

## Index

- Active packaging, 3–4, 141–146, 267–280  
 antimicrobial films and coatings,  
 276–278  
 gas emitters and absorbers, 141–145  
 carbon dioxide emitters, 143, 143*t*,  
 276  
 carbon dioxide scavengers, 142,  
 142*t*–143*t*  
 ethylene absorbers, 275–276  
 ethylene emitters, 145, 145*t*  
 ethylene scavengers, 143, 144*t*–145*t*  
 oxygen scavengers, 272–274, 273*f*  
 gas flushing, 146  
 humidity absorbers, 274–275  
 intelligent packaging, 278–279  
 based on nano titanium dioxide,  
 256–260  
 gas and volatile indicators, 278–279  
 oxygen indicators with controlled  
 activation, 257–259  
 radio frequency identification (RFID),  
 279  
 removal of ethylene by photocatalytic  
 degradation, 259–260  
 time–temperature integrators, 278  
 legislation, 279–280  
 overview, 141, 267–272, 271*t*, 280  
 packaging requirements of fresh-cut  
 produce, 269–270  
 physiological changes of fresh-cut  
 produce during ripening and minimal  
 processing, 268–269  
 Aerobic respiration, 33–34  
*Aeromonas hydrophila*, 61, 65–66  
 Ageless, 145*t*  
 Ageless sachets, 142–143, 142*t*–143*t*  
 Alcohol fermentation, 35  
 Alkyl isothiocyanate, 113*f*  
 $\alpha$ -carotene, 111*f*  
 Anaerobic respiration, 33, 35  
 Anthocyanidins, 107, 107*f*, 109*t*, 122*f*  
 Anthocyanins, 115  
 Antimicrobial films and coatings,  
 276–278  
 Antimicrobial gas releasers, 277–278  
 Antimicrobial nanocomposites, 254–256  
 Antimold, 145*t*  
 Apples  
 ethylene production and sensitivity, 144*t*  
 increase in respiration rate with  
 temperature, 189*t*  
 measuring respiration rate, 14, 15*f*  
 microperforated films, 215  
 phytochemical changes in controlled and  
 modified atmosphere packaging,  
 115–116  
 recommended atmospheres for prolonging  
 shelf life, 186*t*  
 sensory and sensory-related quality of, 72,  
 73*f*, 74  
 Arrhenius equations, 16  
 Asparagus  
 increase in respiration rate with  
 temperature, 189*t*  
 microperforated films, 215  
 respiration rate, 187*t*  
 Avocados  
 ethylene production and sensitivity, 144*t*

- Bananas  
 Breatheway® membrane technology, 194, 194*f*–197*f*, 194*t*, 196  
 ethylene production and sensitivity, 144*t*  
 recommended atmospheres for prolonging shelf life, 186*t*  
 respiration rate, 187*t*
- Belgian endives  
 microperforated films, 216
- Bell peppers  
 microperforated films, 215
- Benzoic acid derivatives, 105, 106*f*
- Berard, 4
- β-carotene, 110, 111*f*
- β-cryptoxanthin, 111*f*
- Biaxially oriented polypropylene (BOPP), 213
- Biodegradable/compostable  
 nanocomposites, 249–254
- Biofresh, 144, 145*t*
- Boltzmann's constant, 22
- Breatheway® membrane technology, 185–208  
 challenges in packaging fresh produce, 185–188  
 different produce needs different beneficial atmospheres, 186–187, 186*t*  
 oxygen consumption increases with increasing temperature, 188, 189*t*  
 oxygen consumption requirements are variable, 187, 187*t*, 188*f*
- description, 188–199  
 adjustable CO<sub>2</sub> TR/OTR permeability ratio, 197, 198*f*–199*f*, 198*t*–199*t*, 199  
 providing very high permeability packages  
 side chain crystallizable (SCC) polymers, 190–191, 190*f*–192*f*  
 fresh produce packages for the military, 204–207  
 cantaloupe, 205, 206*f*  
 iceberg lettuce, 205–207, 206*f*–207*f*  
 overview, 185, 208  
 package ratio (PR), 199–200  
 packages that increase in permeability with temperature, 200  
 pressure equalization in MAP packages, 200  
 temperature switch, 200–201, 201*f*–205*f*, 203*t*–204*t*, 204
- Broccoli  
 increase in respiration rate with temperature, 189*t*  
 microperforated films, 216  
 phytochemical changes in controlled and modified atmosphere packaging, 125–131  
 recommended atmospheres for prolonging shelf life, 186*t*  
 respiration rate, 187*t*  
 sensory and sensory-related quality of, 80–81
- Browning discoloration, 42–52
- Brussels sprouts  
 increase in respiration rate with temperature, 189*t*
- Bush berries  
 recommended atmospheres for prolonging shelf life, 186*t*
- Cabbage  
 increase in respiration rate with temperature, 189*t*  
 recommended atmospheres for prolonging shelf life, 186*t*  
 sensory and sensory-related quality of, 81–82
- CA (controlled atmosphere), definition of, 3
- Campylobacter jejuni*, 61, 64
- Cantaloupes  
 Breatheway® membrane technology, 205, 206*f*  
 recommended atmospheres for prolonging shelf life, 186*t*  
 sensory and sensory-related quality of, 74–76, 75*f*
- Capsanthin, 111*f*
- Carbon dioxide emitters, 143, 143*t*, 276
- Carbon dioxide scavengers, 142, 142*t*–143*t*
- Carotenoids, 104*t*, 107, 109–110, 111*f*, 128, 133
- Carrots  
 ethylene production and sensitivity, 144*t*  
 phytochemical changes in controlled and modified atmosphere packaging, 131–132  
 sensory and sensory-related quality of, 82–84
- Catechins, 106, 108*f*, 115

- Cauliflower  
increase in respiration rate with temperature, 189*t*
- Celery  
increase in respiration rate with temperature, 189*t*  
recommended atmospheres for prolonging shelf life, 186*t*  
sensory and sensory-related quality of, 84–85
- Centers for Disease Control and Prevention (CDC), U.S., 229
- Cherries  
microperforated films, 216  
phytochemical changes in controlled and modified atmosphere packaging, 116  
recommended atmospheres for prolonging shelf life, 186*t*
- Cinnamic acid derivatives, 105, 106*f*
- Clostridium botulinum*, 61, 64–65
- Controlled atmosphere (CA), definition of, 3
- Corn on the cob, microperforated films for, 216
- Cradle-to-cradle concept, 286–288, 287*f*
- Cryptosporidium*, 229
- Cucumbers  
ethylene production and sensitivity, 144*t*
- CVP Systems  
Fresh Vac A-200 overhead bin machine, 228*f*  
Fresh Vac A-600 snorkel machine, 226*f*  
Fresh Vac Z-1200 in line bag machine, 227*f*
- Del-Valle expression, 23–26, 25*t*
- Edible coatings, 269, 277
- Edmund lumped-capacity model, 27
- Endives, microperforated films for, 216
- Enteric viruses, 63  
*Enterobacter agglomerans*, 59
- Epicatechin (EC), 108*f*
- Epicatechin gallate (ECG), 108*f*
- Epigallocatechin (EGC), 108*f*
- Epigallocatechin gallate (EGCG), 108*f*
- Equipment selection. *See* Machinery selection and specification
- Erwinia herbicola*, 59
- Escherichia coli*, 229
- Escherichia coli* O157:H7, 61
- Ethicap, 145, 145*t*
- Ethylene  
absorbers, 275–276  
emitters, 145, 145*t*  
removal by photocatalytic degradation, 259–260  
scavengers, 143, 144*t*–145*t*, 271*t*
- EverFresh bags, 145*t*
- EverFresh Green bags, 142, 142*t*
- EverFresh type G sachets, 142, 142*t*
- Fick's law, 21–23, 23*f*
- Flavan-3-ols, 107*f*
- Flavanones, 107*f*
- Flavenols, 115
- Flavobacterium*, 59
- Flavones, 107*f*
- Flavonoids, 105, 106*f*–108*f*, 133
- Flavonols, 107*f*, 128
- Food and Drug Administration (FDA), U.S., 229–231
- Foodborne pathogens, 60–67  
*Aeromonas hydrophila*, 65–66  
*Campylobacter jejuni*, 64  
*Clostridium botulinum*, 64–65  
enteric viruses, 63  
*Escherichia coli* O157:H7, 61  
hepatitis A (HAV), 63  
*Listeria monocytogenes*, 62–63  
microorganisms of immediate concern, 61–63  
miscellaneous pathogens of concern, 66–67  
Norwalk virus, 63  
pathogens capable of growing in under MAP and/or refrigeration temperature, 64–66  
*Salmonella* spp., 61–62  
*Shigella* spp., 66  
*Yersinia enterocolitica*, 66–67
- Freshlock, 142*t*
- Freshpax, 143, 143*t*
- Fruits  
microperforated films, 216  
phytochemical changes in with controlled and modified atmosphere packaging, 115–125  
apples, 115–116  
cherries, 116  
grapes, 116–117  
jackfruit, 125  
melons, 117–118

- Fruits (*Cont.*)
- peaches, 118–119
  - pears, 119, 120*t*
  - persimmons, 125
  - pomegranates, 123, 125
  - strawberries, 119, 121, 122*t*, 123, 124*t*
  - recommended modified atmosphere, 19*f*
  - sensory and sensory-related quality of, 72–80
    - apples, 72, 73*f*, 74
    - cantaloupes, 74–76, 75*f*
    - honeydew melons, 76–77
    - pineapples, 77–78
    - strawberries, 78–79
    - watermelons, 79–80
- Gas and volatile indicators, 271*t*, 278–279
- Gas emitters and absorbers, 141–145
  - carbon dioxide emitters, 143, 143*t*, 276
  - carbon dioxide scavengers, 142, 142*t*–143*t*
  - ethylene absorbers, 275–276
  - ethylene emitters, 145, 145*t*
  - ethylene scavengers, 143, 144*t*–145*t*
  - oxygen scavengers, 272–274, 273*f*
- Gas flushing, 146
- Glucobrassicin (3-indolymethyl), 114*f*
- Glucoraphanin (4-methyl-sulfinylbutyl), 114*f*, 128
- Glucosinolates, 104*t*, 110, 112–114, 112*f*–114*f*, 125, 126*f*, 128–129, 130*t*
- Grapes
  - microperforated films, 216
  - phytochemical changes in controlled and modified atmosphere packaging, 116–117
- Green beans, microperforated films for, 216
- Green onions, microperforated films for, 216
- Green peppers
  - increase in respiration rate with temperature, 189*t*
- Hazard analysis and critical control points (HACCP), 230
- Hepatitis A (HAV), 63
- Herbs, microperforated films for, 216
- HFFS (horizontal form fill seal) machines, 223–225, 224*f*
- High-density polyethylene (HDPE), 153–155, 154*f*
- Honeydew melons
  - recommended atmospheres for prolonging shelf life, 186*t*
  - sensory and sensory-related quality of, 76–77
- Hooper horizontal form fill seal machine, 224*f*
- Horizontal form fill seal (HFFS) machines, 223–225, 224*f*
- Humidity absorbers, 271*t*, 274–275
- Hydrodynamic flows, 26
- Hydroxycinnamic acid derivatives, 131
- Hygienic design of machinery, 229–236
  - angles, corners, and grooves, 235
  - connections, 235
  - drainage, 232*f*
  - hazard analysis and critical control points (HACCP), 230
  - joints, 234–235, 234*f*–235*f*
  - materials, 233–234
  - overview, 229, 236
  - pipng systems, 235, 235*f*–236*f*
  - primary pathogens, 229
  - shafts and bearings, 235
  - standards and inspections, 230–233
  - Ten Principles of Sanitary Design, 231–233
- Iceberg lettuce. *See* Lettuce
- Indole-3-carbinol, 113*f*, 114
- Indoles, 104*t*
- In line bagging machines, 226–227, 227*f*
- Isoflavonoids, 107*f*
- Isothiocyanates, 113–114
- Isothiocynates, 104*t*
- Jackfruit
  - phytochemical changes in controlled and modified atmosphere packaging, 125
- Jalapeno pepper rings
  - phytochemical changes in controlled and modified atmosphere packaging, 133–134
- Kaempferol, 108*f*
- Kidd, Franklin, 4
- Killefer, 4
- Kiwifruit
  - ethylene production and sensitivity, 144*t*
- Lactobacillus* spp., 59

- LDPE (low-density polyethylene), 150–152, 150*f*, 209, 213
- Leafy Green Marketing Agreement (LGMA), 230
- Leeks
  - increase in respiration rate with temperature, 189*t*
- Legislation
  - active packaging, 279–280
  - food safety, 229–230
- Lettuce
  - Breatheway® membrane technology, 205–207, 206*f*–207*f*
  - browning discoloration, 32*f*, 43*f*, 48*f*–49*f*, 51*f*
  - ethylene production and sensitivity, 144*t*
  - increase in respiration rate with temperature, 189*t*
  - microperforated films, 216
  - phytochemical changes in controlled and modified atmosphere packaging, 132–133
  - recommended atmospheres for prolonging shelf life, 186*t*
  - respiration rate, 187*t*
  - sensory and sensory-related quality of, 85–86
- LGMA (Leafy Green Marketing Agreement), 230
- Life cycle assessment/life cycle impact, 219, 288–289, 289*f*
- Linear low-density polyethylene (LLDPE), 152–153, 152*f*
- Listeria monocytogenes*, 62–63, 229, 231
- Low-density polyethylene (LDPE), 150–152, 150*f*, 209, 213
- Lutein, 111*f*
- Lycopene, 110, 111*f*
- MA (modified atmosphere), definition of, 3
- Machinery, hygienic design of. *See* Hygienic design of machinery
- Machinery selection and specification, 219–228
  - equipment selection, 222–227
    - horizontal form fill seal (HFFS) machines, 223–225, 224*f*
    - snorkel style machines, 225–227, 226*f*–228*f*
    - tray sealers, 225, 225*f*
    - vertical form fill seal machines (VFFS) and flow wrappers, 222–223, 223*f*–224*f*
  - general equipment considerations, 220–221
  - industry standards and codes, 221
  - overview, 219–220, 227–228
  - product and package, 221–222
  - suppliers, 222
- MAP (modified atmosphere packaging)
  - definition of, 11
  - introduction to, 3–6
- Materials for modified atmosphere packaging
  - Breatheway® membrane technology. *See* Breatheway® membrane technology
  - microperforated films. *See* Microperforated films
  - polymeric films. *See* Polymeric films
- Mathematical modeling of modified atmosphere packaging, 11–28
  - description, 17–21
  - overview, 11–13, 27–28
  - perforated MAP models, 21–27
    - Del-Valle expression, 23–26, 25*t*
    - Edmund lumped-capacity model, 27
    - Fick's law, 21–23, 23*f*
    - hydrodynamic flows, 26
    - Maxwell–Stefan equation, 26
  - respiratory rate (RR)
    - measurements and designs, 13–14, 15*f*
    - O<sub>2</sub> and CO<sub>2</sub> concentration and, 16–17
    - stability and, 11, 12*f*
    - temperature and, 14–16, 15*t*
- Maxwell–Stefan equation, 26
- Melons
  - phytochemical changes in controlled and modified atmosphere packaging, 117–118
- Michaelis–Menten model, 16
- Microbiology of fresh-cut produce in modified atmosphere packaging, 57–67
  - foodborne pathogens, 60–67
    - Aeromonas hydrophila*, 65–66
    - Campylobacter jejuni*, 64
    - Clostridium botulinum*, 64–65
    - enteric viruses, 63
    - Escherichia coli* O157:H7, 61
    - hepatitis A (HAV), 63

- Microbiology of fresh-cut (*Cont.*)  
*Listeria monocytogenes*, 62–63  
 microorganisms of immediate concern, 61–63  
 miscellaneous pathogens of concern, 66–67  
 Norwalk virus, 63  
 pathogens capable of growing in under MAP and/or refrigeration temperature, 64–66  
*Salmonella* spp., 61–62  
*Shigella* spp., 66  
*Yersinia enterocolitica*, 66–67  
 modified atmosphere packaging, 58  
 overview, 57, 67  
 spoilage microorganisms, 59–60
- Microperforated films, 209–217  
 applications, 215–217  
 limits of polymeric materials (continuous films) for integral packs with no microperforations, 213–214  
 overview, 209–211  
 pros and cons for microperforations, 211–212  
 technical demands for effective application of microperforated packaging, 214–215, 215*t*
- Military, fresh produce packages for  
 Breatheway<sup>®</sup> membrane technology, 204–207  
 cantaloupes, 205, 206*f*  
 iceberg lettuce, 205–207, 206*f*–207*f*
- Modified atmosphere (MA), definition of, 3
- Modified atmosphere packaging (MAP)  
 definition of, 11  
 introduction to, 3–6
- Mondini tray sealer, 225*f*
- Montmorillonite (MMT) nanocomposites, 243–249
- Mushrooms  
 increase in respiration rate with temperature, 189*t*  
 sensory and sensory-related quality of, 86–88
- Muskmelons, 74
- Myricetin, 108*f*
- Nanostructure packaging technologies, 241–262  
 acceptance and safety issues, 260–261  
 active/intelligent packaging based on nano titanium dioxide, 256–260  
 oxygen indicators with controlled activation, 257–259  
 removal of ethylene by photocatalytic degradation, 259–260  
 nanocomposite technologies, 242–256  
 antimicrobial nanocomposites, 254–256  
 biodegradable/compostable nanocomposites, 249–254  
 montmorillonite nanocomposites, 243–249  
 overview, 241–242, 242*f*, 261–262  
 National Sanitation Foundation (NSF), 233  
 Negamold sachets, 145, 145*t*  
 Neoxanthin, 111*f*  
 Net present value (NPV) analysis, 220  
 Netted melons, 74  
 Norwalk virus, 63  
 Novel packaging technologies  
 active packaging. *See* Active packaging  
 nanostructure packaging technologies. *See* Nanostructure packaging technologies  
 packaging sustainability. *See* Packaging sustainability
- NPV (net present value) analysis, 220
- NSF (National Sanitation Foundation), 233
- O<sub>2</sub> and CO<sub>2</sub> concentration and respiratory rate, 16–17
- Onions (yellow, bulb onion)  
 sensory and sensory-related quality of, 88–89
- Oranges  
 recommended atmospheres for prolonging shelf life, 186*t*
- Orega film, 144
- OxyFresh, 142, 142*t*–143*t*
- Oxygen  
 consumption, 187, 187*t*, 188, 188*f*, 189*t*  
 indicators with controlled activation, 257–259  
 scavengers, 141–142, 271*t*, 272–274, 273*f*
- Oytech L sachets. 145, 145*t*
- Oytec sachets. 145*t*
- Package ratio (PR), 199–200
- Packaging, active. *See* Active packaging

- Packaging materials for modified atmosphere packaging  
 Breathway® membrane technology. *See* Breathway® membrane technology  
 microperforated films. *See* Microperforated films  
 polymeric films. *See* Polymeric films
- Packaging sustainability, 285–292  
 achieving more sustainable packaging, 286–289  
 cradle-to-cradle concept, 286–288, 287*f*  
 life cycle assessment/life cycle impact, 288–289, 289*f*  
 alternative polymer materials, 289–292, 291*t*  
 polycaprolactone, 292  
 polyhydroxyalkanoate (PHA) and polyhydroxybutyrate (PHB), 291–292  
 polylactic acid (PLA), 291  
 overview, 285–286, 292
- Passive MAP, 3–4, 141
- Pathogens capable of growing in under MAP and/or refrigeration temperature, 64–66
- PE (polyethylene), 150–155
- Peaches  
 ethylene production and sensitivity, 144*t*  
 phytochemical changes in controlled and modified atmosphere packaging, 118–119
- Pears  
 phytochemical changes in controlled and modified atmosphere packaging, 119, 120*t*  
 recommended atmospheres for prolonging shelf life, 186*t*
- PEHD (polyethylene high density), 153–155, 154*f*
- Peppers  
 microperforated films, 215  
 sensory and sensory-related quality of, 89–90
- Perforated MAP models, 21–27  
 Del-Valle expression, 23–26, 25*t*  
 Edmund lumped-capacity model, 27  
 Fick's law, 21–23, 23*f*  
 hydrodynamic flows, 26  
 Maxwell–Stefan equation, 26
- Peroxidase (POD), 102
- Persimmons  
 phytochemical changes in controlled and modified atmosphere packaging, 125
- PET (polyethylene terephthalate), 165–167, 165*f*
- PHA (polyhydroxyalkanoate), 291–292
- PHA (polyhydroxyalkanoates)  
 nanocomposites, 251–252
- PHB (polyhydroxybutyrate), 291–292
- Phenolics, 102–103, 105–107, 106*f*–109*f*
- Phytates, 104*t*
- Phytochemical changes of fresh-cut produce in controlled and modified atmosphere packaging, 101–134  
 fruits, 115–125  
 apples, 115–116  
 cherries, 116  
 grapes, 116–117  
 jackfruit, 125  
 melons, 117–118  
 peaches, 118–119  
 pears, 119, 120*t*  
 persimmons, 125  
 pomegranates, 123, 125  
 strawberries, 119, 121, 122*t*, 123, 124*t*  
 overview, 101–103, 134  
 phytochemicals, 103–114  
 carotenoids, 107, 109–110, 111*f*  
 classification and health benefits, 104*t*  
 glucosinolates, 110, 112–114, 112*f*–114*f*  
 phenolics, 105–107, 106*f*–109*f*  
 vegetables, 125–134  
 broccoli, 125–131  
 carrots, 131–132  
 jalapeno pepper rings, 133–134  
 lettuce, 132–133  
 spinach, 133  
 Swiss chard, 133
- Phytoestrogens, 104*t*
- Phytosterols, 104*t*
- Pineapples, sensory and sensory-related quality of, 77–78
- PLA (polylactic acid), 251, 291
- Platenius, 4
- POD (peroxidase), 102
- Polycaprolactone, 292
- Polyesters, 165–167, 165*f*  
 polyethylene terephthalate (PET), 165–167, 165*f*

- Polyethylene (PE), 150–155
- Polyethylene high density (PEHD), 153–155, 154*f*
- Polyhydroxyalkanoate (PHA) and polyhydroxybutyrate (PHB), 291–292
- Polyhydroxyalkanoates (PHA) nanocomposites, 251–252
- Poly(lactic acid) (PLA), 251, 291
- Polymeric films, 149–183
  - abbreviations, 180–183
  - glossary, 169–179
  - overview, 149
  - oxygen and carbon dioxide permeability coefficients, 20*t*
  - polyesters, 165–167, 165*f*
    - polyethylene terephthalate (PET), 165–167, 165*f*
  - polyolefins or polyalkenes, 149–158
    - polyethylene (PE), 150–155
    - polypropylene or polypropene (PP), 155–158, 155*f*–156*f*
  - variables affecting permeability, 167–169
  - vinyl compound polymers or polymers with substituted olefins, 158–165
    - polystyrene (PS) or poly(1-phenylethane-1, 2-diyl), 163–165, 163*f*
    - polyvinyl chloride (PVC) or poly(chloroethanediy), 158–161, 158*f*–159*f*
    - polyvinylidene chloride (PVDC or PVdC) or poly(1,1-dichloroethylene), 161–162, 161*f*
- Polyolefins or polyalkenes, 149–158
  - polyethylene (PE), 150–155
  - polypropylene or polypropene (PP), 155–158, 155*f*–156*f*
- Polyphenol oxidase (PPO), 102
  - pathway, 42–48, 43*f*
- Polyphenols, 104*t*
- Polypropylene or polypropene (PP), 155–158, 155*f*–156*f*, 209
- Polystyrene (PS) or poly(1-phenylethane-1, 2-diyl), 163–165, 163*f*
- Polyvinyl chloride (PVC) or poly(chloroethanediy), 158–161, 158*f*–159*f*
- Polyvinylidene chloride (PVDC or PVdC) or poly(1,1-dichloroethylene), 161–162, 161*f*
- Pomegranates
  - phytochemical changes in controlled and modified atmosphere packaging, 123, 125
- Potatoes
  - increase in respiration rate with temperature, 189*t*
- PPO (polyphenol oxidase), 102
  - pathway, 42–48, 43*f*
- PP (polypropylene, polypropene), 155–158, 155*f*–156*f*, 209
- Pressure equalization in MAP packages, 200
- Profresh film, 145*t*
- Progoitrin (2-hydroxybut-3-enyl), 114*f*
- Protease inhibitors, 104*t*
- Protein nanocomposites, 253–254
- PR (package ratio), 199–200
- Pseudomonas* spp., 59
- PS (polystyrene), 163–165, 163*f*
- PVC (polyvinyl chloride), 158–161, 158*f*–159*f*
- PVDC (polyvinylidene chloride), 161–162, 161*f*
- Quercetin, 106, 108*f*, 132
- Radio frequency identification (RFID), 279
- Raspberries
  - increase in respiration rate with temperature, 189*t*
- Reactive nitrogen species (RNS), 101–102
- Reactive oxygen species (ROS), 101–102
- Respiration and browning discoloration of fresh-cut produce, 31–52
  - browning discoloration, 42–52
  - overview, 31–33, 32*f*, 52
  - respiration, 33–42
- Respiratory rate (RR), 11
  - measurements and designs, 13–14, 15*f*
  - O<sub>2</sub> and CO<sub>2</sub> concentration and, 16–17
  - stability and, 11, 12*f*
  - temperature and, 14–16, 15*t*
- RFID (radio frequency identification), 279
- RNS (reactive nitrogen species), 101–102
- ROS (reactive oxygen species), 101–102



- RR (respiratory rate). *See* Respiratory rate (RR)
- Rubixanthin, 111*f*
- Sachet technologies, 270
- Salmonella*, 61–62, 229
- Saponins, 104*t*
- SCC (side chain crystallizable) polymers, 190–191, 190*f*–192*f*
- Sensory and sensory-related quality of fresh-cut produce, 71–94
- fruits, 72–80
- apples, 72, 73*f*, 74
- cantaloupes, 74–76, 75*f*
- honeydew melons, 76–77
- pineapples, 77–78
- strawberries, 78–79
- watermelons, 79–80
- overview, 71–72, 94
- vegetables, 80–94
- broccoli, 80–81
- cabbage (green), 81–82
- carrots, 82–84
- celery, 84–85
- lettuce (iceberg), 85–86
- mushrooms (table), 86–88
- onions (yellow, bulb onion), 88–89
- peppers (bell), 89–90
- spinach (whole leaves, cut leaves), 91–92
- tomatoes, 92–94, 92*f*–93*f*
- Shigella* spp., 61, 66
- Side chain crystallizable (SCC) polymers, 190–191, 190*f*–192*f*
- S-methyl cysteine sulfoxide, 113*f*
- Snorkel style machines, 225–227, 226*f*–228*f*
- Spinach
- microperforated films, 216
- phytochemical changes in controlled and modified atmosphere packaging, 133
- sensory and sensory-related quality of, 91–92
- Spoilage microorganisms, 59–60
- Starch nanocomposite, 253
- Stayfresh longer bags, 144, 145*t*
- Strawberries
- increase in respiration rate with temperature, 189*t*
- microperforated films, 216
- phytochemical changes in controlled and modified atmosphere packaging, 119, 121, 122*t*, 123, 124*t*
- respiration rate, 187*t*
- sensory and sensory-related quality of, 78–79
- Sulfide-containing compounds, 104*t*
- Sulforaphane, 113*f*, 128
- Sustainability, packaging. *See* Packaging sustainability
- Sustainable Packaging Coalition, 286
- Swiss chard
- phytochemical changes in controlled and modified atmosphere packaging, 133
- Temperature and respiratory rate, 14–16, 15*t*
- Temperature switch, 200–201, 201*f*–205*f*, 203*t*–204*t*, 204
- Ten Principles of Sanitary Design, 231–233
- Terpenes, 104*t*
- Thiol-containing compounds, 104*t*
- Time–temperature integrators, 271*t*, 278
- Tomatoes
- ethylene production and sensitivity, 144*t*
- recommended atmospheres for prolonging shelf life, 186*t*
- sensory and sensory-related quality of, 92–94, 92*f*–93*f*
- Total cost of ownership (TCO), 219
- Tray sealers, 225, 225*f*
- Ulma flow wrapper, 224*f*
- Ulma vertical form fill seal machine, 223*f*
- Ultralow-density polyethylenes (ULDPEs), 213
- USDA (U.S. Department of Agriculture), 231
- Vegetable party trays, microperforated films for, 216
- Vegetables
- phytochemical changes in with controlled and modified atmosphere packaging, 125–134
- broccoli, 125–131
- carrots, 131–132
- jalapeno pepper rings, 133–134
- lettuce, 132–133
- spinach, 133
- Swiss chard, 133

Vegetables (*Cont.*)

recommended modified atmosphere, 20*f*  
sensory and sensory-related quality of,  
80–94

broccoli, 80–81

cabbage (green), 81–82

carrots, 82–84

celery, 84–85

lettuce (iceberg), 85–86

mushrooms (table), 86–88

onions (yellow, bulb onion), 88–89

peppers (bell), 89–90

spinach (whole leaves, cut leaves),  
91–92

tomatoes, 92–94, 92*f*–93*f*

Vertical form fill seal machines (VFFS) and  
flow wrappers, 222–223, 223*f*–224*f*

Vinyl compound polymers or polymers with  
substituted olefins, 158–165

polystyrene (PS) or

poly(1-phenylethane-1, 2-diyl),  
163–165, 163*f*

polyvinyl chloride (PVC) or

poly(chloroethanediyl), 158–161,  
158*f*–159*f*

polyvinylidene chloride (PVDC or PVdC)  
or poly(1,1-dichloroethylene),  
161–162, 161*f*

Violaxanthin, 111*f*

Watermelons

sensory and sensory-related quality of,  
79–80

*Yersinia enterocolitica*, 61, 66–67

Zeaxanthin, 111*f*