Index

'*Note:* Page numbers followed by "f" indicate figures and "t" indicate tables.'

A

Abscisic acid, 483
Accelerated product development, 252
Accountability, 803–804
Accuracy, 399, 583
Accurate labeling, 454
Accurate prediction of health outcomes, 326
Actionable insights, 465
Action triggering, 461
Adani agri, 129–131
Adaptation and modification, 305
Adaptive algorithms, for gas adjustment, 127
Adaptive control algorithms, 123
Adaptive fuzzy logic system (AFLS), 702
Adaptive learning
  algorithms, 129
  for CA conditions, 125
  for humidity dynamics, 126
Adaptive monte carlo localization (AMCL), 620
Adaptive neuro-fuzzy inference system (ANFIS), 706, 738, 816
Adaptive sorting, 122
Adaptive temperature control algorithms, 125
Adequate nutrition, 389
Adulteration, 348–349
Advanced data augmentation techniques, 55–58
Advanced manufacturing technologies, 254
Advanced pattern recognition defects and contamination, 426
Advanced routing algorithms, 786
Advanced spectroscopic techniques, 487t
Advanced technological integration, 131
Adventitious data collection approaches, 48
Aflatoxin, 485
Agile model, 539
Agricultural practices, 782–784
Agricultural sector, 748–749
Agri-food supply chain (AFSC), 69, 661t
  vs. traditional system, 660–662
Agro-food processing industry, 749
AI-based applications in food and nutrition, 322t
AI-based flavor profiling, 272–273
AI-based nutrition recommendation system, 145
AI-based sensory profiling, 264t
AI-based systems, 576, 613
AI-driven analysis, 467
AI-driven approaches in personalized nutrition, 396–398
AI-driven decision support systems, 465
AI-driven detection of mycotoxins, 437–438
AI-driven digital image processing, 356
AI-driven DIP, 356–357
AI-driven environmental management, 130
AI-driven enzyme engineering, 820
AI-driven food fraud detection, 790
AI-driven nutrition, 398
AI-driven optimization, in controlled atmosphere, 129
AI-driven personalized nutrition, 398
  and food safety, 603
AI-driven predictive maintenance, 428
AI-driven robotics, for quality inspection automation, 442
AI-driven sensory analysis and product development, 585
AI-driven supply chains, 725
AI-driven sustainability in food production, 255–256
AI-driven TI systems, 23–24
AI-led innovation in alternative proteins, 820
AI-mediated nutritional modeling, 324–326
AI-powered automation, 48
AI-powered irrigation systems, 783–784
Algorithmic bias, 238, 399
  and fairness, 584
Algorithm limitations, 354
Algorithm selection, 92
Alternative ingredients, 255–256
Amazon Web Services (AWS), 572
Ambient light and external factors, 450
American Dietetic Association (ADA), 395
Amino acids, 490
Anomaly identification, 429
Anomaly scores, 452
ANSYS Gambit, 362–363
Ant colony swarm intelligence (ACOA), 310
Antimicrobial resistance (AMR), 593–594
Antimicrobial resistance in food safety, 597
Ant lion optimization, 309–310
Apple ripeness detection, 346
Appropriate tools, selection of, 209
Architectures, 98
Artifacts, 457
Artificial bee colony (ABC) optimization, 308
Artificial intelligence (AI), 24, 243–244, 250, 339, 401–402, 528, 590, 718–721, 732–733, 754–755, 798–802, 801f, 817–819
  adoption, 1, 438–440
  in agriculture, 748–749
  algorithms, 403
    in food quality control, 429–433
    in nutrition, 400
    for real-time sensors for food quality, 462t–463t
  analysis, 742
  in analyzing individual health data, 396–397
  applications, 121–124, 256–258, 785t, 791
    across diverse industries, 438
    in bioprocess industry, 34–36
    in food processing, 615
    in food quality monitoring, 455–456
    in food safety, 596t–597t
    in food science, 29–34
    in predicting safety, 402–403
    in real time, 709–710
  approaches, 564–565
  in beer brewing, 792
  bibliometric analysis of integrating, 320f
  for bioactive compound discovery, 792–793
  in bioprocess optimization, 774–775
  and blockchain to enhance, 551–552
  in building trust, 603
  in chain optimization, 798
  in combating climate change impacts on food safety, 605
  in consumer-centric food experiences, 821–822
  in educational and consumer engagement, 329
  to enhance food safety, 776f
  ethics in food industry, 771–772
  with external sensors, 816–817
  fairness and bias in, 764–766
  in food and bioproducts, 321–324
  in food industry, 11–17, 615–620
  in food integrity, 813f
  in food logistics, 720f
  in food manufacturing, 585–586
  in food packaging, 617–618
  in food processing, 368–372, 749
  in food product demand forecasting, 709

Artificial intelligence (AI) (*Continued*)
in food production, 312–313, 755
in food quality, 438, 440–442, 565t
control, 701–708
monitoring, 463–465
in food safety, 33–34, 470–471, 476, 593–599, 603–605, 604t, 615–616, 773, 798, 821
in food science, 1–5, 37–38, 53–54, 243–245, 258–259, 379–380, 763–764
in food science and nutrition, 319
in food sector, 814t
in food supply chain, 721–725
for food traceability, 599–602
in food waste, 619, 790
frameworks, 459
historical evolution and key drivers of, 571–572
historic evolution of, 572f
in identifying functional properties, 246–247
implementation, 466, 579–585
improve bioprocessing, 820–821
in ingredient discovery, 245–247
innovations driving food quality, 566t
integration, 455–456, 764, 765f, 771t
in food industry, 799f, 802–804, 803t, 804f
in food quality monitoring, 456–458
in sensor technologies, 458–460
interventions for healthy, 150–156
interventions for promoting healthy eating, 156–157, 160–161
behaviors, 159–160
ethical challenges of, 157
limitations of, 157
limitations of, 36–37
methods and classification, 591f
to mitigate, 453–455
in new product development, 616
in non-food sensory analysis, 276t
and personalized nutrition, 327–328, 402–403, 773–774
in precision nutrition or personalized functional foods, 402
for predictive analytics, 465, 467
processes IoT-generated data for supply chain, 602
processing layer, 464
in process optimization, 571
in product innovation and development, 819–820
production processes through, 785
in public health, 590
quality assurance, 821
in quality check, 705t, 708t, 710t, 792
in quality control
of finished products, 707–708
during packaging, 708
during processing, 704–707
of raw materials, 702–704
in raw material, 703t
revolutionizing food quality control, 425–427
in robotic system, 622f
and robots in restaurant, 620–621
roles on food quality and safety, 749–752
sectors in, 751f
and sensor integration in food quality monitoring, 464
in sensory, 275–276
analysis, 266–268, 273–274
science, 268–270, 274t
in shelf-life prediction, 381–383, 382t
solutions, 15–16, 727
in sorting fresh produce, 615
for supply chain, 619–620, 719–721, 725–726
systems analyze data, 812–813
techniques, 266, 472–473, 473t
applied in food and nutritional modeling, 322t
for detecting biological contaminants, 471–472
in nutritional modeling, 321
for optimizing food processes, 370t
for shelf-life prediction, 381
technologies, 38, 476–477, 763
in health and nutrition, 396
in nutritional assessment, recommendations, and meal planning, 397–398
restaurant menu optimization with, 787
tools, 474t, 577–579, 580t–582t
in food industry, 579
utilization in cold chain, 132
Artificial neural network coupled genetic algorithm (ANN-GA), 323–324
Artificial neural networks (ANN), 7–8, 26–29, 65, 97, 221, 225, 266, 304, 359–360, 371, 381, 434–435, 460, 471–472, 483–484, 707, 734–737, 734f, 749, 815–816
architecture and process in food quality control, 435
in food processes, 310
food quality models, 435t
Association for Computing Machinery (ACM), 145–146
Atmospheric gas concentrations, 448
Augmented reality (AR), 329, 586, 680
Autocorrelation, 452
Autoencoder-RNN (AE-RNN), 104
Automated feature selection, 93
Automated file naming, 353
Automated image-based tasks, 335
Automated inspections, 426–427, 590
stations, 529
Automated order fulfillment, 132
Automated quality inspection, 597
Automated sensory evaluation, 275–276
Automated sorting, 620
and grading, 121–122
Automated storage and retrieval systems (AS/RS), 291
Automated strategies, 59–60
Automated techniques, 559
Automation and transparency, 355
Automotive industry, 440
Autonomous equipment management, 129
Autonomous monitoring and management systems, 804–805
Autoregressive integrated moving average (ARIMA), 690, 694

B

Bacillus cereus, 413
Backpropagation (BP), 707
Backpropagation artificial neural networks (BP-ANN), 598
Bacterial load detection, 449
Baking, 362
Balancing sustainability and profitability, 238
Barcodes, 419
Baseline correction and drift compensation, 457
Bat algorithm, 309
Bayesian forecasting techniques, 722
Bayesian networks (BNs), 590, 737
"Beany" flavor, 232
Beef traceability in South Korea, 552
Beer–Lambert's law derivation, 501
Behavioral change and adherence, 393
Bias
in data and quality outcomes, 438
and discrimination, 273
Bidirectional Encoder Representations from Transformers (BERT), 598
Big data analytics, 15–16
Big data infrastructure, 114
Binary bat algorithm, 309
Binary data, 344
Binary image, 336
Biogenic amines index (BAI), 707
Bioinspiration, 304–306
principles of, 304–306
Bioinspired algorithms, 303
Bio-inspired algorithms (BOT), 304
Bioinspired design, 306
Bioinspired optimization
methods, 306–310
techniques in food industry, 306, 313–315
Bioinspired technologies, 305
Biological data analysis, 249–250
Biomimicry lessens, 304
Biopharmaceutical classification system (BCS), 174
Bioprocess systems, 24, 294–297
engineering case studies, 792–793
optimization, 818
optimization using deep learning, 112t
Bio-refinery model, 732
Biosensors, 473–474
"Black box,", 238, 354
Black-box deep learning models, 770–771
Black soldier fly (BSF), 752

Blockchain, 294–297
adoption in food supply chains, 657, 662–663
and AI, 786
for improved food traceability, 585–586
integration, 600–601
challenges, 658t
in food industry, 436
in food supply chains, 654–657
operational benefits, 656
sustainability benefits, 656–657
integration, 590
network, 542–543
system, 542, 552
for traceability and transparency in food safety, 474–475
types, 544t
Blockchain-based quality monitoring, 551
Blockchain-enabled systems, 284–285
Blockchain-IoT-based food traceability system (BIFTS), 601
Blockchain networks
deployment on, 545
types of, 543–544
Blockchain technology (BCT), 58, 281–283, 385, 436, 443, 537, 542–545, 592, 651–654, 660t
applications in food industry, 545–550
in food sector, 657–660
on food supply chain, 654
in quality control, 436
Blood glucose data, 154
Blood pressure data, 154
BMP, 336
Bottleneck identification, 571
Brand reputation, 574
Bureaucratic impediments, 552

C

Calibration
for size and scale, 343
stability, 452
California Consumer Privacy Act (CCPA), 272, 770
Capture environmental data alongside images, 353
Carbon footprint analysis, 236
Carbon footprint reduction through AI, 791
Carcinogenic and neurotoxic effects, 437
Cardano's blockchain initiative, 550–551
Cellular agriculture, 237
Centralize data storage, 454
Chain management, 720t
Change management, 213
Chemical and biochemical indicators, 448–449
Chemical composition, 227
Chemical compositions, 267
Chemical data, 271
analysis, 249
Chemical reactions, 448–449
Chemicals and biological sensors, 285–286
Chemometrics, 493
in excellence assessment of fruits and fruit products, 482–483
instruments, 480t
methods and data analysis, 561–562
in quality assessment
of beverages, 482–486
of honey, 483–484
of olives and olive oils, 485–486
in quality control, 492–493
in quality evaluation of crops, 484–485
techniques, 479, 481–482
tools, 493
Cholesterol-lowering peptides (CLP), 321
Chronic conditions, 393
CI-guided advances in extrusion technologies, 232–233
Circular economy integration, 237
Citrus limetta, 739–740
Clostridium, 469
Cloud and IoT integration, 463
Cloud-based data storage, 465
Cloud-based solutions and IoT in food quality control, 465
Cloud computing, 463, 572
Cloud technologies, 38
Clustering, 81, 87–88
algorithms, 88–89
and dimensionality reduction in food science, 92–93
in food science, 90–92
and machine learning models, 457
Clusters analysis, 481
Cognitive biases, 265
Cognitive modeling, 275
Cold chain efficiency, through multimodal integration, 131
Cold chain monitoring, 428, 549
Cold storages, 132–134
Collaborative robots, 529
Collaborative training, 432
Color, 448
calibration, 350
depth, 336
feature extraction, 347
fidelity, 343
image, 336
temperature, 353
Color space conversion (Optional), 345
Communication protocols and data acquisition from sensors, 464–465
Communication strategies, for cross-functional teams, 210
Competitive adaptive reweighted sampling (CARS), 489
Complex data modeling, 250–251
Complex food matrices, technologies in, 476
Complex geometry, 353
Complexity due
to nature of input variables, 711
to nature of output variable, 711
to temporality, 711
Compliance monitoring and regulatory compliance, 789
Compound annual growth rate (CAGR), 23–24, 220, 411
Comprehensive environmental assessment, 236
Computational fluid dynamics (CFD), 204–205, 250–251, 314, 359
aided AI in food industry, 372
in emerging food technologies, 365–367
in food processing technology, 361–365
software, 361, 364t
Computational intelligence (CI), 220–221, 235, 239
applications in ingredient analysis, formulation, and optimization, 222
in fermentation process optimization, 234–235
in food science, 222–226
methods, 221–222
in modern food systems, 219–220
Computational methods for lifecycle analysis, 236–237
Computational modeling and simulation, 250–251
Computational models, ethical considerations and biases in, 238
Computational resource requirements, 113–114
Computational tools, transforming ingredients with, 226–231
Computer-aided design (CAD), 252–253, 314–315
Computer-aided engineering (CAE), 204
Computer graphics, 336
Computer vision
and pattern recognition, 338
system, 574
Computing infrastructure, 459
CONCOR, 129–131
Conditional GANs (CGANs), 5
Condition monitoring sensors, 124
Consensus mechanism, 552
Consistent sample handling, 353
Consortium blockchains, 544
Consumer data, 815
Consumer education and awareness, 130
Consumer engagement, 239, 274, 549–550
Consumer experience and retail, 819
Consumer preferences, 692
modeling, 232
studies, 270
Consumer safety, 524–525
Consumer satisfaction and market demand, 252
Contaminants, 348–349
detection, 464
Continuous flow model, 539
Continuous improvement, 211, 213, 817
through data analysis, 129
Continuous learning, 463
Continuous research and development, 130
Conventional approaches in data collection, 46–48

Conventional monitoring systems, 592–593
Conversion and analysis, tools for, 346
Convolutional neural networks (CNN), 65, 338, 367, 384–385, 430–432, 437, 461, 574, 590, 675, 704, 798–800
Convolution layer, 430
Cooltrans express, 132
Core image attributes, 341, 342t
Corporate responsibility and consumer trust, 772–773
Cost and expertise, 13–14
Cost and resource constraints, 272
Cost and resource efficiency, 236
Cost and resource limitations, 271
Cost barriers, 438
Cost-effective scalability, 465
Cost efficiency and sustainability, 252
Cost optimization and sustainability, 124
Cost reduction, 268
Cost savings, reduced need for physical prototypes, 209
Cox regression models, 185–186
Creaminess, 234
Critical process parameters (CPP), 4–5, 106–108, 775
Critical quality attributes (CQA), 4–5
Critical tracking events (CTEs), 540
Crop optimization and yield improvement, 310
Cross-chain technology, 553
Cross-commodity AI models, 437–438
Cross-commodity application for scalability, 427
Cross-commodity modeling, 438
Cross-correlation, 452
Cross-disciplinary collaboration, 59–60, 258, 566–567
Cross-industry applications, 563–566
Cross-section of foods, 183t
Cross-validation methods, 267, 455
Crowdsourcing
  for consumer insights, 55
  for food data, 48
Cultural and social influences, 394
Cultural influences, 265
Current applications, 550–552
Custom-configured model, 539
Customer trust and safety, 425
Customized and focused quality control, 427
Customized cold chain solutions, 131
Cutting edges in food science, 378–380
Cutting-edge technologies, 6–7
Cyber-physical systems (CPSs), 311, 493, 623, 631–633
Cybersecurity, in AI-based supply chain systems, 725

D

Dairy substitutes, 235
Dairy supply chain, with blockchain technology, 552
Danone, 792
Data acquisition, 271–272
  for AI-based flavor profiling, 270–272
  layer, 464
  methodologies for, 271
  and preprocessing, 672–675
  through sensor technology, 428–429
  tips, 350–353
Data aggregation and storage layer, 464
Data analysis, 150, 177, 573
Data analytics (DA), 33, 253, 286–289, 508
Data archiving, 454
Data augmentation, 457
Data availability and quality, 12–13, 113
Database Management System (DBMS), 55
Data chronology, 542
Data cleaning and preprocessing, 454
Data collection, 46, 54–55, 433, 463, 465, 573
  and analysis, 381–383
  integration, and management, 593
  and preprocessing, 52–55
  protocols, 271
  and sampling, 454
Data collection tools, 58
Data complexity, 579–583
Data diversity, 257
Data-driven class modeling (DD-SIMCA), 489
Data-driven customization, 237
Data-driven supply chain visibility, 131
Data employed, 154
Data explosion, 572
Data flow, 461
Data for flavor profiling, 270–271
Data fusion, 457–458
Data gathering, in food science, 46–48
Data guardianship in AI-driven supply chains, 725
Data imputation, 51
Data integration, 271, 350
Data management, 271, 354
Data modeling, potential outbreaks through, 594–595
Data normalization and scaling, 454
Data preprocessing, 45, 49, 516–517, 583
  and noise reduction, 455–456
  for predictive maintenance, 429
  techniques, 48–52
Data privacy, 238
  in AI/ML applications in food, 769–771
  and consumer consent, 272–273
  and cybersecurity concerns, 466
  measures, 355
  and security, 355, 475, 583
Data quality, 58, 399
  and availability, 256–257, 403
  and processing, 353
  and reliability, 271
  and variability, 272
Data representation and structures, 344–345
Data requirements, 456, 584
Data scaling and transformation, 52
Data sensitivity, 398
Dataset, dealing with, 66
Data sources
  for AI-driven personalization, 398–399
  for functional foods, 400–401
Data storage
  and analysis, 463
  and management, 454
Data structures for digital images, 344–345
Data transmission gateways, 427
Data visualization, 463
Data workflow, 248f
Decentralization, 542
Decision-making processes, 461, 476
  layer, 464
  system for customers, 32
Decision support, 463
Decision systems for predictive maintenance, 429
Decision tree, 737–738, 737f
  algorithm and quality index method, 513
  and random forest, 508
Deep learning (DL), 1, 23–24, 97–98, 221, 225–226, 243–244, 338, 455, 556, 719
  automated feature extraction with, 346
  in food science, 98–106
  methods, 798–800
  and neural networks in food science, 249–251
  for sensory data analysis, 273
  techniques, 107t
    in bioprocess optimization, 106–111
    in food industry, 26–29
  technologies, 5
Deep-learning-based defective bean inspection scheme (DL-DBIS), 105
Deep learning–based spectral analysis for quality, 509–511
Deep neural networks (DNNs), 105–106, 321, 437
Demand estimation aids, 721
Demand forecasting, 132, 575, 692, 721
  models, 722t
  and planning, 68–69
Demand-supply chain management, 33
Demand variability, 716–717
Demographic information, 271
Density-based clustering, 89–90, 90f
Derived quality metrics, 452
Design of experiments (DOE), 34, 253, 481
Detect anomalies, 461
Dietary and clinical practices, 161
Dietary reference intakes (DRIs), 390
Diffuse light sources, 350
Digital cameras, 336
Digital image processing (DIP), 335–348, 338t
  algorithms, 335
  in food and bioprocessing, 350
  to food industries, 338
  in food processing, 351t
  hardware and software recommendation for, 352t
  technologies relevant to food and bioprocessing industries, 338–339
Digital images, 335–336
  advantages of, 337
  analysis, 337–338, 343–344
  creation and capture of, 336

data types for, 344
processing in food safety, 354
types, 341t–342t
Digital matter eagle cellular data, 286
Digital support, 620
Digital twins (DTs), 109, 371–372, 749–750
Digitized ecosystem, 696
Dimensionality reduction techniques, 86, 93, 450
Discrete wavelet transform (DWT), 704
Distance metric, 434
Distributed ledger, 542
Distributed ledger technologies (DLTs), 383, 542
Distribution system, 716–717
Diverse methodologies, 266
Diversified legal policies, 552
DNA-based methods, 471–472
Documentation and traceability, 211
Dominant frequency, 452
Drift compensation models, 457
Drift correction, 454
Dropout layer, 432
Drug administration, 184t
mode of, 183
Drugs, foods, and health conditions, 181–183
Drying, 310, 362–363
of foods, 69–71
process control, 34
Dual-mode multispectral imaging systems, 556
Dynamic and real-time analysis, 237
Dynamic environmental control, 123–124
Dynamic features, 452
Dynamic flavor adjustments, 232
Dynamic humidity control systems, 126
Dynamic humidity regulation, 125
Dynamic price strategy, 690
Dynamic pricing strategies, 727, 790
Dynamic process optimization, 234
Dynamic product development, 274
Dynamic temperature regulation, 123, 125–126

E

Eco-friendly packaging, 410
Eco-green AI, 442
Economically motivated adulteration (EMA), 768
Economic indicators, 692
Economic order quantity (EOQ), 688
Edge clarity, 343
Edge computing, 427
in food, 427
Edge detection, 345
Edge processing
layer, 464
for low latency, 454
Effective cleaning in place systems, 616
Effective inventory management, 690
Efficient chain model, 539
Efficient data processing, 326
Efficient design processes, 252–254
Efficient resource utilization, 427
Efficient supply chain, 785–786
Electric tongues (Ets) and noses (Ens), 750
Electroencephalography (EEG), 275
Electronic noses (E-noses), 598
Electronic sensing devices, 560
Electronic sensing technologies, 271
Emerging sensor technologies, 466–467
Emerging technologies, 356–357, 384–385, 531–532
and innovations, 473–475
in smart packaging, 411–412
Emerging trends in virtual product testing, 213
Empirical studies, 185–186
Empirical *versus* ML-based studies, 191–192
Employee training and awareness, 128–129
Encoding labels, 346
Energy and resource management, 575–576
Energy consumption, 584
optimization, 575–576
Energy dispersive X-ray spectroscopy (EDXRF), 486
Energy efficiency considerations, 123
Energy-efficient lighting, 128
Energy-efficient technologies, 128–129
Energy-efficient temperature control, 126
Energy management software, 128
Energy optimization, 256
Enhanced consumer experience, 237
Enhanced data acquisition technologies, 273
Enhanced decision-making, 559–560
Enhanced flexibility and scalability in testing scenarios, 209
Enhanced network capacity and failure resistance, 542–543
Enhanced nutrient retention, 233
Enhanced objectivity, 268
Enhanced privacy, 427
Enhanced sensory analysis via integration, 426
Enhanced visualization techniques, 339
Enhancement, 348
of customer experience, 800
E-nose sensors, 437
E-nose technology, 560–561
Ensemble methods, 695
Ensure consistent lighting, 350
Ensure data security, 454
Ensure food quality and safety, 412–413
Ensuring fair and nonbiased assessment, 355
Entropy and complexity measures, 450
Environmental and operational factors, 452
Environmental and sustainability considerations, 355–356
Environmental factors, 353
Environmental impact, 273
assessment using CI tools, 236
modeling, 224, 226
and safety, 207
and sustainability, 584
Environmental parameters, 448
Environmental science and sustainability, 275
Environmental sustainability, 800
Environmental waste, 719
Enzyme-responsive system, 413
Equipment cleaning and maintenance, 32
Equipment cost and maintenance, 353–354
Equipment lifespan improvement, 573
Escherichia coli, 589
E-sensing devices, 560–561
E-sensing technologies, 560–563
Ethereum's transition to proof-of-stake, 553
Ethical AI
and data privacy for food science, 775
frameworks and best practices in food science, 771–773
Ethical data restructuring, 59
Ethical transparency and accountability, 584
Ethiopian Commodity Exchange (ECX), 550–551
Ethiopia's digital transformation strategy, 551
Ethylene scrubbing and removal, 127–128
Ethylene sensitivity considerations, 125
E-tongues complement, 560–561
European hydroponic systems, 9
European Union (EU), 419, 593
Evolutionary algorithms (EAs), 221
Excitation–emission matrix (EEM), 491
Exclusive feature bundling (EFB), 65
Execution, 545
Expectation effects, 265
Experimental design, 271
Explainable artificial intelligence (XAI), 114, 274, 355, 367, 555, 603, 765
Exponential smoothing, 693–694
Extra-virgin olive oil (EVOO), 485–486
Extrusion, 310
cooking, 229
process, 232

F

Failure forecasting, 429
Fast chain model, 539
Faster decision-making, 620
Faster product development, 576
Faster time to market, 620
Fast-moving consumer goods (FMCG), 539, 748–749
Fault prediction and diagnostics, 124
Feature extraction (FE), 81–82, 87, 345–346, 433, 457, 463
and dimensionality reduction, 456
techniques, 346–347
Feature selection (FS), 81–82, 87, 267, 434, 460
and dimensionality reduction, 51–52
and engineering, 816
Federated learning (FL), 109, 432
for privacy-preserving, 432
Feedback loop, 463
Field of view (FOV), 343
Finite element analysis (FEA), 204
First-in-first-out (FIFO), 671, 688

Fixed order quantity (FOQ), 688
Fixed positioning, 350
Flattening, 345
Flavor and aroma analysis, 223, 226
Flavor and sensory profiling, 576–577
Flavor masking and enhancement, 229
Flavor perception, 263–265
  components of, 264
Flavor prediction models, 71–73, 230, 232
FlavorPrint, 270
Flavor profiling, 263, 266, 576
  and predictive modeling, 235
Flexibility and comprehensive data, 207
Flexible packaging, 577
Flexible storage capacities and scalability, 131
Floating point data, 344
Fluorescence images, 341
Fluorescence spectroscopy (FS), 491–492, 499
Focus on traceability and transparency, 339
Food adulteration, 75–76
  detection, 556–557
Food AI systems, 772
  responsibility in, 768–769
Food and Agricultural Organization (FAO), 219, 410, 599, 669
Food and bioprocessing
  industries, 348–350, 557f
  integrating emerging technologies in, 356–357
Food and bioprocess systems, 283–285
Food and Drug Administration (FDA), 174
Food and drug interaction, 189–190
Food and nutrition, 389
Food authentication and adulteration detection, 598–599
Food authenticity and fraud prevention, 549
Foodborne illnesses, 447, 589
Foodborne outbreaks, 753–754
Foodborne safety, 787
Food business, 749
Food by-products in circular economy, 732
Food categorization, 73–74
Food chain, 785–786
Food composition database (FDB), 320
Food composition table (FCT), 320
Food consumption trends, 69–71
Food-contact materials (FCMs), 419
Food contamination, 100
  by AI, 789
  risks, 594
Food distribution, 756
Food–drug interactions, 187t–188t
Food–drug reactions, 185
Food engineering, 69
Food flavor development and predicting consumer preferences, 32–33
Food industries, 26, 29, 72t, 246, 447, 547t, 611–612, 772, 781
Food ingredients, 753–754
Food manufacturers, 377
Food packaging, 411t, 415t, 617
  innovations, 819
Food processing, 702t
  challenges, 753–754
  companies, 575
  plants, 784–785
  supply networks, 715–716
  techniques, 323–324
  technologies through AI and ML, 622–623
Food product development, 817–818
Food production, 310–315, 524
  and processing, 637, 784–785
Food products, 476, 717t
  authentication and traceability of, 349
  recommender systems for, 787
Food quality, 100–101, 631, 701
  assessment, 562–563
  control, 425, 434, 447, 565–566
  control and inspection, 429, 431t
  dimensions of, 633f
  evaluation, 56t
  index algorithm, 546
  inspection, 428t
  management, 749–751
  monitoring, 449t, 545–546
  and safety, 74–76, 328, 634t, 767f
Food recognition assistance and nudging insights (FRANI), 152–153
Food-related AI models, 766–767
Food safety, 440, 469–471, 589–590
  and disease detection, 100–102
  management, 751
  and quality assurance, 102–106, 818–819
  and quality benefits, 654–656
  and traceability, 591–593
Food Safety Modernization Act (FSMA), 592
Foods and pharmacokinetic, 186–189
Foods and supplements, 181
Food science, 46, 226
  AI/ML models, 764–769
  and bioprocess, 4–5, 822–823
    development, 5–11, 813–817
    sectors, 23–24
  data science, and engineering, 258
  of dimensionality reduction, 92
  ethical considerations in, 764
  sector, 23–24
  and technology, 275
Food sector, 623
Food security, 798
Food security information network (FSIN), 687
Foods for specific health uses (FOSHU), 394–395
Food shelf life, 380t
Food Standards of Australia and New Zealand (FSANZ), 73–74
Food supply chain management (FSCM), 631, 636t, 718–719
Food supply chains (FSCs), 537–542, 538f–539f, 627, 651–652, 716
Food supply systems and traceability, 283
Food systems, 639–641
Food tampering, 754
Food technology, 369t
Food traceability system, 540–542, 546
Food waste (FW), 69, 246, 311, 656, 669–670, 673t, 715, 731, 821
  analytics, 675–679, 676t–678t
  identification and quantification, 670–672
  management, 751–752
  reduction and circular bioeconomy, 548–549
  valorization, 733f
Forecasting models, development of, 690–693
Formulation, 223–224, 226
  optimization using AI and ML, 251–254
Fourier transform infrared spectroscopy (FTIR), 702
Fraud prevention through immutable records, 601
Frequency band energy, 452
Frequency-domain features, 452, 457, 460
Freshcold solutions, 132
Freshness index, 452
Freshness indicators, 414–416
Frosttech logistics, 132
Fruits and vegetables, 101
Full-scale implementation, 209
Fully connected (FC) layer, 98, 432
Functional foods, 394–395
  health benefits of, 395
Functional ingredient development, 403
Functional magnetic resonance imaging (fMRI), 275
Functional polysaccharide (FP), 708
Functional properties, 227
Fusarium culmorum, 484
Fusarium graminearum, 484
Fusarium verticillioides, 484
Fuzzy clustering, 90
Fuzzy inference system (FIS), 292
Fuzzy intelligence, 814–815
Fuzzy logic (FL), 71, 221, 291–293
  in bioprocessing systems, 293–294
  techniques, 26, 370–371
Fuzzy logic-enabled food, 294–297
Fuzzy logic model (FLM), 707
Fuzzy particle swarm optimization (FPSO), 367
Fuzzy system in bioprocess systems, 295t–296t

G

GAN-structured automated labeled data augmentation method (GALDAM), 105
Gas chromatography with mass spectrometry (GC-MS), 109–110, 271
Gas composition, 635
  management, 123, 127–128
Gas concentration dynamics, 125
Gas indicators, 414
Gas sensors, 460
Gather data, 691
Gaussian Mixture Models (GMM), 3–4

Gaussian process regression (GPR), 737, 740
Gene expression programming (GEP), 740
General Data Protection Regulation (GDPR), 59, 221–222, 272, 770
Generate alerts, 461
Generative adversarial networks (GANs), 58–59, 435–436, 585
Generative AI, in supply chain management, 442
Genetic algorithm (GA), 71, 221, 223–224, 303–304, 306, 696
Genetic data analysis, 396
Genetic factors, 393
Genetic Programming (GP), 306
Genomics, 396
Global food industry, 359
Global food supply chain, 589
Global food system, 627, 732
Global food waste, 669
Global market, 615
Global network against food crises (GNAFC), 687
Global Positioning System (GPS), 639
Global report on food crisis (GRFC), 687
Global standards, 432
Global Summit on Regulatory Science (GSRS21), 769
Global sustainability leadership, 239
Global warming, 629
Glucose, 389–390
Glycemic index (GI), 173–174
Gold nanoparticles (AuNPs), 704
Good catch foods, 231
Government and institutional studies, 47
Gradient-based One-Side Sampling (GOSS), 65
Gradient Boosting Decision Trees (GBDT), 65
Gradient boosting machines, 65
Grading and sorting
  of agricultural produce, 349
  fruits and vegetables, 598
Grasshopper optimization algorithm, 308–309
Grayscale conversion, 345
Grayscale data, 344
Grayscale images, 336, 340, 345
Gray wolf optimizer, 307
GridSearchCV model, 190
Gut microbiota, 394, 396–397

H

Halal food supply chain's (HFSC), 639
"Halo effect,", 265
Handling supply chain perils, 721–722
Hardware limitations, 353–354
Hazard analysis critical control points (HACCP), 283–284, 414, 525, 549, 753
Healthcare blood management case study, 563–564
Health conditions
  based on food–drug interactions, 192–193
  and intervention, 153–154
Health monitoring integration, 237
Heat exchangers, 364
Heat recovery systems, 128
Heat transfer coefficient (HTC), 364
Hierarchical and adaptive clustering, 93
Hierarchical cluster analysis (HCA), 3
Hierarchical clustering, 88f, 89
High data costs and time investment, 438
High-level processing, 618
High-performance computing (HPC), 679
High-Performance Liquid Chromatography (HPLC), 271
High-pressure processing (HPP), 310
High-profile food safety incidents and their impacts, 593
High-quality images, optimize camera settings for, 350
High sensitivity and specificity, 437
High-throughput screening (HTS), 253–254
Histogram of oriented gradients, 345
Historical data analysis, 122
Historical sales data, 692
Holistic health insights, 397
Holt–Winters model, 693–695
Human–computer interaction (HCI), 193
Human-in-the-loop, 463
Human nutrition, 324
Human oversight, 804
Humidity, 448
  optimization in controlled atmosphere, 126–127
  sensors, 460
Humidity-resistant packaging strategies, 126
Humidity-triggered responsive system, 412–413
HW additive (HWA) and multiplicative (HWM), 695
HyBDL model, 104–105
Hybrid Blockchain, 544
Hybrid neural network (HNN), 111
Hydrothermal carbonization process, 738
Hygienic food production, 429–430
Hyperledger fabric platform, 436
Hyperspectral imaging (HSI), 2, 6, 63, 114, 340, 356–357, 437, 562, 594
  spectroscopy, 502–503
Hyperspectral microscopic imaging (HMI), 597–598
Hypertonic multilayer perceptron (HC-MLP), 6

I

IBM and food industry, 268–269
Image acquisition, 574
Image analysis, 618
  complexity of, 354
Image collection, 346
Image containers in software libraries, 345
Image depth information, 343
Image description, 618
Image formats, 336
Image interpretation, 618
Image noise level, 343
Image processing, 337, 617–618
Image pyramids, 344
Image quality with sample data sets, 353
Image recognition, 618
Image representation, 618
  in pixels, 345
Images and image formats, 340–341
Image segmentation, 618
Image to machine language conversion, 345–346
Immersive virtual reality (VR), 329
Immutability, 552
Immutable nature or immutability, 542
Implementation methodology, 559
Implementation strategies, 209–210
Implemented systems, 529–530
Impossible foods, 233–234
Improved food safety with predictive analytics, 586
Improved image quality, 335
Improved safety, 573
Imputing missing values, 51
Inclusive data collection, 274
Inconsistent illumination, 353
Increased accuracy, 574
Increased efficiency, 268
Increased innovation and experimentation opportunities, 209
Increased intersubjectivity, 93
Indexed image, 336
Individual differences, 265
Industry 4.0, 311–312, 532–533
Information and communications technologies (ICTs), 540, 628
Information technology (IT), 631
Infrared spectroscopy, 488–489, 501
Ingredient analysis, 222–223
Ingredient discovery processes, 245–246
Ingredient performance, 247–248
Ingredient profiling, 91–92
Ingredient properties using computational intelligence (CI), 226–227
Ingredient transformation process, 230–231, 239
Ingredient weighing and measuring, 577
Innate sensor integration, 427
Innovations, 530–533
  in cold chain logistics, 131
  and emerging technologies in AI for food, 585–586
  in food industry, 244–245
  and new product development, 620
  in packaging for extended shelf life, 130
Innovative approaches to data collection, 55–58
Innovative dairy substitutes, 234–235
Innovative data augmentation strategies, 58–59
Innovative meat substitutes, 231–234
Inspection tasks, complexity of, 526
Institute of Food Technologists (IFT), 395
Integrated communication for predictive systems, 429
Integrated farming system (IFS), 310–311

Integrated monitoring systems, 427
Integrated pest management (IPM), 782–783
Integration
  of advanced sensing technologies, 273
  with asset management systems, 124
  with bioprocess simulations and systems, 817
  with CA gas control, 126
  with CA systems, 124–125
  of chemical, biological, and sensory data, 250
  of CI in novel technologies, 237–238
  with energy-efficient systems, 129
  with existing processes, 14–15
  with existing systems, 114, 354, 399
  with global health initiatives, 329
  with human needs, 305
  with IoT, 339
  of machine learning, 338
  of ML models with XAI, 558
  of multimodal data, 272, 397
  of robotic systems in food production, 528–529
  of sensory data, 251
  of sensory modalities, 264
  with temperature and gas control, 127
  with temperature and humidity control, 127
Integrity sensors, 414
Intelligent route planning, 132
Interactive sensory platforms, 274
Interface design and reporting tools, 429
Intermediate-level processing, 618
International diabetes federation, 145
International Organization for Standardization (ISO), 283
International standards organization, 752
Internet of Bio-Nano Things (IoBNT) technology, 109
Internet of Medical Things (IoMT), 564
Internet of Things (IoT), 10, 64, 113–114, 251, 281, 294–297, 379–380, 417, 427, 447, 475, 549, 558, 590, 602, 627, 670, 740–741, 741f, 752
  in bioprocess development, 287t–288t
  in bioprocess industries, 285–286
  collecting and monitoring system, 427
  and edge technology, 516
  in food quality control and safety, 634–637
  in food science and bioprocess development, 285
  integration, 251, 463, 465
  in livestock health management, 629–631
  in quality control, 290–291
  in smart and precision agriculture, 628–629, 630t
  and smart devices for real-time monitoring, 475
  in supply chain management, 631–634
  terminals for collecting data, 55
InterPlanetary File System (IPFS), 284, 546
Interpretability, 92, 456
  and explainability, 455
Interpretation, 347
  and decision-making, 574
  and visualization, 268
Interquartile range (IQR), 50–51, 457
Intrinsic quality parameters of food, 448
Inventory management, 575, 722–723, 723t
  in retail industry, 690
  systems, 133
Inventory optimization, 428
IoT-based optimization, Siemens mindsphere for, 577–578
IoT-enabled livestock management systems, 632t–633t
Irrigation management, 289–290
Isothiocyanates (ITCs), 185–186
Iterative techniques, 89
Iterative testing, 211

J

Just-in-time (JIT), 688

K

Key data elements (KDEs), 540
Key preprocessing techniques, 50–52
K-means clustering, 3–4, 86, 516
K-nearest neighbors (KNN), 51, 75–76, 88, 434, 461, 508, 675
Knowledge-based expert system in food industry, 369–370

L

Labeling, 346
  and annotation, 454
  and sealing, 577
Labor displacement and workforce adaptation, 584
Lack of standardization, 266
Last-in, first-out (LIFO), 688
Layer 2 scaling, 553
Learning techniques in food technology, 367–368
Leave-One-Out Cross-Validation (LOO-CV), 68
Legal frameworks governing data privacy in food science, 770–771
Lens cleaning, 353
Lessons learned and best practices, 55
Lifecycle analysis, 275
Life cycle assessment (LCA), 226, 254, 637, 791
Lifestyle and behavioral factors, 394
Light Detection and Ranging (LiDAR), 528
Light gradient boosting machine (LGBM), 66–68
Lighting conditions, 343, 353
Light-responsive systems, 413
Linear discriminant analysis (LDA), 267, 481, 508
Linear Kernel, 432
Linear models, 690
Linear programming (LP) methods, 8
Linear random forest (LRF), 64
Lithium polymer (LiPo), 620–621
Livestock management, 289
Logistic regression (LR) analysis, 65–66
Logistics, 575
Long short-term memory (LSTM), 696, 710
Low cost of production, 425
Lower costs, 573
Low latency, 427
Low-level processing, 618
Low-quality data, 92

M

Machine learning (ML), 2–4, 25–29, 82–83, 243–244, 250, 253, 339, 356–357, 528, 572–577, 590, 718–721, 798–802
  adoption across key industries, 438–440
  and AI in personalized nutrition, 798–800
  algorithms, 82–83, 122–123, 273–274, 471–472, 785–786
    applied in spectroscopy technique, 503–508
    in food processing, 578t
    in nutrition, 399–400
    in PdM systems, 429
  applications, 121–124, 256–258, 356, 785t, 791, 817–819
    across diverse industries, 438
    in food processing, 615
    in food safety, 596t–597t
    in food science, 29–34
    in food sector, 814t
  approaches, 84–85, 564–565
  based functional profiling, 227
  in chain optimization, 798
  concepts, 243–244
  deep learning, and quick learning, 368
  feature, 452
  flow enchanting in food sector, 815f
  in food industry, 11–17, 615–620
  in food integrity, 813f
  in food packaging, 617–618
  in food quality control, 440–442, 565t
  in food quality monitoring, 463–465
  in food safety, 470–471, 476, 593–599, 615–616, 798
  for food safety and quality assurance, 821
  in food science, 1–5, 37–38, 53–54, 243–245, 258–259, 379–380, 763–764
  in food supply chain, 721–725
  for food traceability, 599–602
  for functional and nutritional profiling, 227–228
  in identifying functional properties, 246–247
  improve bioprocessing, 820–821
  in ingredient discovery, 245–247
  innovations driving food quality, 566t
  integration, 764, 765f, 771t
  integration in food industry, 799f, 802–804, 803t, 804f
  limitations of, 36–37
  to mitigate, 453–455

models, 27t, 190–191, 399–400, 428–429, 435–436
effectiveness, 190
fairness and bias in, 764–766
to predict supply chain bottlenecks, 601–602
in new product development, 616
in nutrition, 399
for nutritional profiling, 227–228
for predictive analytics, 465
in process optimization, 571
in product innovation and development, 819–820
research model development, 193
revolutionizing food quality control, 425–427
in robotic system, 622f
for sensory analysis, 273–274
in sensory analysis, 266–268
in shelf-life prediction, 381–383, 382t
in sorting fresh produce, 615
in spectroscopy, 500–501
studies and empirical studies, 183–186
for supply chain, 619–620, 719–721, 725–726
techniques, 266, 371, 472–473, 473t
for detecting biological contaminants, 471–472
tools, 577–579, 580t–582t
in food industry, 579
vectorization for, 346
for waste valorization, 733–741
Machine learning–assisted SERS, 513–516
Machine learning–based model for sensory quality, 511–513
Machine vision systems (MVSs), 599, 615, 617, 617f, 784
Magnetic resonance imaging, 503
Maintain camera stability, 350
Maintenance approaches, comparison of, 429
Maintenance scheduling, 573
Manual feature extraction, 345
Market growth, 410–411
Marketing and consumer behavior, 275
Market sensitivity, 539
Mass spectrometry imaging (MSI), 3–4, 502
Material handling systems, 133
Mathematical tools, 347
MATLAB matrix, 345
Matrix-assisted laser desorption ionization time-of-flight (MALDI-TOF), 502
Mean absolute error (MAE), 104, 693
Mean Average Percentage Error (MAPE), 693
Mean square error (MSE), 692
Meat or seafood, contaminants in, 598
Meat product spoiling, 414
Meat substitutes, 233–234
Medical imaging devices, 336
Medical science research, 193
Medium-term effects, 623
Message Queuing Telemetry Transport (MQTT), 464
Metabolic profiles, 394
Metabolomics, 396
Microbial contamination indicators, 449
Microbial detection, 500
Microbiome analysis, 396
Microfluidics in food manufacturing, 367
Micromechanical properties (MMPs), 71
Micronutrients, 389–390
Microsoft Azure machine learning, 579
Milk, 235
Miniaturization, 273
Minimizes human errors, 620
Min-max scaling, 457
Missing value imputation, 460
Mitigate food waste problem, 688–689
Mixing and homogenization, 364–365
Miyoko's creamery, 231, 235
ML-assisted SERS, 515t
ML-based bio-sensors for food safety, 509
ML-based sensors for real-time monitoring, 598
ML-equipped spectroscopy technique, 505t–506t
Model-based clustering (MCA), 3, 90, 91f
Model calibration, 306
Model deployment and management tools, 459
Model development, 816–817
Model evaluation, 691
Model generalization and validation, 475–476
Modeling ingredient-attribute relationships, 254–255
Model interpretability
and reliability, 257–258
and transparency, 114
Model-planning process, 64
Model prediction, 573
Model predictive control (MPC) system, 29
Model retraining, 463
Model training, 463, 691
and validation, 267–268
Model updating and retraining, 454–455
Modern systems, 628
Modified atmosphere packaging (MAP), 414
Molecular imprinting technology (MIT), 207
Molecularly imprinted polymers (MIPs), 207
Molecular structure analysis, 227
Moth flame optimization, 307–308
Multi-attribute decision making (MADM), 371
Multibody dynamics (MBD), 205
Multidisciplinary techniques, 350
Multi-layer perceptron (MLP), 108–109, 437, 694–695
Multimodal data fusion, 273
Multimodal data integration, 93
Multimodal transportation integration, 130–131
Multinational corporations (MNCs), 539
Multiparameter analysis, 122
Multiple food combinations, 191
Multiple health conditions or underlying conditions, 191
Multiple linear regression (MLR), 321–323
Multiple nonlinear regression (MNLR), 71
Multiresponsive systems, 413
Multiscale modeling in food science, 328
Multisensor integration, 122
Multisensory systems, 750–751
Multispectral and hyperspectral imaging, 339
Multispectral imaging (MSI) systems, 340, 556–558
Multivariate analysis, 250
Multivariate data analysis, 493
Multivariate sensor fusion, 450
Mycobacterium tuberculosis, 597
Mycotoxigenic fungi, 439t–440t
Mycotoxins, 437
contamination, 605
detection, 473
in foods, 439t–440t

N

Nanobiosensors, 473–474
Nanofluid dynamics involve food productions, 367
Nanotechnology, 473–474
Natural language processing (NLP), 24, 275, 329, 719, 781–782
Natural taste, 71–73
Near-infrared (NIR) spectroscopy, 13, 109–110, 502, 708
Nestlé's AI-driven product development, 269
Neural networks (NNs), 6, 65, 97, 249, 618, 694–695, 719–721
Neuroscience and sensory psychology, 275
New food product development, 32
New visual perception systems, 527
Next-generation sequencing (NGS), 615–616, 751
NIR spectroscopy (NIRS), 488
Node diagram showing, 162
Noise, 457
and artifacts, 353
filtering, 452
reduction, 53–54, 347, 454, 457, 460
Noncommunicable diseases (NCDs), 327–328, 391–392, 631
Nondairy milk, 235
Nondestructive testing, 339
Nonnegative matrix factorization (NMF), 8
Normalization and scaling, 345
Nuclear magnetic resonance (NMR) spectroscopy, 67f, 489–490, 502
NumPy Array, 345
Nutraceutical food, 706–707
Nutrigenomics for functional foods, 400
Nutrition, 232
Nutritional analysis, 92, 500
and fortification studies, 349
Nutritional and health benefits, 252
Nutritional challenges, 234
Nutritional genomics research, 321

Nutritional knowledge and education, 394
Nutritionally mediated chronic diseases, 82
Nutritional modeling, 319–321, 327t
Nutritional quality, 425
Nutrition research, 325t

O

Oceanic taste, 231
Off-chain resources, 552
Offer workforce transition programs, 355
Office of Naval Research (ONR), 693
OGS optical guidance system, 755
"One-size-fits-all,", 390, 402
OpenCV Mat Object, 345
Operational efficiency, 572, 574
Operational policy optimization, 306
Optical sensors, 460
Optimization, 224–226, 465
  algorithms, 230
  of plant-based ingredients, 228
Optimized formulations in food science, 251–252
Optimizing flavor
  development, 275
  in plant-based proteins, 229
Ordinary least squares (OLS), 481–482
Organize and label image data, 353
Orthogonal signal correction (OSC), 489–490
OSC filter was combined with PCA (OSC-PCA), 490
Outlier detection
  and removal, 457
  and treatment, 50–51
Out-of-bag (OOB), 433
Overall migration limit (OML), 420

P

Packaging, 291
  integrity monitoring, 464
  and storage conditions, 349–350
Panax notoginseng, 489
Panelist training, 265
Paper chromogenic arrays, 6
Paper identification and search strategy, 146
Partial differential equations (PDEs), 360–361
Partial least squares (PLS), 481–482, 492, 508
Partial least squares regression (PLSR), 102, 250, 321–323, 490, 597
Partitioning-based clustering, 89
Passive devices capture, 528
Pasteurization, 363–364
Pattern recognition, 452
Peak detection, 450
Peer-to-peer (P2P), 282, 542
Peer-to-peer smart food delivery platform, 546
Performance metrics and validation results, 557–558
Perishability and waste, 716
Perishable commodities, 695–696
Personalization, 228, 239, 268, 274
  of consumer experience, 576–577
Personalized health goals, 395–396
Personalized nutrition (PN), 325–326, 390–396, 798
  and diet planning applications, 787
  historical perspectives on, 391–392
  and made-to-order products, 586
  at scale, 820
  solutions, 5
Personalized probiotics, 397
Personalizing customer experience, 787–790
Persuasive strategies, 154–156, 165
Pharmacokinetic impact of food-drug interaction, 186–191
Pharmacokinetic impacts, 189–190
pH-responsive system, 412
Physical properties, 267
Physical waste, 671
Physiological Factors, 265
Pilot testing, 209
Pixels, 335–336
Pixel value extraction, 345
Plant-based alternatives, 219, 239
Plant-based dairy alternatives, 230
Plant-based diet with AI driven personalization, 237
Plant-based food materials (PBFMs), 71
Plant-based meat alternative, 230
Plant-based production systems, 236
Plant-based proteins for texture and taste, 228–230
Plant-based yogurts, 235
Plant proteins, 229
PNG, 336
Polarized light images, 341
Policymakers and food industry stakeholders, 775–776
Polygenic Risk Scores (PRS), 396
Polymerase chain reaction (PCR), 381, 469, 516
Polynomial Kernel, 433
Pooling layer, 430–432
Population, intervention, comparator group, outcome, and study design (PICOS), 176–177
Portability, 273
Postharvest loss mitigation and quality management, 34
Postprocessing, 361
Potential applications beyond product development, 213–214
Poultry, 595
Power spectrum, 452
Practical applications in food science, 773–775
Practical solutions for data challenges, 58–59
Precision agriculture, 782
  and crop management, 827
  and sustainable farming practices, 790
Precision gas monitoring sensors, 127
Precision medicine initiatives, 397
Precision nutrition (PN), 82
Predetermined Change Control Plans (PCCPs), 438–440
Predict food quality, 461
Predictive AI, 455
Predictive analytics, 450, 572–574, 590, 594–597
  for pest control and disease, 782–783
  for shelf-life estimation and waste minimization, 426
Predictive capabilities, 465
Predictive demand forecasting, 790
Predictive flavor modeling, 232
Predictive maintenance (PdM), 132, 428, 571–573
  for energy systems, 128
  and IoT-Enhanced monitoring, 585
  for storage equipment, 124
Predictive microbiology, 696
Predictive modeling, 275, 396, 690–696
  for quality and spoilage, 456
  and simulation, 253
Predictive quality control, 573–574, 574t
  with XAI, 558–560
Predictive quality monitoring, 122–123
  for controlled atmosphere storage, 124–125
Predictive temperature adjustments, 125
Predictive traceability, 601–602
Preexisting quality management systems, 438
Preferred Reporting Items for Systematic Review and Meta-analyses (PRISMA), 176
Prescriptive maintenance strategies, 124
Pressure sensors, 460
Primary packaging, 577
Principal component analysis (PCA), 3, 51–52, 102, 250, 267, 450, 471–472, 479, 481, 508, 561
Privacy compliance, 455
Privacy-preserving techniques in food AI, 770
Privacy risks and challenges, 769–770
Private blockchain, 543–544
Process alignment, 539
Process designing, 306
Process flow of supervised machine learning, 66–68
Process modeling and simulation, 236
Process optimization, 6–7, 224, 226
Product development, 7–8, 239
Product development cycle time, 208–209
Product information, 692
Product optimization, 267
Product quality and consistency, 251
Product sorting and packaging, 31–32
Programmable logic controllers (PLCs), 459
Promote sustainable practices, 356
Promotional activities, 692
Proof-of-concept (POC), 436
Proof of Stake (PoS), 653
Proof of Work (PoW), 653
Protein denaturation and aggregation, 229

Protein hydrolysis, 229
Protein structure role in texture optimization, 229
Pseudomonas aeruginosa, 6
Psychological factors, 265
PsycInfo database, 146
Public blockchain, 543
Public policies and ethical guidelines, 680
Python libraries, 346

Q

QR codes, 419
Quadtree, 344
Quality analysis, 290–291
Quality Analysis and Critical Control Point (QACCP), 414
Quality and accuracy concerns in simulation results, 211
Quality and safety standards, 583–584
Quality assurance
  and compliance, 131
  and inspection, 597–598
Quality by design (QbD), 4–5
Quality consistency, 464
Quality control (QC), 6f, 50–51, 91–92, 354, 436, 493, 573, 724
  by AI and ML systems, 800
  and assurance, 5–6
    in food processing, 348
    with machine vision, 784
  and automation, 226
  benefits, 432
  in dairy products, 53
  data, 815
  in ensuring food safety, compliance, and consumer satisfaction, 425
Quality evaluation of extra virgin olive oil, 53
Quality index (QI), 707
Quality Index Method (QIM), 513
Quality inspection, 435, 525–526, 530
  in food production, 524–525
Quality management (QM), 631
Quality monitoring systems, 122
Quantitative polymerase chain reaction (qPCR), 595
Quantum computing, 59
Quantum resilience, 553
Quick learning (QL), 367

R

Radial basis function (RBF), 696, 710
Radial basis function (RBF) Kernel, 433
Radio frequency identification (RFID), 411, 593
  tags, 417–419
Raman spectroscopy, 501–502, 560
Random forest (RF), 64, 102, 266, 461
  in food quality control, 433
Rapid Alert System for Food and Feed (RASFF), 768
Rapid food analysis, 766f
Rapid prototyping (RP), 205–207
Rapid time-to-market, 204
Raw format, 350
Raw materials, 553
Raw signal, 456
Reactive oxygen species (ROS), 413
Ready-to-eat food processing, 595
Real-time analysis, 465
Real-time analytics integration, 383
Real-time clustering, 93
Real-time dashboards, 465
Real-time data collection, 122, 251
Real-time data gathering by IoT, 427
Real-time data processing, 425–426
  and model deployment, 454–455
Real-time decision-making and automated control, 456
Real-time environmental monitoring and alerts, 129
Real-time feedback
  and decision-making, 450
  loop for gas adjustments, 127
Real-time food quality monitoring, 451t
Real-time food safety monitoring, 54–55
Real-time information systems, 719
Real-time inventory tracking, 790
Real-time inventory updates, 132
Real-time monitoring, 275
  and alerts, 127
  and automation, 339
  of bioprocessing and fermentation, 349
  of food quality, 448, 592–593
  of food quality using sensors, 453–455
  solutions, 466
Real-time prediction, 463
Real-time process control, 232–233
Real-time processing, 122, 456
Real-time quality assurance AI, 455
Real-time quality monitoring, 571
Real-time sensors, 467
  data, 450–453
  for food quality monitoring application, 460–463
  networks, 123
Real-time tracking of food products, 601
Real-world applications, 755–756
Real-World Data (RWD), 769
Real-world food production, 67t
Recipe optimization, 223, 226
Recommended dietary allowance (RDA), 389
Record temperature and humidity, 353
Recurrent neural networks (RNNs), 65, 384–385, 590
Recursive feature elimination (RFE), 51–52
Reduced costs, 574
Reduced environmental impact, 575
Reduced waste, 574
Reducing food waste and enhancing sustainability, 586
Reducing inefficiencies in food processing, 311–313
Reducing reliance on trial-and-error testing, 255
Refrigeration, 365
Regression models, 694
Regular calibration, 353
Regularized least squares (RLS), 8
Regulatory compliance, 398–399, 525
  and ethical concerns, 583–585
Regulatory engagement, 213
Regulatory frameworks, 476
Reinforcement learning (RL), 2, 371, 455, 719, 816
  for dynamic quality control, 432
Reliability, 257–258
Remote cropping monitoring, 289
Remote monitoring, 463
  and control, 465
  and telemetry, 124
Remote visioning, 428
Renewable energy integration, 128, 130
Representative sampling, 265
Research communities, 161
Research infrastructure (RI), 771
Research initiatives in academic institutions, 269–270
Research institutions, 130
Resolution limitations, 353
Resource optimization in production processes, 256
Respiration quotient (RQ), 418–419
Respiration rates and ethylene control, 127
Response surface methodology (RSM), 323–324, 734
Responsible AI practices, 274
Reynolds-averaged Navier– Stokes (RANS), 360–361
Reynolds Stress Model (RSM), 360–361
RGB (color) images, 340
Ripening identification system, 704
Ripening stages, responsive to, 126–127
Robotic inspection systems, 526–528
Robotic process automation (RPA), 585
Robotics, 523–524, 577, 754–755
  and automation, 275–276, 613
  for food industry, 33
  in food processing, 531f, 752–754
  in food production, 523–524
  in warehousing, 132
Robust data management, 559
"Robust model,", 103–104
Robust quality control, 447
Root Mean Square (RMS), 450
Root Mean Squared Log Error (RMSLE), 693
Root mean square error (RMSE), 104–105, 693
Round-the-clock working, 620
Route optimization, 723–724
  and logistics management, 786
Rule-based detection, 457
Run-length encoding, 344

S

Safety Impact Methodology (SIM), 207–208
Sample characteristics, 353
SAP Leonardo for supply chain, 579

Scalability, 92, 552
Scale and frequency bands, 452
Scanners, 336
Scenario-based impact predictions, 236
Scenario testing and optimization, 237
Screening process, efficiency improvement in, 437
Seafood, 595
Seamless integration with emerging technologies, 239
Seasonal trends, 692
Secondary ion mass spectrometry (SIMS), 502
Secondary packaging, 577
Segmentation, 347, 457
Selection and data extraction, 146–149
Selection criteria, and synthesis, 176–177
Semi-supervised learning, 782, 783f
Sensomics-based expert system (SEBES), 707
Sensor fusion, 450
  techniques, 458
  technology, 124
Sensors, 102
  accuracy, technical challenges in, 465–466
  calibration and drift, 450
  data for AI algorithms, 457–458
  drift and environmental, 456
  integration, 427
  and IoT devices, 46–47
  types of, 448
  and vision systems, 528
Sensor signals, 448–450
  components, 456–457
  preprocessing, 456–457
Sensor technologies
  for food quality monitoring, 447–450
  for shelf-life monitoring, 384t
Sensory analysis, 90–92
Sensory attribute prediction, 267
Sensory data, 270–271
  analysis, 250
Sensory descriptors, 267
Sensory evaluation and consumer testing, 254
Sensory perception systems, 4, 275
Sensory precision, 122
Sensory profiling, 576
Sentiment analysis, 275
Shape analysis, 347
Shelf life, 378–379, 724–725
  extension and safety, 252
  and freshness, 425
  monitoring, 500
  optimization, 132
  prediction, 255, 464
    methods, 378t
    and spoilage detection, 349
Shell and tube heat exchangers (STHEs), 364
Shortage of skilled personnel, 438
Short food supply chains, 538
Shutter speed, 350
Signal amplitude and frequency, 449
Signal characteristics, 450
Signal drift, 452
Signal entropy, 452
Signal normalization and scaling, 457
Simplified molecular-input line-entry system's (SMILES), 184–185
Simulate real-world conditions, 455
Singapore Food Agency (SFA), 550
Singular value decomposition (SVD), 3
Sitophilus oryzae, 704
Sliding window technique, 457
Small- and medium-sized enterprises (SMEs), 214, 674, 800–801
Smart agriculture, 290, 628
  application in, 286–290
Smart contracts, 282–283, 542
  creation of, 544–545
  development, 544–545
  management solutions, 553
Smart factories, 532–533, 631–633
Smart food packaging, 418f
Smart industrial robot systems, 756
Smart IoT devices and sensors, 602
Smart microbial strain design, 820–821
Smart packaging and inventory management, 791
Smart refrigeration systems, 128
Smart retail initiatives and customer interaction, 638–639
Smart retail technologies, 640t–641t
Smart sensing and traceability on food quality, 413–419
Smart sensors in modern food production, 313
Smart solutions and components of industry 4.0, 311–312
Smart warehouse
  and logistics management applications, 291
  operations, 132
Smoothing techniques, 457
Social and economic barriers, 13
Software and hardware requirements, 209
Software challenges, 354
Software compatibility, 350
Solid-phase micro-extraction gas chromatography/mass spectrometry (SPME-GC/MS), 73
Sorting, 577
  and grading, 464
Sparse matrix, 344
Spatial calibration, 350
Spatial distribution, 452
Specific migration limits (SMLs), 420
Specific valorization methods, 742
Spectral analysis
  for composition testing, 455
  methods, 599
Spectral characteristics, 343
Spectroscopic measurements, 493
Spectroscopic methods, 290–291
Spectroscopic techniques, 516–517
  in food quality analysis, 499–500
  using machine learning, 501–503
Spectroscopy, 499
  for food analysis, 500
  techniques, 504t
Sphingosine-1-phosphate (S1P), 190
Spoilage probability, 452
Stacking/racking systems, 133
Standardization, 354, 399
  and automation of image analysis protocols, 339
Standard Normal Variance (SNV), 74
State-of-the-art digital technologies, 38
State-of-the-art methods, 205
Statistical features, 450
Statistical techniques, 457
Steady growth, 220
Sterilization, 363–364
Stock keeping units (SKUs), 540–541
Storage and sharing, 337
Storage bins, 133–134
Strain selection and microbial modeling, 234
Strategic investment, 213
Strategic location planning, 131
Strategic partnerships, for enhanced solutions, 131
Stream data processing, 454
Subjectivity and variability, 265
Sum of squared errors (SSE), 86
Supervised learning (SL), 243–244, 346, 455, 461, 500–501, 503–508, 816
  in ingredient analysis, 247–249
Supervised machine learning, 63–66, 69–76
Supply chain
  characteristics, 718–719
  complexity, 716
  efficiency, 571
  IoT, 428
  optimization, 236, 546–548, 574–575
  transparency, 600–601, 620
  and waste reduction, 224, 226
Supply chain management (SCM), 9–10, 631, 798
Support vector machines (SVM), 6, 8, 25, 65, 102, 225–226, 266, 432–433, 437, 460, 508, 618, 718
  for support vector machines, 221
Support vector regression (SVR), 508, 737–740, 739f
Surface-enhanced Raman spectroscopy (SERS), 472–473, 513–514, 514f
Surface variability, 353
Surveys and consumer feedback, 47–48
Sustainability, 245
  assessment tools, 254
  and ethics, 305–306
  goals, 385–386
  initiatives, 130
  and resource efficiency in the future of food, 821
  and scalability, 235–237, 239
  and waste management, 819
  and waste reduction, 10–11
Sustainable development goals (SDGs), 329, 548–549, 663
Sustainable farming practices, 310–315

Sustainable flavor profiling, 275
Sustainable food production, 328
Sustainable sourcing and supply chain optimization, 790
Swarm Intelligence (SI), 221
"Symbolic AI,", 26
Synergistic product development, 238

T

Tailored consumer experiences, 274
Tailored nutrition plans, 393
Tailoring functional foods using AI, 400–402
Takagi-Sugeno Kang (TSK), 370–371
Taste, texture, and shelf life predictions, 254–255
Taste prediction, 254
Technical complexity, 579–583
Technological advancements, 394
Temperature, 448
  compensation, 452
  control algorithms, 132
  and humidity, 353
  sensors, 460
Temperature-triggered systems, 413
Temporal stability, 343
Tensor, 345
TensorFlow for predictive quality control, 578–579
Terahertz imaging spectroscopy, 503
Texture, 231–232, 448
  analysis, 347
  features, 460
  prediction, 254–255
  and structural analysis in food processing, 349
Texture and taste optimization, tools for, 229–230
Texture profile analysis (TPA), 254–255
Thermal analysis, 205
Thermal (infrared) images, 340
Thermal imaging (TI) equipment, 23–24
3D array, 344
3D imaging, 340–341, 353
  and reconstruction, 339
3D printer role in food industry, 366–367
3D printing of plant-based foods, 238
Threshold and alert generation, 450
TIFF, 336
Time and cost constraints, 265–266
Time and cost efficiency, 205–207
Time-consuming, 266
Time-domain features, 457, 460
Time-frequency domain features, 452
Time of flight (TOF) sensors, 528
Time series analysis, 694
Time-series trends and patterns, 449–450
Time-temperature indicators, 416–417
Top-down and side views, 350–353
Topics, theories, and models explored, 151–152
Total volatile basic nitrogen (TVBN), 412
Tournament selection (TALO), 309–310
Traceability system, 540
Traceability through blockchain, 440–442
Traceable resource unit (TRU), 540–541
  attributes of, 541–542
  mechanism for identifying, 540–541
Traditional Chinese medicine (TCM), 152
Traditional discriminant analysis (LDA), 102
Traditional machine learning methods, 85
Traditional quality control, 425–427, 426t
Traditional sensory evaluation, 265–266, 267t
Traditional testing methods, 211
Traditional traceability systems, 593
Training, 433
  and capacity building, 130
  complexity, 583
  and optimization, 817
  process of CNN, 432
  and skill development for engineers, 210
  and testing dataset, 66–68
Transfer learning, 106f, 273
Transformer models, 436
  in time series data, 435–436
Transparency, 455
  and accountability, 238
  and explainability, 767–768, 803
  in supply chains, 592
Trimethylamine (TMA), 414
Trust and consumer perception, 585
Trusted third-party (TTP), 542
Type 2 diabetes mellitus (T2DM), 189–190

U

Ultrasound imaging (USI), 503
Unconventional spectroscopy methods, 486–493
Uniformity of sample positioning, 343
Unilever's sensory analysis optimization, 269
Unique selling proposition (USP), 541–542
United Nations Environment Programme (UNEP), 709
Universal data protocols, 59
Universal Product Code (UPC), 419
Unsupervised learning, 86, 455, 461, 508, 816
  in food science, 93
Unveiling robotics inspection system dimensions, 530f
Upward traceability, 540
Use comprehensive datasets, 355
Use controlled lighting, 350
Use mounts and tripods, 350
User-centric design, 404
UV visible, 490

V

Validation
  and testing, 817
  and verification, 211–213
Vapnik's statistical learning model, 738–739
Variability in food products, 526
Variable Speed Drives (VSDs), 128
Variational autoencoders (VAEs), 93
Vector autoregression (VAR), 690
Vegan cheeses, 235
Vehicle routing problem, 723
Vehicle-to-pedestrian (V2P), 207–208
VeriTAG's blockchain-based food safety initiatives, 550
Versatile models, 696
Vibration and movement, 353
Virgin olive oil (VOO), 485–486
Virtual-environment (VVE), 207–208
Virtual food prototyping and sensory analysis, 820
Virtual function (VF) system, 50f
Virtual integration, 539
Virtual product testing, 203–205, 205f, 208–209, 211
  into product development, 209
  and simulation, 204
Virtual prototyping (VP), 211
  design, 211–213, 212t
Virtual reality (VR), 638, 680
  and augmented reality, 213
  for training and maintenance, 586
"Virtual Testbeds" (VTs), 205–207
Virtual testing, 204, 206t, 209
  implementing, 211
  methods, 204–205
  over physical testing, 205–207
  in product development, 207–208
  throughout product lifecycle, 210–211
Visual quality assessment, computer vision for, 455
Volatile organic compounds (VOCs), 437, 448, 560

W

Warehouse Management Systems (WMS), 786
Warehouses
  management, 291
  types of, 132–133
Waste reduction, 575
Water resource management, 576
Wavelet coefficients, 452
Wavelet energy distribution, 452
Wavelet transform, 457
Wearable wireless sensor systems (WWSSs), 629
Weather patterns, 692
Web crawling, 48
Western food markets, 765
Whale optimization algorithm, 306–307

Wi-Fi and bluetooth, 464
Working principle and algorithm, 83−84

X

XAI-Faster RCNN model, 10
X-ray-fluorescence-based methods, 486−488
X-ray images, 340

Y

Yogurts, 235
YOLOv7 target detection model, 105

Z

Zero-shot learning, 442
Zigbee, 464
Ziziphus jujuba, 483
Zonal temperature management, 125
Z-score normalization, 457
Zuogui Jiangtang Qinggan Fang (ZGJTQGF), 185