15.2 Causes of spoilage of organic goods

Changes in the quality of organic goods with a high water content, which include a large number of foodstuffs, may be caused by five factors:

- Infestation with microorganisms (mold and rot)
- Biochemical changes, in particular respiration and ripening processes
- Physical changes, in particular in the form of drying-out (shriveling, weight loss)
- Chilling damage and frost damage
- Postharvest diseases
- Mechanical damage during handling and transport

These factors frequently interact with one another.

15.2.1 Microbiological causes of spoilage

Layers of mold and areas of rot are caused by the activity of microorganisms, primarily including fungal molds, yeast and bacteria. When accompanied by a high water content, foodstuffs form an ideal nutrient medium for microbes, which break down carbohydrates, proteins and fats with the assistance of enzymes so impairing quality, consistency and edibility.

Microbes are microscopically small living organisms. The small size of the cells, which have a very large surface area relative to their mass, results in lively metabolic activity, so leading to rapid cell enlargement and multiplication and a high level of cell respiration. They are capable of surviving unfavorable living conditions (e.g. unfavorable temperatures) by forming spores. If living conditions then become favorable again, they germinate. Thus, for example, if a container has not been carefully cleaned, goods may subsequently become infected with spores from previous cargoes which resume activity in the new environment (secondary infection). This is why refrigerated containers must be in a thoroughly hygienic condition.

Fungal molds form hyphae. i.e. branched fungal filaments, which are visible as an absorbent cotton-like covering (mycelium) and break up the surface of the substrate or make it slimy. The actual layer of mold is formed by the conidiophores, which produce the spores (conidia). The development of fungal molds is divided into four phases, damage to goods occurring in the third and fourth phases:

1st phase - Germination of an unbranched mycelium fiber (Fig. 68)

2nd phase - Formation of the original mycelium, which grows and forms four to five hyphae (Fig. 69)

3rd phase - Developed mycelium with numerous hyphae and a number of fruiting bodies (Fig. 70, Fig. 74)

4th phase - Reproductive stage with very dense mycelium layers and numerous conidiophores with spores (Fig. 71, Fig. 75).

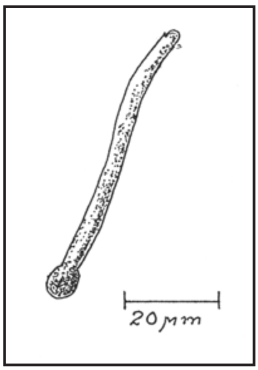


Figure 68:
Stage I of mycelial growth

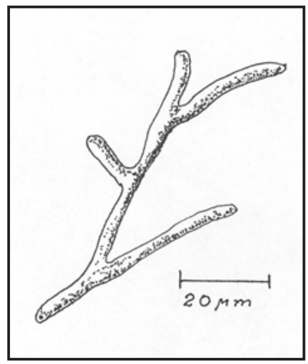


Figure 69:
Stage II of mycelial growth

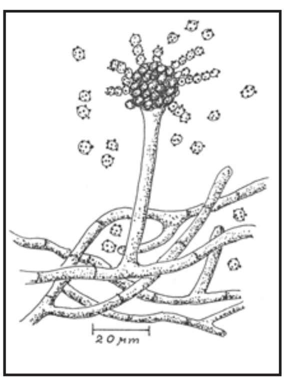


Figure 70:
Stage III of mycelial growth

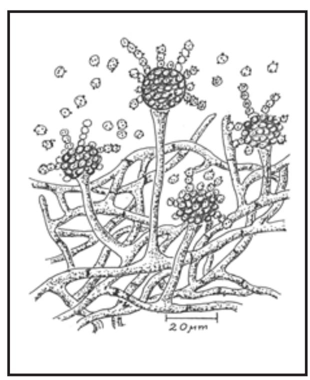
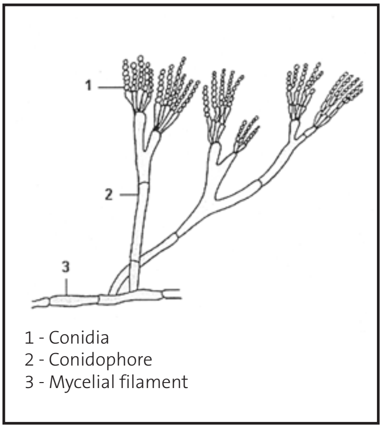


Figure 71:
Stage IV of mycelial growth



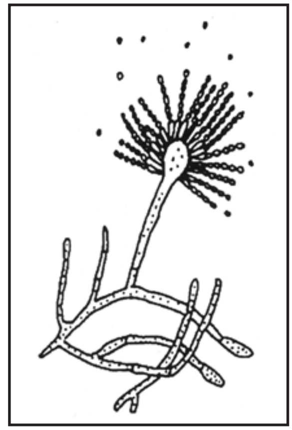


Figure 72:
Penicillin mold (Penicillium italicum) [29]

Figure 73:
Aspergillus flavus [34]

Figs. 72 and 73 show two important examples of fungal molds, penicillin mold (Penicillium italicum) and Aspergillus flavus; the latter forms aflatoxin which is one of the most potent cytotoxins which has yet been discovered.

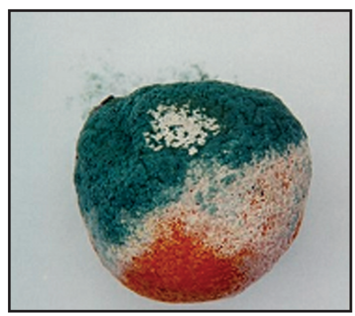


Figure 74:
Lemon, suffering from green mold - stage III (white) and stage IV (green)

Figure 75:
Blue mold caused by the fungal mold Penicillium italicum, stage III (white) and stage IV (blue), on an orange. Spores can be seen at the top.

Fig. 76 shows fresh ginger, which began to go moldy (white) and to sprout (green) in a refrigerated container because the temperature and humidity were too high.

Figure 76:
Fresh ginger, which began to go moldy (white) and to sprout (green) in a refrigerated container because the temperature and humidity were too high

15.2.2 Living conditions of microorganisms

15.2.2.1 Temperature requirements

As far as the temperature requirements of microorganisms are concerned, it is possible to distinguish between three groups of „living temperatures", at which metabolic and multiplication activities proceed, as do spoilage processes in foodstuffs:

- types that thrive at low temperatures (psychrophilic),
- types that thrive at medium temperatures (mesophilic)
- types that thrive at high temperatures (thermophilic), (see Table 4 and Fig. 77)

Group	Minimum (°C)	Optimum (°C)	Maximum (°C)
Cryophilic or psychrophilic microorganisms	-10 - 0	15 - 20	20 - 30
Mesophilic microorganisms	10 - 30	20 - 37	35 - 50
Thermophilic microorganisms	25 - 50	50 - 65	60 - 95

Table 4: Classification of microorganisms by temperature group

The optimum temperature is the temperature at which the highest level of multiplication occurs, while the minimum and maximum temperatures represent the lower and upper multiplication limits respectively. However, spores may survive at much higher and lower temperatures.

The most important rot and fermentation pathogens are mesophilic microorganisms. The minimum temperature shows clearly that metabolic activity can be restricted by refrigeration.

Also of relevance to the cargo care of chilled goods are psychrophilic microorganisms, whose minimum temperature may be as low as -10°C (yeasts, molds, bacteria), so meaning that they may still remain active in chilled storage. These may cause secondary infection of chilled goods in refrigerated containers which have not been carefully cleaned.

Molds generally belong to the mesophilic temperature group; however, some types do also thrive on frozen fish and water-containing fats down to temperatures as low as -10°C.

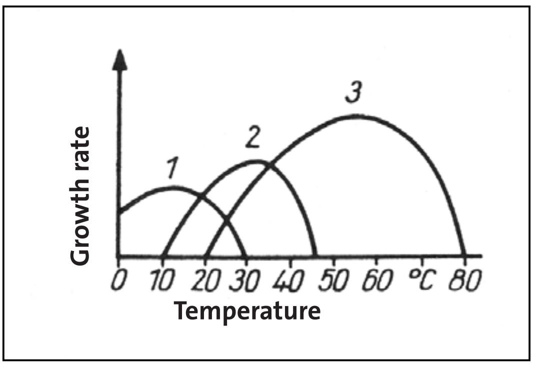


Figure 77:
Dependency of bacterial growth on temperature [57]

1 Cryophilic (psychrophilic) types
2 Mesophilic types
3 Thermophilic types

15.2.2.2 Humidity/moisture requirements

The nutrients are absorbed by the microorganisms after having been dissolved by means of enzymes. Molds are divided into three groups (see Fig. 78).

1. Types surviving at low relative humidities of approx. 75% (xerophilic), such as green mold
2. Types thriving at relative humidities of over 86% (mesophilic), such as Mucorales fungi
3. Types requiring a relative humidity of over 90% (hygrophilic), such as Geotrichum candidum
4. Bacteria are active above 95% relative humidity.

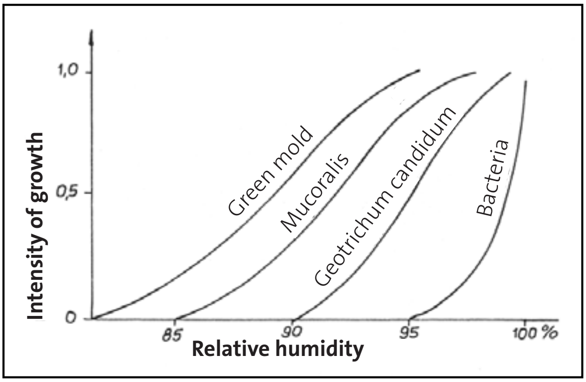


Figure 78:
Intensity of microbial growth as a function of relative humidity; Hermann [17]

Overall, the mold growth threshold should be deemed to stand at 75% relative humidity, while bacteria only become active above 95%. This explains why fruit firstly suffers mold attack, with bacterial decomposition processes only starting at a higher relative humidity resulting, among other things, from the associated higher level of respiration.

15.2.2.3 Atmospheric oxygen requirements

As far as the atmospheric oxygen requirements of microorganisms are concerned, it is possible to distinguish between three groups:

1. Types which absolutely have to have atmospheric oxygen to live (obligate aerobe)

2. Types which thrive only in the absence of atmospheric oxygen (obligate anaerobe)

3. Types which live in both the presence and absence of oxygen (facultative anaerobe)

Molds are generally typical aerobes, meaning that as a rule they colonize the surface of the goods (see Figs. 74 and 75). Controlled atmosphere storage, e.g. of apples, is an effective method of inhibiting aerobes. On the other hand, a large number of rot pathogens are anaerobes, capable of causing damage to preserved foods, for example.