, 336
 - stretch-sleeve 334, 335
- slider ‘M’ system 352
- slime linings 478
- smell, sense of 675, 676
- smoked malt 164
- smoky-flavor beer 222
- snifting 290
- soaking 354
- soda alkalinity 105
- sodium, in beer 526
- sodium carbonate 599
- sodium hydrogen carbonate 108
- sodium hydroxide
 - for cleaning 597, 609, 615–618
 - to prevent microbial growth during steeping 151
- sodium hypochlorite 601
- sodium metabisulfite 151
- sodium metasilicate 597
- sodium polyphosphate 599
- soft boiling method ‘SchoKo’ 194
- soft resins 87
- soils, for hop cultivation 86
- solid electrolyte sensors 539
- solid separation, of waste water 668
- solubilizers 598
- soluble nitrogen 160
- solvent, as flavor attribute 680, 682
- sorghum adjunct 181, 182
- sorghum grits 65, 66
- sorghum malts 65, 66, 164
- sorghum millet 61
- sorghum (*Sorghum bicolor*) 43, 65, 66
 - acreage and production of 59
 - for gluten-free beer 246
 - properties of 56, 57
 - starch granules 50
- Soufflet Group 501, 503
- sour flavor 676
- South African beer market 509
- South America
 - beer consumption in 506
 - malt and 502
 - malting barley varieties 500
- space requirements, brewery 570
- Spain, beer market 506, 508, 510
- special beers 222
- specifications, new brewery 575
- specific gravity analysis 440, 441, 443
- spectral photometers 464
- spectrum line photometer 464
- spelt (*Triticum spelta*) 14, 56, 57, 66, 67
- spent grain analysis 459
- spent grain and yeast 674
- sphingolipids 125
- spicy flavor attribute 680, 684
- split streams 629–631
- sports drink, beer as 523
- spray balls 606, 607
- squalene 129
- stability of beer 399–433
 - colloidal stability 428–432
 - flavor stability 399–423
 - foam 362, 369
 - hop aroma 371
 - lightstruck flavor 423–428
 - stabilization systems 432, 433
- stabilization 231, 232
 - filtration and stabilization plant design 232–234
- stack cleaning and disinfecting 603
- staling process. *see* flavor stability
- starch
 - breakdown to sugar 170
 - formation of 47–50
 - gluten-free 246
- starch crystallinity 49
- starch granules 49
 - properties of 50
- starch synthases 49
- starch syrup 261
- starchy endosperm 45, 46
- starchy raw materials 43–71
 - brewing cereals 55–70
 - structure and metabolism 44–55
- Statistical Estimates of the Materials of Brewing* (Richardson) 31
- steeping 150, 151, 554
 - process scheme 558, 559
- Steinfurth foam stability tester 455, 456
- Steinheil, C. 31
- step-mashing process 173, 174
- sterilization, steam 618
- sterols 125, 129
- stomach, beer and protection of 522
- storage
 - of barley and malt 555
 - beer foam and 364
 - characteristics 564
 - of hops 100
 - of malt 156, 157
 - maturation and 215
 - staling and 421, 422
 - turbidity and 432
 - of yeast 141, 142, 220, 221

- storage/cabinet cooling, in draft beer system 342
 - storage cellar
 - design of 657, 658
 - waste water and 625, 630
 - storage proteins 50–52, 55
 - storage tank 418, 419, 531–533, 565
 - cleaning 607–610
 - stout 95, 254, 504, 505, 507. *see also* porter
 - barley flakes in 177
 - dispensing 348
 - Imperial 223
 - Irish 60
 - strainmaster 186
 - straw, yeast preservation and 12
 - Strecker aldehydes 187, 239, 408, 423
 - stretch-sleeve process 334, 335
 - strip gluing 324–326
 - stroke, beer and 516, 518, 519
 - Stromboli internal boiler 190, 191
 - strong beers 222, 223
 - strongly hopped beer 95
 - strychnine 32
 - Subjet internal boiler 191, 192
 - sucrose 49, 127, 209, 440, 689
 - sucrose test 422
 - sugars
 - in beer-based mixed drinks 261, 262
 - fermentable 127, 128
 - gluten-free 245
 - sulfate 111, 448
 - determination of 447
 - sulfate ions, ratio to chloride ions 689
 - sulfhydryls 360
 - sulfides 89
 - sulfur 130
 - sulfur compounds 211
 - sulfur dioxide 214
 - as allergen 211, 437, 525
 - determination of 465, 467, 468
 - as flavor attribute 211, 679, 680
 - formation of 135
 - sulfur heterocycles 89
 - sulfuric acid 598, 599, 612
 - supply contracts 653
 - surface filtration 226
 - surfactants 598, 599, 618
 - swabbing method, to detect beer pests 485–488
 - sweet 676
 - sweetening in beer-based mixed drinks 261, 262
 - sweetness, assessing 680, 689
 - Switzerland, dietetic beer in 241
- t**
- Tabarié relationship 442, 443
 - Tacitus 9
 - tamper-evident sealing 327, 332
 - Tango 259
 - tanning agents 525
 - tannins, turbidity and 231, 232
 - Tasmania, brewing in 36
 - taste 361, 676
 - taste testing 675
 - Taurus hops 368
 - taverns 15
 - taxes
 - on ale 21
 - on beer 23, 27, 497
 - on brewing 19
 - TBI (thiobarbituric acid index) 386, 409, 414, 422, 446, 447
 - TBN (thiobarbituric acid number) 161, 162, 187, 188
 - TBN (total bound nitrogen) 627
 - TC-Tank Jet 611
 - Technical Instruction for Air Pollution Prevention 670
 - technology
 - grinding 165–168
 - hopping 91–100
 - inspection 318, 319
 - lautering 181–186
 - mashing 168–181
 - measurement 533–542
 - robot 582–584
 - Xan 243
 - teff (*Eragrostis tef* (Zucc.) Trotter) 62
 - temperature
 - alkaline cleaning agents and 613
 - anaerobic waste water treatment and 638
 - of barley malt enzymes in mash 171
 - condensation 659
 - DMS and 387
 - filling 285
 - gelatinization 170, 172
 - germination and 152, 154
 - for hop storage 100
 - keg storage 339
 - kilning 155, 407–409
 - during mashing process 410, 411
 - measurement of 534, 535
 - pasteurization and 271
 - steeping 150
 - step-mashing and 174
 - withering 405, 406
 - yeast propagation and 139
 - for yeast storage 142

- temperature tests, for draft beer systems 355, 356
- Temporary Beer Law 241, 242
- testing
- draft beer systems 355, 356
 - sensory 693, 694
- testing and calibration laboratories 494
- tetraden formation 483
- tetrahydro- α -acids 428
- tetrahydro-iso- α -acids 93, 94, 98, 426, 428, 689
- tetrahydro-iso extract 503
- trans*-tetrahydro-iso-humulone 427
- tetraploid durum (*Triticum durum* L., *T. turgidum* L., *T. polonicum* L.) 67, 68
- Tettang Tettninger hops 377
- theoretical production time 706, 707
- thermal conductivity detector 463
- thermal dealcoholization, in alcohol-free beer production 236, 237
- thermal energy 643
- thermal energy analyzer (TEA-detector) 463
- thermal power stations 669
- thermal treatment of beer 422, 423
- thermo-analytical measurement 443
- thermometer 31
- thiamin 130
- thiazoles 381
- thin film evaporator 199, 200
- thiobarbituric acid index (TBI) 386, 409, 414, 422, 446, 447
- thiobarbituric acid number (TBN) 161, 162, 187–189
- thioesters 89, 682
- thiols 211, 681
- Thomson, T. 31
- tiazole 408
- time on tap 339
- time-related archiving 552
- (TIN) total inorganic nitrogen 627
- titah* 5
- titration methods 449–451
- TKN (Kjeldahl nitrogen) 627
- tocopherol, applied to beer-based mixed drinks 269
- top fermentation 22, 26, 55, 58, 119, 222, 223
- top-fermented beers 223, 224
- top-fermenting yeasts 121, 122, 207, 479, 480
- topping-up 209, 214
- Torulopsis* 252
- total bound nitrogen (TBN) 627
- total inorganic nitrogen (TIN) 627
- total waste water 627–629
- touch, sense of 676
- toxic constituents, of waste water 624
- trace elements, as yeast nutrients 129, 130
- training, for sensory evaluation 694–697
- transaminase system 128
- transgenic plants 53
- transglutaminase 245
- transmission 444
- tray packer 589, 590
- Treatise on the Adulteration of Food and Culinary Poisons*, A (Accum) 32
- treatment zones, in bottle washing 306, 307
- triangle test 693, 695
- tricarboxylic acid cycle 131
- trichloroanisole 267
- 2,3,5-trimethyl-pyrazine 385
- triticale (*xT. riticosecale* Wittmack) 50, 56, 57, 68
- triticins 51
- tritordeum 56, 57, 68
- trub 140, 142
- cold 202
- true density 440
- true to type 679
- tunnel pasteurizers 646
- turbidity 377, 428
- composition of 430
 - formation of 430, 431
 - measurement of 456, 457, 539, 540
 - stabilization 231, 232
- turbidity photometers 456
- turbulent cleaning 618
- two-mash procedure 169, 170
- twopenny 23
- two-row barley 498
- two-sink glass washing installation 343
- two-step wort cooling 649
- tyrosol 132
- U**
- UB (unfiltered beer) 562
- ultrafiltration 116
- umami 676
- umbels 87, 88
- 9-undecanal 400
- n*-undecanal 400
- unfiltered beer (UB) 562
- United States
- beer consumption in 503, 506
 - beer market 506, 508, 510
 - brewing in 33–36
 - dietetic beer in 240, 241

- hop farms 502
- top brewers 512
- U.S. Department of Agriculture 518
- U.S. Department of Health and Human Services 518
- utilities and power supply 568, 571, 574
 - carbon dioxide recovery 568
 - with coldness 568
 - with compressed air 568
 - with electrical power 569
 - with fresh water 569
 - with heat 568
- utilization factor 706
- UV irradiation, labeling using 331–333
- UV irradiation/oxidation, combination processes using 112

V

- vacuoles 124, 126
- vacuum evaporation 197, 198
- valeric acid 483
- valine 128, 129, 132
- vanillin 689
- van Leeuwenhoek, Antonie 119
- vapor condensate 191, 202
 - re-use of 201
 - waste heat from 650
- vapor condenser, heat recovery and 649, 650
- vapors 670
- Varioboil 197, 199
- vats 24
- Venezuelan beer market 509
- vertical integration 552
- very high rice adjunct addition, mashing with 177–180
- vicinal diketones 211, 686
 - formation of 132, 133
- 4-vinylguaiaicol 89, 134, 223
- 4-vinylphenol 134, 223
- viscosity
 - dynamic 457
 - kinematic 457
 - measurement of 457, 458
- vitamins
 - in beer 525, 526
 - as yeast nutrients 130
- Volumetric VOC filler 296–300
- Volumetric VODM-PET filler 296, 297, 300, 301

W

- Wagner, John 35
- Wakley, Thomas 32
- Wanderhaufen vessel 152
- warm maturation 215
- waste 673, 674
 - kieselguhr 674
 - production 673
 - spent grains and yeast 674
- waste heat
 - from compressed air 650, 651
 - from refrigerating system 651
 - from vapor condensate 650
- waste management regulations 674
- waste water 621–640
 - aerobic treatment 635–637, 640
 - anaerobic treatment 637–640
 - analysis of 623–625
 - biological degradation of 666
 - composition of 666
 - constituents 622–624
 - direct discharge of 666
 - environmental protection and 665–668
 - indirect discharge of 666–668
 - in-house measures 631–634
 - measurement 626, 627
 - mixing and equalizing tanks 634, 635
 - neutralization 632–634
 - neutralization of 668
 - parameters of 627–631
 - pollutant load 625, 626
 - split streams 629–631
 - total 627–629
 - treatment of 632–640
 - types of 621, 622
 - volume and concentrations 626, 627
 - waste water plant planning 625, 626
- water. *see also* brew water; waste water
 - in beer-based mixed drinks 261
 - beer quality and 105
 - in bottle washing 306
 - fresh water requirements in brewery 621, 622
 - reduction of usage 665
 - for steeping 150
 - in yeast cell 124
- water balance regulations 674
- water supply 569
- water treatment 110–117
 - activated-carbon filtration 112
 - aeration 112
 - combination processes using oxidation/UV irradiation 112
 - deferrization and demanganization 110, 111
 - heat requirements 648
 - ion exchange 113–115
 - lime softening 112, 113

- membrane processes 115–117
- nitrate reduction 111
- removal of problematic inorganic substances 110, 111
- removal of problematic organic substances 112
- waste water 632–640
- weakly hopped beer 94
- Weiba 259
- Weizenbock beer 223
- Wendes 16
- Western Brewer* 35
- wet chemical analysis, of beer-based mixed drinks 263, 264
- wet end of the line 305
- wet-glue labeling 324–327
- wet milling 165
- wheat beer mixtures 259
- wheat beers 68, 69, 223, 235, 504
 - Belgian 69
 - dispensing 348
 - phenolic compounds in 134, 135
 - white 27
 - Xan 243
- wheat group (*Triticum* L.) 66–69
 - einkorn 67
 - emmer 67
 - spelt 66, 67
 - tetraploid durum 67, 68
 - triticale 68
 - tritordeum 68
 - wheat 68, 69
- wheat kernel
 - nutrients in 47
- wheat malt 17, 164, 224
- wheat (*Triticum aestivum*) 3, 43, 68, 69
 - acreage and production of 59
 - aleurone layer 45
 - amino acids 51
 - endosperm 45, 46
 - grain ripening 48
 - properties of 56, 57
 - proteins in 47, 51
 - starch granules 50
 - starch in 46, 47
- Whewell, William 2
- whirlpool 531, 532, 534
- Whitbread, Samuel 24
- white barley beer 27
- white wheat beer 27
- widgits 278, 299
- Wiener beer 360
- WinCoS 551
- winter barley malts, beer foam and 363
- Winthrop, John 35
- Wismar 17
- withering 387, 388, 405–407, 557
- wood, as fuel source for brewing 20, 27, 648
- woodruff 253, 259
- working pressure 344
- work safety, cleaning and 620
- world beer production (1900, 2003) 34
- world market 497–513
 - Africa 509
 - America 508
 - Asia 509
 - Australia and Pacific 509, 510
 - barley and malt market 498–501
 - beer consumption 503
 - beer markets 505–510
 - beer styles 503–505
 - branding 511, 513
 - Europe 507, 508
 - global malt production 501
 - hop market 501, 502
 - packaging 505
 - profitability 510
 - raw materials 498–503
 - statistics 498–505
 - top brewers 510–512
 - use of hop and hop products 502, 503
- wort 4
 - cooling 27
 - fermentation and composition of 213
 - flavor stability and preparation of 409–413
 - high original 246–248
 - *N*-heterocycles of 384
 - as nutrient for yeast 127
 - from oat malt 61
 - quality of 704
 - yeast cultivation in 136, 137
- wort/beer losses, calculating 563
- wort boiling 186–202, 386, 413, 414
 - beer foam and 363, 364
 - boiling systems 190–200
 - cold trub 202
 - dynamic low-pressure boiling 194, 196
 - evaporation 186–189
 - external boiler 192, 193
 - flash evaporation ‘Varioboil’ 197–199
 - high temperature 194, 195
 - hot holding 186
 - internal boilers 190–192
 - optimized internal boiler ‘Stromboli’ 190, 191
 - optimized internal boiler ‘Subjet’ 191, 192
 - soft boiling method ‘SchoKo’ 194
 - thin film evaporator ‘Merlin’ 199, 200

- turbidity and 431
- vacuum evaporation 197, 198
- vapor condensate 201, 202
- wort stripping 196
- wort cooler 531–534
- wort cooling 564
 - heat recovery and 648, 649
 - optimization of 661
- wort kettle 531, 532, 534
- wort production 165–202
 - flowchart 166
 - grinding technology 165–168
 - for lambic and gueuze beers 251
 - lautering technology 181–186
 - mashing technology 168–181
 - wort boiling 186–202
- wort stripping 196
- wort sugar content 31
- wrap-around packaging 584–587

x

- Xan beer 235, 243
- Xan technology 243
- xanthohumol 89, 97, 243, 377–379, 437, 522
- Xenophon 6
- xerogels 432
- X-rays 319

y

- yeast 119–142
 - ale vs. lager 121–123
 - beer recovery from 221
 - brewing 119–127
 - brewing privilege and 12
 - chemical composition of 124
 - classification of 121
 - dried 137
 - flocculation 123
 - foreign 480, 481, 485–489
 - history of yeast research 119, 120

- morphology and chemical composition 124–127
- repitching 140
- spent 674
- strains of brewing 120, 121
- yeast cellar 138–140
- yeast cold-contact process 238, 239
- yeast conservation starter culture 4
- yeast crop 140, 141, 220, 221
- yeast management 127–142, 566
 - cultivation 135–138
 - esters, formation of 134
 - flavor stability and 414–417
 - higher alcohols, formation of 132, 133
 - metabolic pathways during propagation and fermentation 131–135
 - nutrient requirements and intake 127–130
 - phenolic compounds 134, 135
 - post-fermentation treatment 140
 - propagation in yeast cellar 138–140
 - sulfur dioxide, formation of 135
 - treatment after cropping and storage 141, 142
 - vicinal diketones, formation of 132
 - vitamins and other growth factors 130
 - yeast crop 140, 141, 220, 221
- yeast storage 220, 221
- yeasty flavor attribute 680, 686
- Young, William 120
- young beer 207

z

- zearalenon 438
- zinc 127, 129, 130
- Zosimus of Panopolis 7
- Z protein 51
- zymolectin 123
- zymosterol 125
- Zymotechnic Institute 33
- zythos 7, 8