# 1. SAFE STORAGE CONDITIONS

## 1.1. INTRODUCTION

From the moment of harvest to the moment of its use in processing for human food or animal feed, grain should be stored so as to prevent quality deterioration. The grain, together with microorganisms and foreign material, make a system of living organisms, also called an artificial ecosystem of grain in bulk (Jayas et al. 1995). Any quality deterioration of such a system is a result of simultaneous biological, physical and chemical processes (Multon 1988). The following quantities and factors can be distinguished that characterize these processes or influence them: temperature, moisture content, carbon dioxide ($CO_2$), oxygen ($O_2$), as well as biological state of the grain, microorganisms – especially moulds (as shown in Figure 1.1), insects and mites at the moment of harvest. Moreover, rodents, birds, climatic conditions, transport and cleaning, and the applied technology of ventilation, drying, cooling and storing all have their influence. The ecosystem of stored grain should be properly protected against all risks that can reduce quality or lead to spoilage (Figure 1.1).

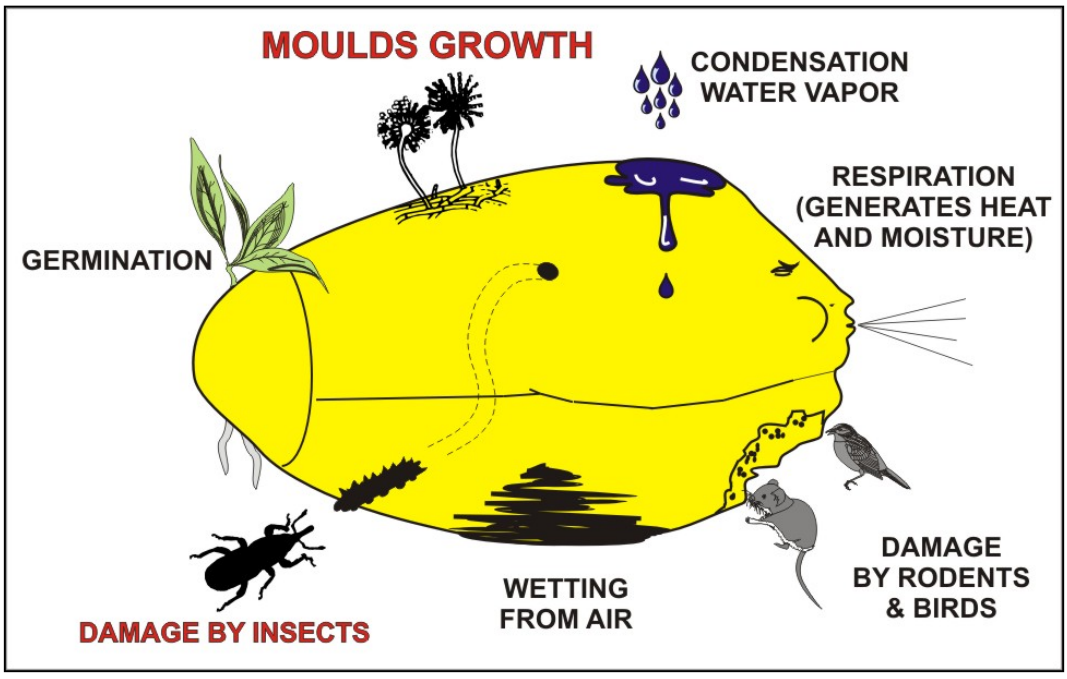


**Figure 1.1.** Various **risks of quality deterioration** in the ecosystem of bulk grain.

Post-harvest preservation of grain tries to inhibit those biological processes in the ecosystem of the grain bulk that are a cause of quality deterioration. The largest influence on these bio-processes arises from the moisture content and temperature of kernels, as well as the air humidity in the inter-granular spaces.

## 1.2. SAFE STORAGE TIME

*Question 1.1. How long can cereal grains or rapeseed of particular moisture content and temperature be stored without the risk of the quality deterioration?*

To test the effect of grain parameters on the safe storage period, three criteria have been applied: carbon dioxide ($CO_2$) development, germinability, and visible mould growth (Brooker et al. 1974). For wet grain being preserved at near-ambient temperatures, deterioration in quality is most likely to be as a result of mould growth (Nellist 1997). So the best criterion for safe storage times is the one that is based on the time to the appearance of visible moulds (Kreyger 1972, Brook 1987, Ryniecki and Nellist 1991, Nellist 1998).

Known in the bibliography of the subject are tables and graphs of safe storage times, i.e. time before the appearance of visible mould on grain, showing the dependence upon temperature and moisture content of the kernels. Popular graphs are shown in Figures 1.2 and 1.3.

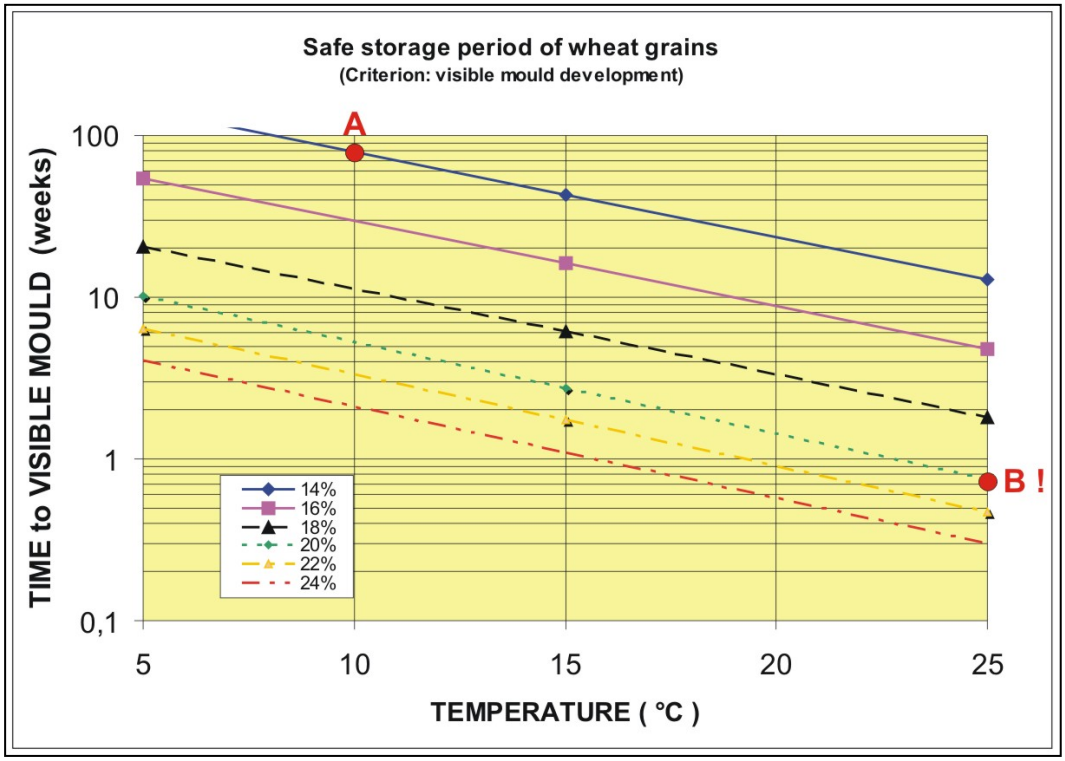


**Figure 1.2. Safe storage time** to the appearance of visible mould on **wheat** as dependent upon temperature and moisture content (% w.b.) (predicted by the mathematical formula of Frazer and Muir 1981, validated for moisture content in the range 12 – 24% and temperature 5 – 25 °C). We can assume that periods of safe storage of other cereal grains are very similar.

Here are some of the examples of how to read information from the graph. The first, point A on Figure 1.2, is optimistic: the bulk of wheat which has been dried to a moisture content of 14% w.b. and cooled down to a temperature of 10 °C, can be safely stored free of visible mould growth for 78 weeks, i.e. 1.5 years. The next information is disturbing: the safe storage time of grain with moisture content of 20% w.b. and temperature of 25 °C is only about

one week (point B on Figure 1.2). From time to time, wheat with such conditions is harvested directly from the field – it means one can easily spoil the crop by neglecting proper, post-harvest preservation.

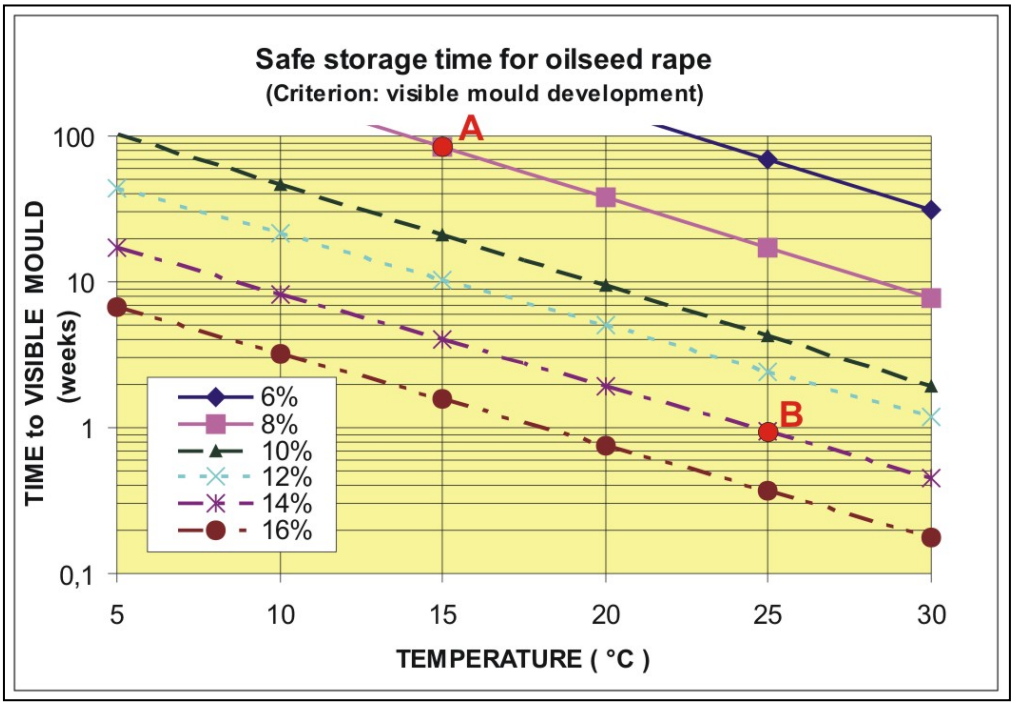


**Figure 1.3. Safe storage time** to the appearance of visible mould on **rapeseed** as dependent upon temperature and moisture content (% w.b.) (predicted by the mathematical formula of Muir and Sinha 1986, validated for moisture content in the range 8 – 18% and temperature 5 – 25 °C). Information from the graph: a) optimistic (point A, safe storage time equals to 1.8 years) and b) **disturbing** (point B, period of safe storage equals to less than 1 week).

## 1.3. SAFE STORAGE CONDITIONS

*Question 1.2. What are safe storage conditions (moisture content and temperature) for cereal grains to be stored for particular period of time (e.g. 6 months or 1 year)?*

In a situation where we intend to store grain for a fixed period of time one can use the graphs in Figures 1.4 - 1.7. In Figure 1.4 an answer to the following question can be found: what should be the combination of grain moisture content and temperature values so as to ensure safe storage for one or half a year according to the criterion of visible mould growth. The period of 6 months can provide an example: grain quality will not be reduced after half a year if the grain moisture content is equal to 12.5% w.b. and the temperature is 25 °C (point C on Figure 1.4). The second example for the same safe storage time of 6 months is: the grain moisture content equal to 17.5% w.b. and the temperature 5 °C (point D on Figure 1.4). There are of course many other combinations of moisture content and temperature of grain that result in the same safe storage time. A pattern can be observed: the lower the moisture content, the higher the acceptable temperature.

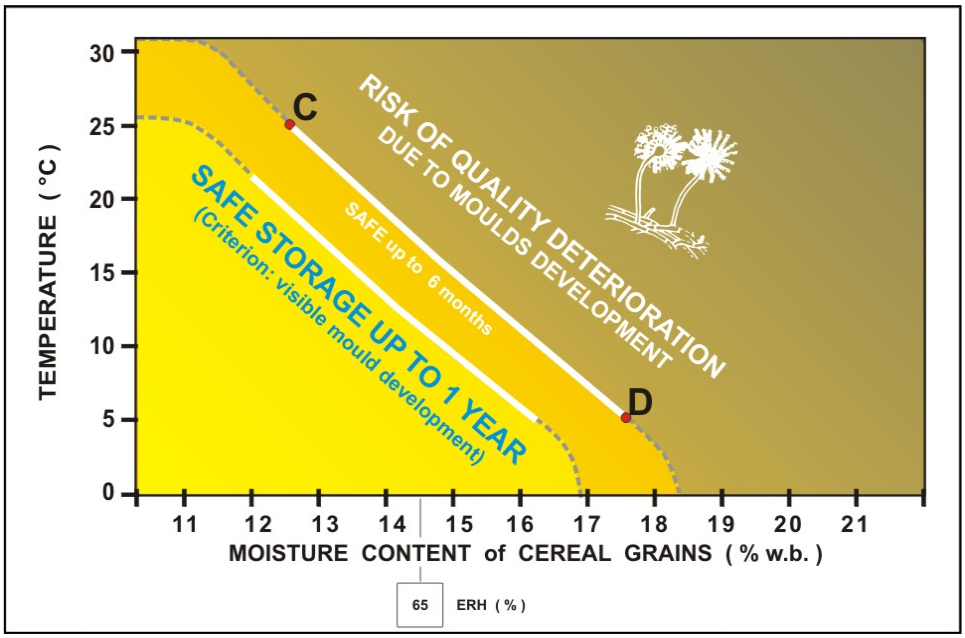


**Figure 1.4. Safe storage conditions** for cereal grains from the point of view of the risk of quality deterioration or spoilage caused by mould development. Safe storage conditions depend upon temperature and moisture content. This figure is based on the data shown in Figure 1.2. Dashed lines indicate that data were no validated in the range and shapes of lines were assumed. The term "ERH" is explained in the section 2.2.

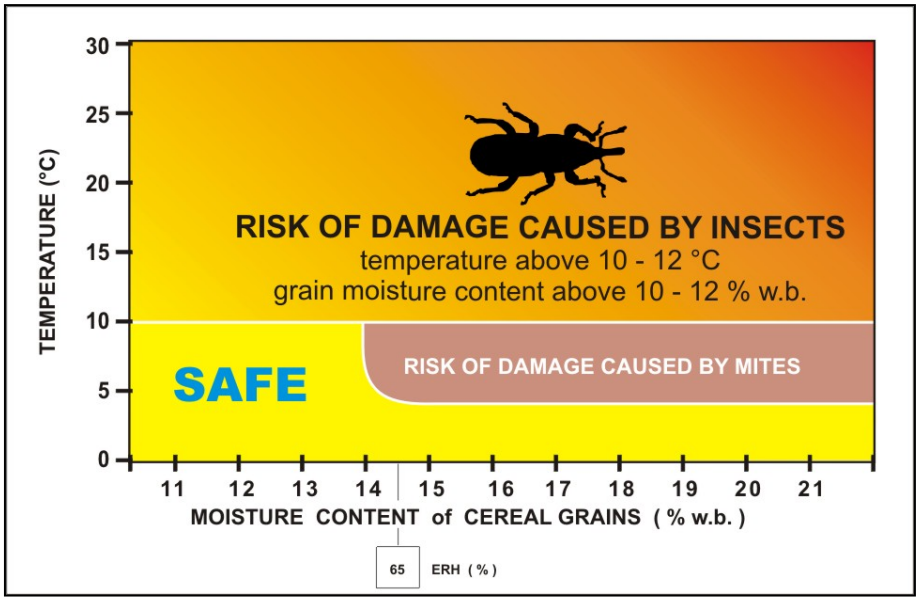


**Figure 1.5.** Safe storage conditions from the point of view of the risk of damage caused by insects and mites (Brooker et al. 1974, McLean 1989). The term "ERH" is explained in the section 2.2.

To ensure the safety of stored grain for a fixed period of time, the risk of grain quality deterioration due to insect and mite activity has to be taken into account. These are shown in Figure 1.5. In the case of insects, the temperature limit for safe storage is 10 °C and the moisture content of grain kernels is not relevant as long as it is a moisture content level encountered in practice. However, because of the threat of mite activity, the safe zone on the

graph will decrease, since mites develop at temperatures above 4 °C, but only in limited grain moisture content, namely above 14% w.b. of cereal grains - as is shown in Figure 1.5. A completely safe storage area is formed by overlapping the conditions safe from insects and mites, presented in Figure 1.5, with the safe conditions from mould development (for cereal grains presented in Figure 1.4). The safe area for cereal grains is now more restricted, as shown in Figure 1.6. The safe area for oilseed rape was developed in similar way as it was done for cereal grains and is shown in Figure 1.7. The fully protected area is described in both Figures (1.6 and 1.7) by the word "SAFE".

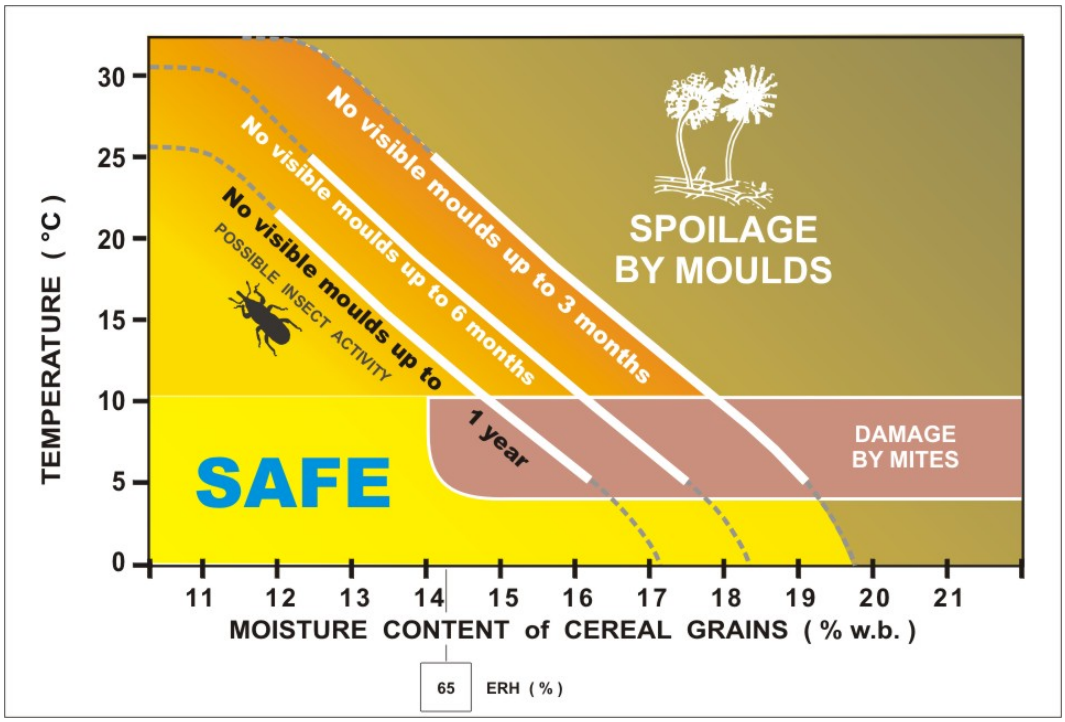


**Figure 1.6. Safe storage conditions for cereal grains** based on data shown on Figures 1.2, 1.4 and 1.5. The term "ERH" is explained in the section 2.2. Dashed lines indicate that data were no validated in the range and shapes of lines were assumed.

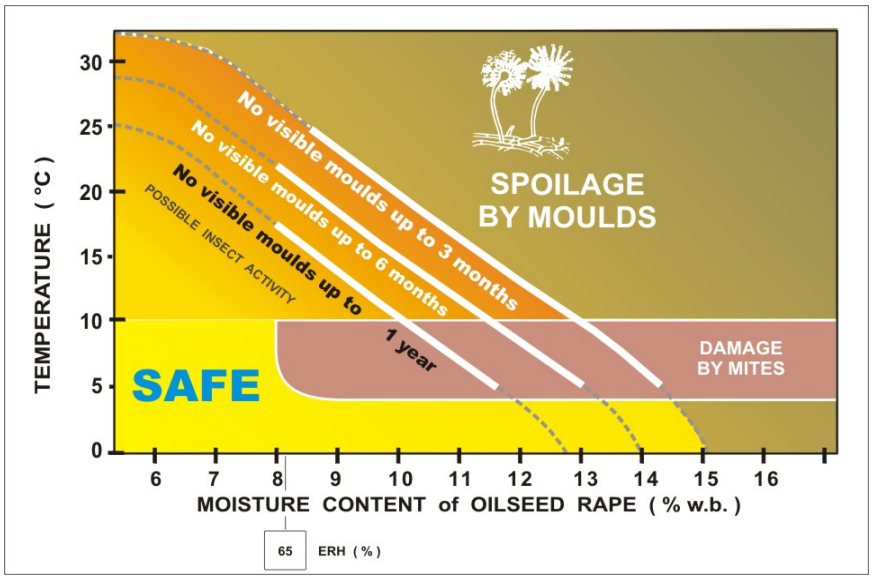


**Figure 1.7. Safe storage conditions for rapeseed** based on data shown on Figures 1.3 and 1.5. The term "ERH" is explained in the section 2.2. Dashed lines indicate that data were no validated in the range and shapes of lines were assumed.