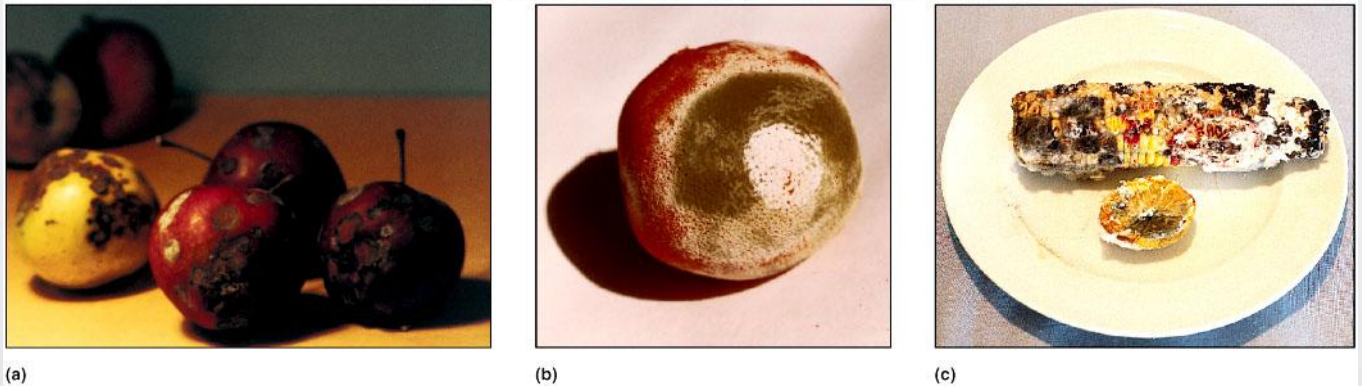
Food Microbiology

Factors Influencing Growth of Microorganisms in Food

- Understanding factors that influence microbial growth essential to maintaining food quality
  - In production and preservation
- Conditions naturally present in food termed intrinsic factors
- Environmental conditions are termed extrinsic factors
- Factors combine to determine which microbes grow in particular food and at what rate



(a) (b) (c)

Factors Influencing Growth of Microorganisms in Food

- Intrinsic factors
  - Multiplication of food greatly influenced by inherent characteristics of food
    - Microbes multiply most rapidly in moist, nutritionally rich, pH neutral foods
  - Intrinsic factors include
    - Water availability
    - pH
    - Nutrients
    - Biological barriers
    - Antimicrobial chemicals

Factors Influencing Growth of Microorganisms in Food

- Intrinsic factors
  - Water availability
    - Foods vary dramatically in terms of water availability
      - Fresh meats and milk have high water content
        - Supports microbial growth
      - Breads, nuts and dried foods have low water availability
        - Defined populations can grow in these specific environments
    - Water activity (a_w) used to designate amount of water available in foods
      - Pure water has a_w of 1.0
        - Most bacteria require a_w of above 0.90
        - Most fungi require a_w of above 0.80

Factors Influencing Growth of Microorganisms in Food

- Intrinsic factors
  - pH
    - Important in determining which organisms can survive and thrive on specific foods
    - Many microorganisms inhibited by acid conditions
      - Exception include lactic acid bacteria
    - Lactic acid bacteria used in fermentation process of food production
    - Also prime cause of spoilage of unpasteurized milk and other foods
    - Fungi able to survive at relatively low pH
      - Most acid foods spoil from fungal contamination as opposed to bacteria
    - pH can determine bacteria's ability to produce toxin
      - Toxin production of many organisms is inhibited by acid pH

Factors Influencing Growth of Microorganisms in Food

- Intrinsic factors
  - Nutrients
    - Nutrients present in food determine organisms that can grow in foods
  - Biological barriers
    - Rinds, shells and other outer coverings help protect foods from microbial invasion
      - Microorganisms will eventually breakdown coverings and cause spoilage
  - Antimicrobial chemicals
    - Some foods contain natural antimicrobial chemicals that inhibit growth of organisms responsible for spoilage

Factors Influencing Growth of Microorganisms in Food

- Extrinsic factors
  - Extent of microbial growth largely dependent on storage of food
  - Microbes multiply rapidly in warm, oxygen-rich environments
  - Extrinsic factors include
    - Storage temperature
    - Atmosphere

Factors Influencing Growth of Microorganisms in Food

- Extrinsic factors
  - Storage temperature
    - Storage temperature affects rate of microbial growth
      - Below freezing water availability is significantly decreased
        - Water crystallizes and is unavailable halting microbial growth
      - At low temperature (above freezing) enzymatic action is very slow or non-existent
        - Results in inability of microbe to grow

Factors Influencing Growth of Microorganisms in Food

- Extrinsic factors
  - Atmosphere
    - Presence or absence of oxygen affects type of microbial population
      - Obligate aerobes cannot grow under anaerobic conditions
      - Obligate anaerobes will grow in anaerobic conditions
        - Including certain foodborne pathogens

Microorganisms in Food and Beverage Production

- Acid produced in yogurt, cheese and pickled vegetables inhibit growth of many spoilage organisms and foodborne pathogens
- Fermentation historically important method of food preservation

Microorganisms in Food and Beverage Production

- Lactic acid fermentations by lactic acid bacteria
  - Tastes of yogurt, pickles, sharp cheeses and some sausages due to production of lactic acid by lactic acid bacteria
- Cheese, yogurt and other fermented milk products
  - Milk is sterile in cow's udder
    - Rapidly becomes contaminated during milking and handling
      - Lactic acid bacteria generally reside ON the udder
  - Aesthetic features of milk change due to production of acid
    - Causes milk proteins to coagulate or curdle
    - Sours flavor

Microorganisms in Food and Beverage Production

- Production of fermented milk products do not rely on naturally occurring lactic acid bacteria
- Starter cultures added to milk
  - Strains carefully selected to produce desirable flavors and textures
- Starter cultures must be carefully maintained and protected against contamination

Microorganisms in Food and Beverage Production

- Cheese production
  - Can be made from milk of wide variety of animals
    - Cow’s milk most common
  - Cheeses classified as very hard, hard, semi-soft and soft
    - Classification passed on percentage of water content

Microorganisms in Food and Beverage Production

- Cheese production
  - Cottage cheese easiest cheese to make
    - Pasteurized milk inoculated with starter culture
      - Culture causes milk proteins to coagulate
        - Coagulated proteins called curd
    - Curd heated and cut into small pieces to facilitate drainage of liquid waste
      - Waste termed whey

Lactic acid production and rennin activity cause the milk proteins to coagulate. The coagulated mixture is cut to facilitate the separation of the solid curds and liquid whey.

The curds are heated and cut into small pieces. The liquid whey is removed by draining.

Curds are salted and pressed into blocks or wheels for aging.

Microorganisms in Food and Beverage Production

- Cheese production
  - Most other cheeses undergo further microbial processing termed ripening or curing
    - Cottage cheese is unripened
  - Enzyme rennin is added to fermenting milk to hasten protein coagulation
  - Curds salted after whey is separated and pressed and ripened to encourage changes in texture and flavor
    - Ripening can take weeks to years
      - Longer ripening produces more acidic sharper cheese
      - Certain organisms produce certain characteristics
        - » *Propionibacterium shermanii* → Swiss cheese
        - » *Penicillium roquefortii* → Roquefort, and gorgonzola

Microorganisms in Food and Beverage Production

- Yogurt
  - Pasteurized milk is concentrated slightly then inoculated with starter culture
  - Mixture is incubated for several hours at 40° C - 45° C for several hours
    - Thermophilic bacteria grow rapidly at higher temperatures
      - Produce lactic acid and other end products
        - Contribute to flavor
  - Controlled incubation ensures proper levels of acid and flavor compounds

Microorganisms in Food and Beverage Production

- Acidophilus milk
  - Sweet acidophilus milk retains flavor of fresh milk because it is not fermented
    - Culture is added immediately before packaging
    - Bacteria are added for purported health benefits
      - Prevent and reduce severity of some diarrheal diseases

Microorganisms in Food and Beverage Production

- Pickled vegetables
  - Pickling originated as way to preserve vegetables
    - Particularly cucumbers and cabbage
  - Pickling uses naturally occurring lactic acid bacteria residing on vegetables
    - Unlike fermentation of milk products which relies on starter culture

Microorganisms in Food and Beverage Production

- Fermented meat products
  - Traditionally were produced by letting small numbers of lactic acid bacteria to multiply to dominance
    - Natural fermentation of meat inherently risky
      - Incubation that initiates fermentation can support growth and toxin production of pathogens
        - » *Clostridium botulinum* and *Staphylococcus aureus*

Microorganisms in Food and Beverage Production

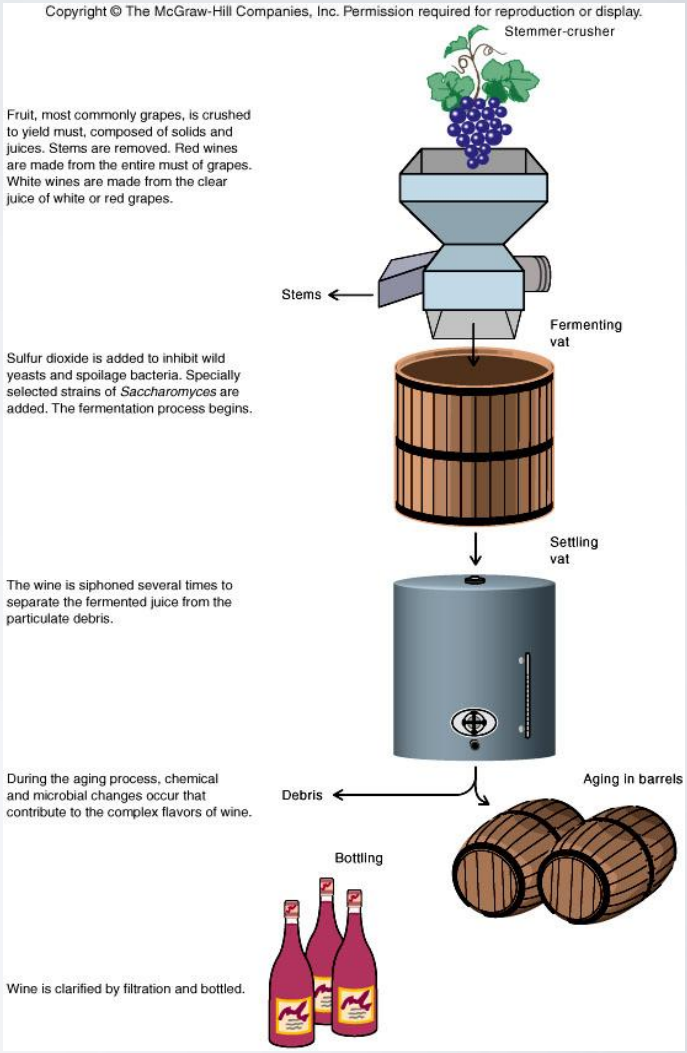
- Alcoholic fermentations by yeast
  - Some yeasts ferment sugars to produce ethanol and carbon dioxide
  - Yeasts are used to make variety of alcoholic beverages as well as vinegar and bread
    - Alcoholic beverages include
      - Wine
      - Beer
      - Distilled spirits

Microorganisms in Food and Beverage Production

- Wine
  - Product of alcoholic fermentation of naturally occurring sugars in juices of fruit
    - Most commonly grapes
  - Commercially made wine produced by crushing selected grapes
    - Stems are removed and solids collected
      - Entire grape used in red wines
      - Juice only used in white wines
      - Solids removed after one day and juice fermented to produce rose wines

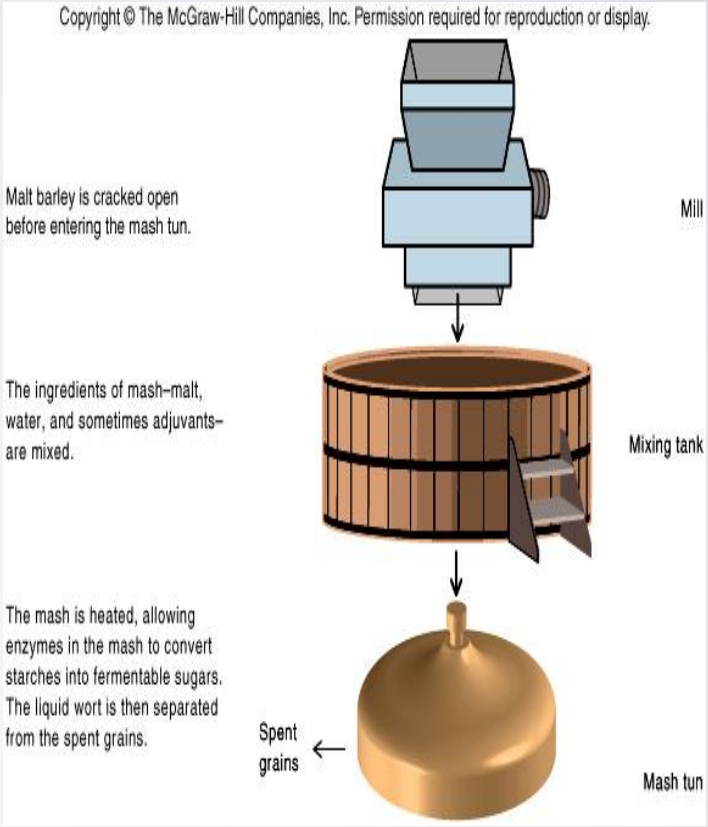
Microorganisms in Food and Beverage Production

- Wine
  - Fermentation must be carefully controlled to ensure proper reactions
  - Sulfur dioxide is added to inhibit growth of natural microbial population
    - These convert alcohol to acetic acid (vinegar) and most responsible for spoilage
  - Fermentation process is initiated by addition of selected strains of yeast
  - At completion of fermentation wine siphoned several times to separate juice from sediment
  - Wines then aged in oak barrels
  - Wine is filtered for clarification then bottled



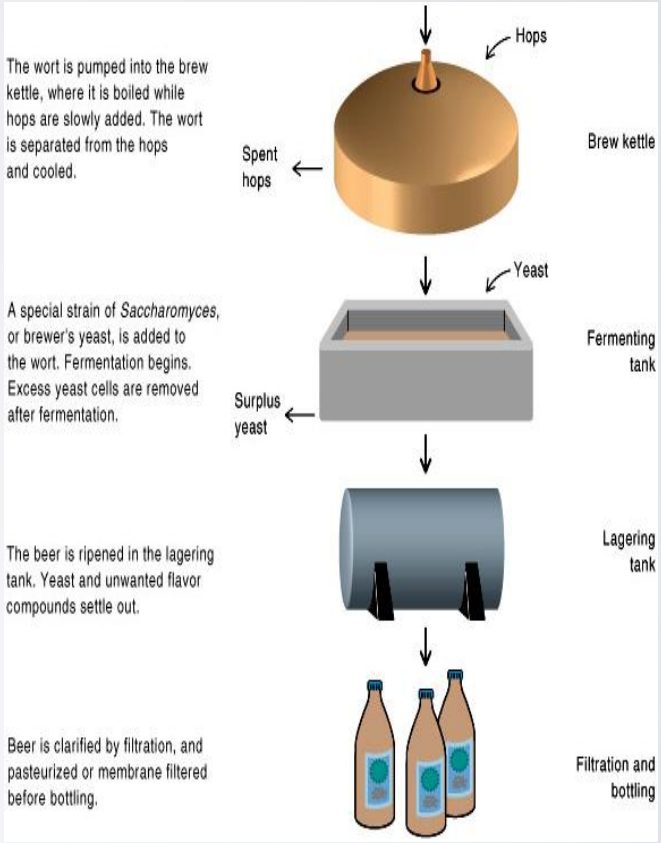
Microorganisms in Food and Beverage Production

- Beer
  - Production of beer is multistep process
    - Designed to breakdown starches in grain to produce simple sugars
      - Sugars are fermented
  - Yeast lack enzymes to convert grains to alcohol
    - Malted barley (malt) contains enzymes
  - Malt and starch, sugars and other adjuncts soaked in warm water
    - Termed mashing
      - Enzymes in malt act on starches converting to fermentable starches
  - Spent grains removed
    - Remaining liquid called wort



Microorganisms in Food and Beverage Production

- Beer
  - Hops are added to wort
    - Gives beer distinct bitter taste
    - Also has natural antimicrobial substances
  - Hops/wort mixture boiled
    - Extract flavor of hops
    - Concentrate wort
    - Inactivates enzymes and precipitates proteins
  - Wort centrifuged to remove solids and cooled
  - Brewer's yeast added to initiate fermentation
    - Bottom fermenters clump and sink to bottom of fermentation tank
      - Produces lager beers
    - Top fermenters distributed throughout
      - Produces porter and stout beers



Microorganisms in Food and Beverage Production

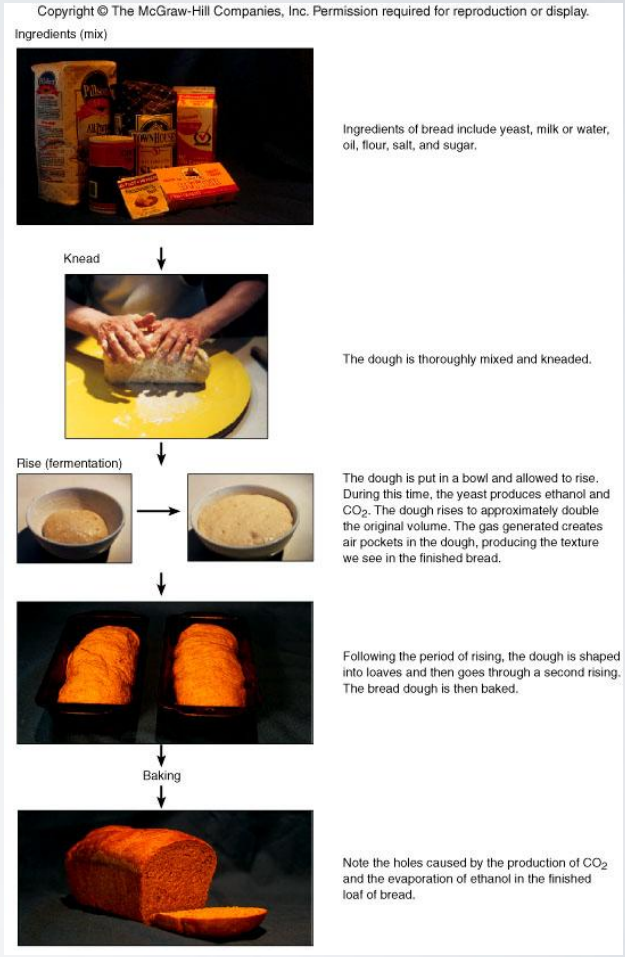
- Distilled spirits
  - Fermentation process nearly same as beer
    - Wort is not boiled
      - Degradation of starch continues through fermentation
  - When fermentation is complete ethanol is purified and distilled
  - Different types of spirits made with different substrates
    - Rum → fermentation of molasses
    - Scotch whiskey → fermentation of barley the aged
    - Tequila → fermentation of agave plant

Microorganisms in Food and Beverage Production

- Vinegar
  - Aqueous solution of at least 4% acetic acid
  - Product of oxidation of ethanol
  - Strictly aerobic process
    - Fermenting bacteria are obligate aerobes
  - Organisms can tolerate high concentration of acid
  - Vinegar generator produces available oxygen to hasten oxidation
    - Sprays alcohol on biofilm of acid bacteria on wood chips
      - Alcohol trickles down and is oxidized by bacteria

Microorganisms in Food and Beverage Production

- Bread
  - Bread rises due to carbon dioxide produced through fermentation of sugars by baker's yeast
    - Any alcohol produced evaporates during baking
  - Characteristic flavor of sour dough bread due to the addition of lactic acid bacteria to bread making ingredients



Food Spoilage

- Food spoilage encompasses any undesirable change in food
  - Spoiled food is generally not harmful
- Spoiled food considered unsafe because high numbers of spoilage organisms indicate foodborne pathogen may be present

Food Spoilage

- Common spoilage bacteria
  - Wide range of bacteria important in food spoilage
    - *Pseudomonas* can metabolize a wide variety of compounds
  - Psychrophilic organisms can multiply in refrigerator
    - Most common genera include
      - *Erwinia*
      - *Acetobacter*
      - *Alcaligenes*
  - Endospore forming organisms can survive cooking and in some cases canning processes
    - Prevalent spore formers include
      - *Clostridium* species
      - *Bacillus* species

Food Spoilage

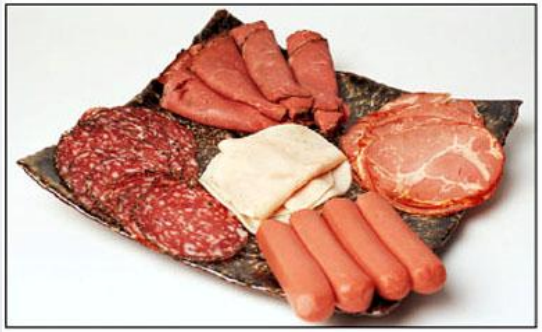
- Common spoilage fungi
  - Wide variety of fungi spoil foods
    - Some of the most common include
      - *Rhizopus*
      - *Alternaria*
      - *Penicillium*
      - *Aspergillus*
      - *Botrytis*
  - Fungi grow readily in acidic low-moisture environments

Foodborne Illness

- Commonly referred to as food poisoning
  - Occurs when a pathogen or its toxin is consumed
  - Consumers must employ sound preserving, preparation and cooking techniques to avoid hazards of food products
  - Estimated millions of cases of food poisoning occur each year
    - Vast majority could have been prevented

Foodborne Illness

- Food intoxication
  - Illness resulting from consumption of an exotoxin produced by organisms growing in food product
    - When food is ingested it is the toxin responsible for illness not organism
  - Common causes of foodborne intoxication are
    - *Staphylococcus aureus*
    - *Clostridium botulinum*



Foodborne Illness

- ***Staphylococcus aureus***
  - Produces toxin that causes nausea and vomiting
  - Thrives in moist, rich foods in which other organisms have been killed or inhibited
    - Survives well in unrefrigerated foods with high salt content
  - Source of *S. aureus* generally human carrier
    - Organism is inoculated into food during preparation
    - Food left at room temperature allows organism to grow and produce toxin
      - Toxin is heat stable and not inactivated by cooking

Foodborne Illness

- Botulism
  - Paralytic disease caused by ingestion of a neurotoxin
    - Produced by *Clostridium botulinum*
  - Growth of organism or production of toxin may not result in changes in taste or appearance of food
  - Canning process designed to destroy endospores
    - Processing errors can allow germination of endospores
      - Errors extremely rare in commercial canning
    - Home canned foods should be boiled for 10 to 15 minutes immediately before consumption
      - Heat destroys toxin

Foodborne Infection

- Foodborne infection requires consumption of living organisms
- Symptoms do not appear for at least one day after ingestion
  - Major symptom usually diarrhea
  - Thorough cooking of food immediately before consumption will kill organisms
    - Prevent infection
  - Foodborne illness commonly caused by
    - *Salmonella*
    - *Campylobacter*
    - *Escherichia coil* O157:H7

Foodborne Infection

- *Salmonella* and *Campylobacter*
  - Commonly associated with poultry products
  - Inadequate cooking can result in foodborne infection
  - Cross-contamination can result in transfer of pathogens to other foods
    - Cutting boards and knives often become contaminated

Foodborne Infection

- *Escherichia coil* O157:H7
  - Causes bloody diarrhea
  - Sometimes develops into hemolytic uremic syndrome (HUS)
    - Life threatening
  - *E. coli* O157:H7 responsible for several large food poisoning outbreaks
  - Ground meats are troublesome source of foodborne infection
    - ground meat should be cooked thoroughly through

Food Preservation

- Preventing growth and metabolic activities of organisms that cause spoilage and foodborne illness preserves food quality
- Preservation methods include
  - Canning
  - Pasteurization
  - Cooking
  - Refrigeration
  - Freezing
  - drying,/reducing water availability

Food Preservation

- Canning
  - Destroys all spoilage and pathogenic organisms
  - Low acid foods use steam under pressure to destroy endospores
    - Acidic food methods not as stringent
      - Spore forming bacteria can't grow or produce toxin in high acid environment
- Pasteurization
  - Heating foods under controlled conditions at high temperatures for short periods
    - Reduces number of spoilage organisms
    - Does not alter taste of food significantly

Food Preservation

- Cooking
  - Can destroy non-spore forming organisms
  - Alters characteristics of food
  - If heat is uneven some organisms may survive in undercooked portion of food
- Refrigeration
  - Preserves food by slowing growth rate of spoilage organisms
    - Many organisms unable to multiply in low temperatures

Food Preservation

- Freezing
  - Stops microbial growth
    - Water unavailable due to ice formation
  - Portion of organisms remaining can grow when food is thawed
- Drying/reducing water availability
  - Inhibits microbial growth by decreasing available moisture
    - Molds may grow eventually