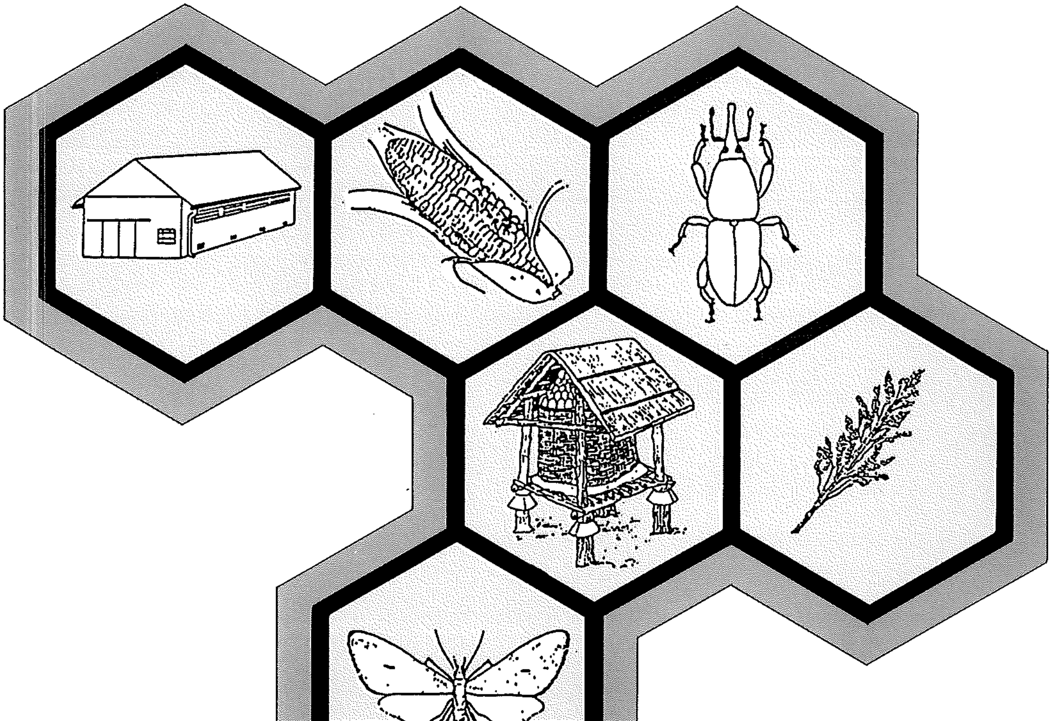
MANUAL ON THE PREVENTION OF POST-HARVEST GRAIN LOSSES

J. GWINNER R. HARNISCH O. MÜCK

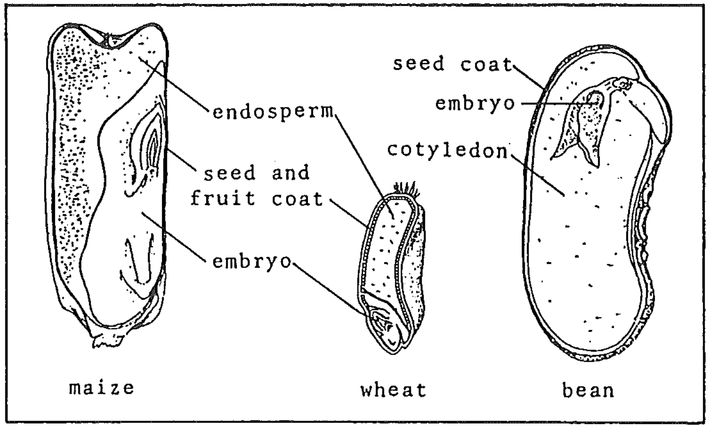


2 The Fundamentals of Storage

2.1 Properties of Stored Produce

The most commonly stored forms of food (cereals and legumes) are living seeds. They contain a high concentration of nutrients and are easily storable due to their low moisture content.

Three examples shall serve to illustrate the structure of a grain:



The most important components of a seed are:

- The **embryo**, from which the new plant grows. It contains a large amount of oil, protein and vitamins.

- The **endosperm**, which constitutes the nutritional reserves for the embryo. It consists largely of starch.

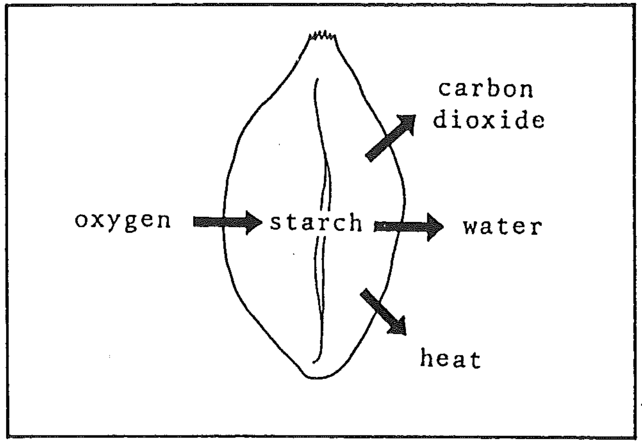
- The **seed coat**, made of several layers which protect the seed from any damaging influences.

Legumes do not have any endosperm. Instead of this, the cotyledones are developed to a thick and fleshy nutritive tissue.

The storage ability is determined by the following properties of the seeds.

2.1.1 Respiration

A grain is a living organism which breathes. During respiration, starch and oxygen are converted to carbon dioxide as well as water and energy:



An increase in the storage temperature leads also to an increase in the respiration rate. Nutrients being respirated lead to losses in the weight and quality of stored produce.

2.1.2 Moisture Content

Grains contain water. The moisture content of stored produce is fluctuating. A higher moisture content is conducive to infestation with fungus and insects and makes the produce more rapidly perishable.

2.1.3 Heat Conductivity

Cereals and legumes have low heat conductivity. This means that local fluctuations in temperature in the stored produce are only noticeable over short distances or long periods. This leads to the accumulation of heat with all of the accompanying disadvantages, such as increased respiration, higher insect infestation and condensation (see Sections 2.1.1, 2.2.1 and 2.2.3).

2.2 Climatic Factors in Storage

The temperature of the air, the relative humidity and the moisture content of the stored produce are closely interrelated.

2.2.1 Effect of Temperature

The temperature has a great influence on the respiration rate of the stored produce and pest organisms as well as on the relative humidity and the grain moisture content. The temperatures to be found in tropical and subtropical climates provide ideal living conditions for insect pests and, in places where there is also high relative humidity, also for fungi.

2.2.2 Effect of Relative Humidity (r.h.)

The moisture content of the air may vary, as well as that of the stored produce.

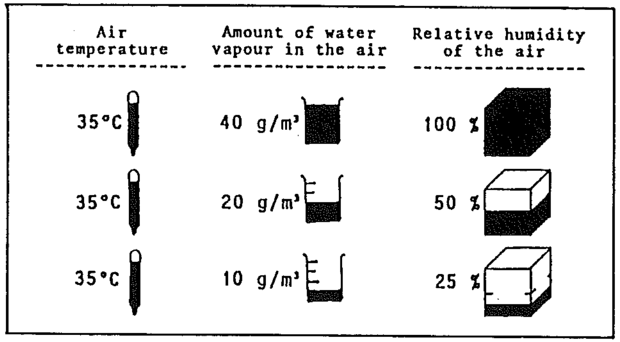
The moisture absorbed by the air in the form of water vapour is referred to as **absolute humidity** and expressed in g/m^3 air.

The air is, however, not able to absorb an unlimited amount of moisture. There is a maximum amount the atmosphere can absorb at any specific temperature. If the atmosphere does actually contain this maximum amount, we speak of **saturation** and the **saturation moisture content** of the air.

The relative humidity at saturation point is 100 %.

If the absolute humidity is only half the saturation moisture content, the relative humidity is 50 %; if it is only a quarter of it, the relative humidity is 25 %; etc.

Relative humidity thus expresses the degree of saturation of the air with vapour in %.



Hygrometers show the relative humidity in per cent.

As already mentioned, the saturation moisture content of the air depends on the temperature, i.e. the higher the temperature of the atmosphere the more moisture it is able to absorb:

Air temperature	Maximum amount of water vapour in the air	Relative humidity of the air
35°C	40 g/m³	100 %
26°C	25 g/m³	100 %
22°C	20 g/m³	100 %

This means that saturation is reached with different amounts of water vapour at different temperatures.

The absolute moisture content of the air will change, for example, when it rains. There will be more moisture available for the air to absorb, thus causing a rise in the relative humidity.

On sunny days, the absolute humidity will remain more or less constant. What will then occur if the temperature fluctuates?

If the air gets warmer, its ability to absorb moisture increases, i.e. the saturation moisture content will be

higher. If the amount of moisture in the air remains constant, the degree of saturation will then drop. **The relative humidity will fall.**

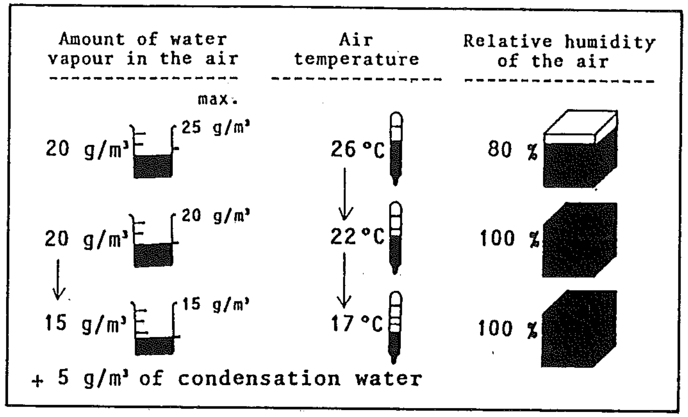
If the air gets cooler, its ability to absorb moisture decreases, i.e. the saturation moisture content will be lower. If the amount of moisture in the air remains constant, the degree of saturation will go up. **The relative humidity will rise** (see also Section 2.2.3).

Amount of water vapour in the air	max.	Air temperature	Relative humidity of the air
20 g/m³	20 g/m³	22°C	100 %
20 g/m³	25 g/m³	26°C	80 %
20 g/m³	40 g/m³	35°C	50 %

This means that on days without rain, the relative humidity is at its highest in the early morning, and at its lowest shortly after midday when the temperatures are highest, increasing again towards the evening as the air cools down.

2.2.3 Condensation

If the air cools strongly down, a relative humidity of 100 % and thus saturation point **(dew point)** may be passed. This means that there is now more moisture in the air than it is able to contain at this low temperature. Condensation occurs, which means that the excess vapour appears as liquid water on cool surfaces.

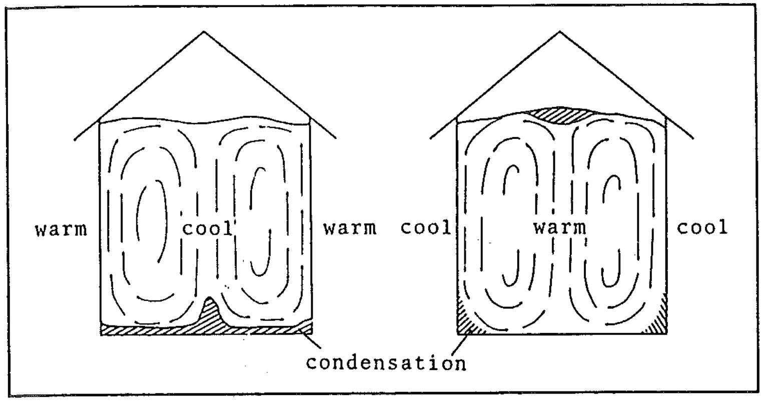


Condensation occurs in stores primarily when there are great differences in the temperatures inside and outside the store. A typical example is when the outside walls become hotter or colder (temperature fluctuations between day and night).

Imbalances in temperature thus cause the air in the stored produce to circulate.

If the outside walls of a store are warmed up by sun radiation, the inside air close to the walls will also be heated. The increase in its temperature will cause the relative humidity to drop. The air is thus able to absorb additional moisture from the stored produce. If this air then comes into contact with colder surfaces, it will cool down. The drop in its temperature will cause the relative humidity to rise, possibly even passing saturation point. Condensation will occur.

The same applies if the outside temperature is lower than the temperature inside the store.

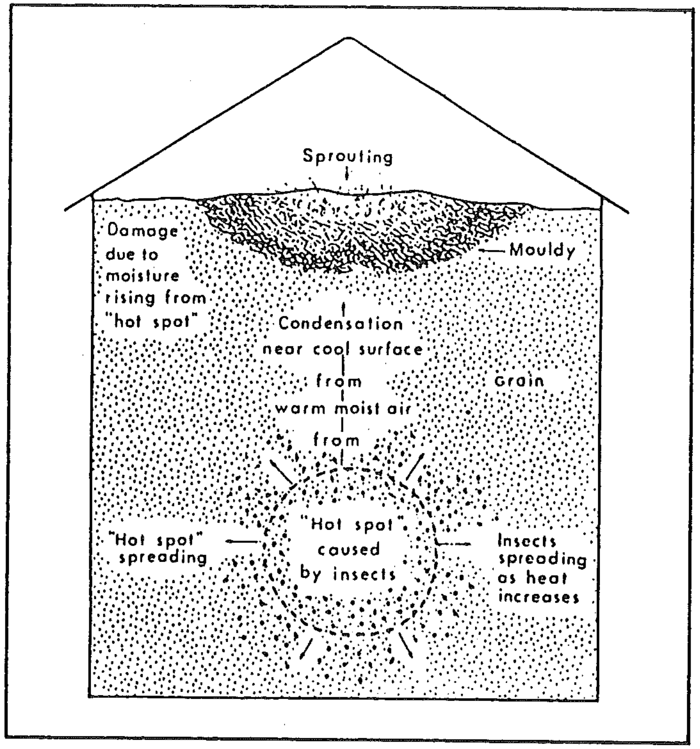


Condensation occurs particularly in silos, but also in warehouses, mainly close to the walls and roofs from where it drops down onto the stored produce. Sometimes it is also found under the tarpaulins of stacked commodities.

This often leads to mould developping and sometimes even to germination of the stored produce.

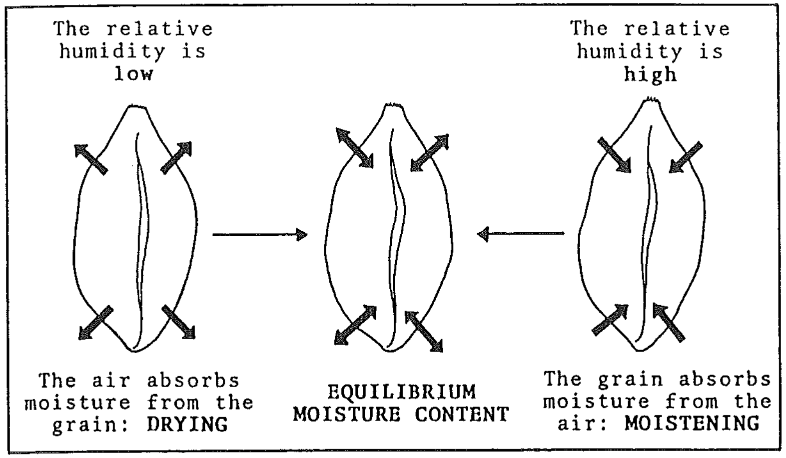
Condensation may also occur if there is a high insect infestation at certain points in the stored produce. The respiratory activity of the insects leads to an increase in the temperature and the humidity. "Hot spots" are formed.

If the temperature in one of these "hot spots" passes 40°C, it becomes too hot for the insects and they will move to cooler surroundings. The "hot spot" thus spreads.



2.2.4 Effect of the Relative Humidity on the Moisture Content of the Stored Produce

The moisture content of the stored produce and the relative humidity of the surrounding air in the store attempt to find a state of equilibrium. Depending on the prevailing relative humidity, the stored produce either releases moisture into the atmosphere (drying) or absorbs moisture from the atmosphere (moistening) until an equlibrium has been reached.



Controlled ventilation of the store (aerating the store when the relative humidity is low, and closing it when the relative humidity is high) allows further drying of the produce during storage (see Section 5.2.4.2).

2.2.5 Safe Moisture Content of Stored Produce for Long-Term Storage

When the stored produce is moist, there is a danger of fungi and mould developpment. Fungi start growing at an r.h. of above 65-70 %. The safe moisture contents for foodstuffs for long-term storage are therefore those which provide an equilibrium at a r.h. of 65-70 %.

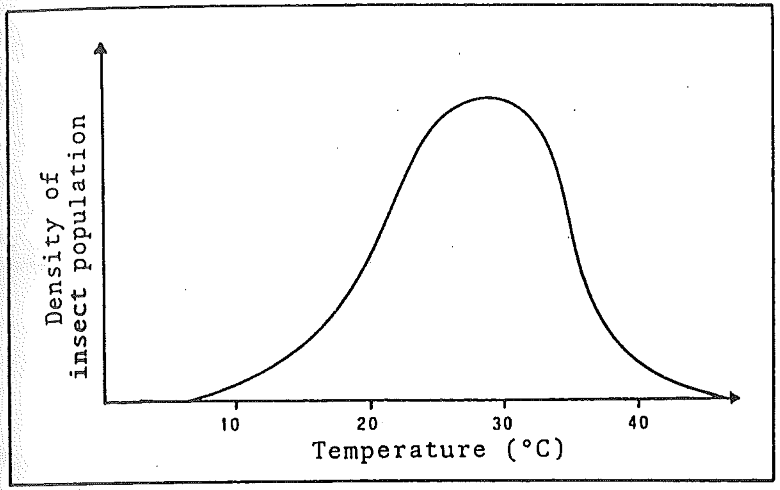
Produce	Safe m.c.	Produce	Safe m.c.
Maize	13 %	Cowpeas, Beans	15 %
Wheat	13 %	Groundnuts	7 %
Millet	16 %	Cocoa	7 %
Sorghum	12.5 %	Copra	7 %
Paddy	14 %	Palm kernels	5 %
Rice	13 %	Coffee	13 %

The values vary with the differences in the chemical composition of the various types of stored produce. Seeds with a high lipid content (fats, oils) will, for example, have a much lower equilibrium moisture content than cereals, which are composed largely of starch.

In sealed containers the moisture content of the produce for long-term storage must be at least 3-4 % lower than that stated above, as any moisture produced by the stored produce itself cannot be eliminated by means of ventilation.

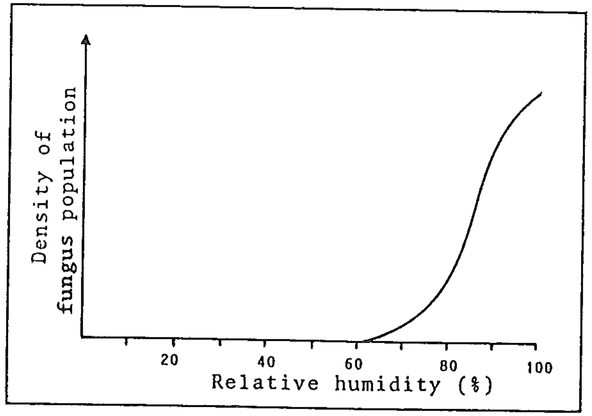
2.2.6 The Effect of Climatic Conditions on the Growth of Pests and Microorganisms

Pests and microorganisms, like all living beings, are dependent on specific climatic conditions for survival. Certain temperature and humidity ranges generally exclude the possibility of life, in particular in extremely cold, hot and dry zones. Certain pests are very adaptable in terms of climate, while others are subject to very strict limitations.



Stored product pests generally find the best conditions for development at temperatures between 28 and 33°C and relative humidities between 60 and 80 %. Around these perfect conditions, a rapid sequence of generations will lead to mass reproduction (see Section 7.4).

Mould will begin to develop at a relative humidity of 65-70 %. The higher the relative humidity, the better the conditions for the development of fungi and mould. The range of temperatures within which fungi will develop varies according to the particular species. This also applies to the emission of highly toxic metabolic products, known as mycotoxines, which can be observed in connection with fungus infestation (see Section 6.2).

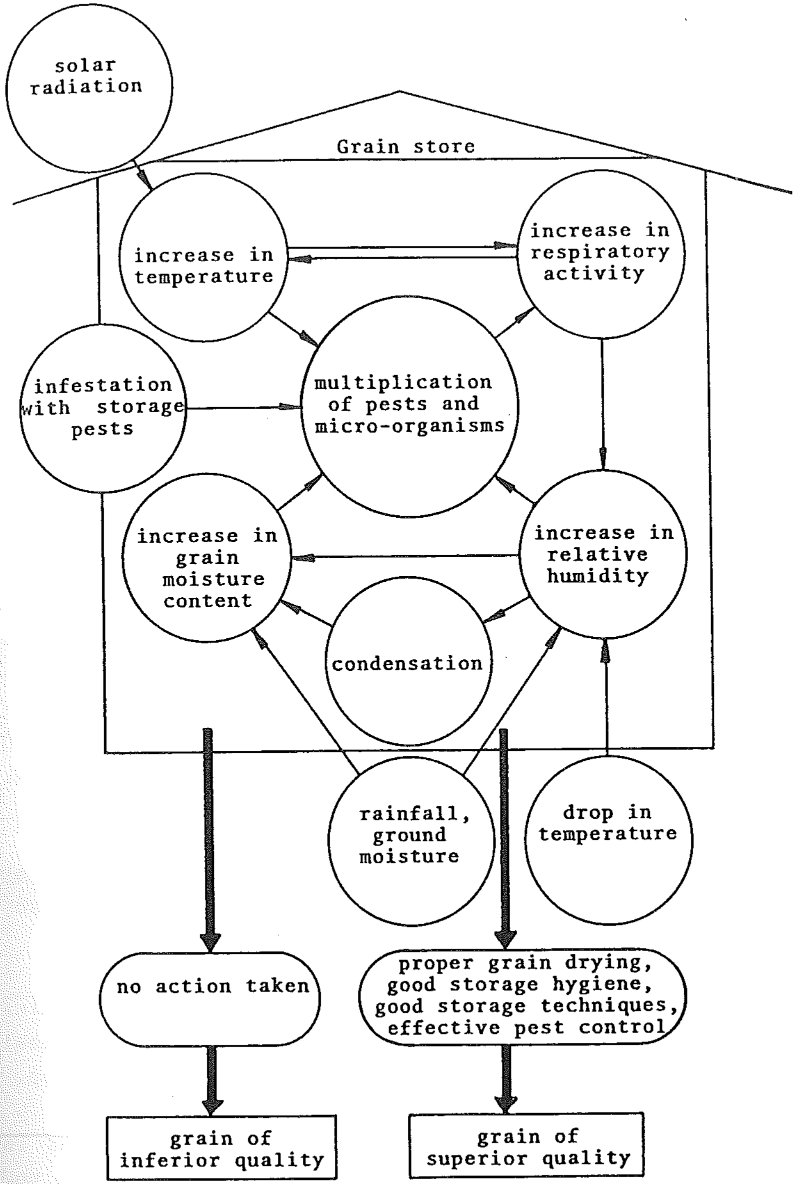


2.2.7 **Summary of the Effects of Climatic and Biotic Factors on the Quality of Stored Produce**

High temperatures, high relative humidity and high moisture contents of stored produce are favourable to the development of pest organisms. The respiration of pests (and of the stored produce) releases moisture and heat, which further improves the living conditions and leads to an increase in the pest population.

Rainfall, ground moisture and a drop in temperature increase the relative humidity. Rainwater and ground moisture may be absorbed directly by the grain.

High relative humidity leads to a rise in the moisture content of the stored produce and under certain conditions to condensation. If no measures are taken to counteract this, considerable losses are likely to occur. Only when the necessary steps are taken, which include good storage hygiene, controlled ventilation, pest control and drying of the produce, the quality of the stored produce can be maintained.



Low, even temperatures and low relative humidity are favourable for maintaining the quality of the stored produce.

Therefore:

Store cool and dry!

2.3 Further Literature

Anonymous, 1983. Food Storage Manual, FAO/WFP, TDRI, London, 263 pp.

Anonymous, 1988. Conservation des Grains en Régions Chaudes, CEEMAT, Ministère de la Coopération et du Développement, Paris, France, 529 pp.

Anonymous, 1985. Prevention of Post-Harvest Food Losses: A Training Manual, FAO Training Series No. 10, FAO, Rome, 120 pp.

Appert, J., 1985. Le stockage des produits vivriers et semenciers, Vol. 1 et 2, Maisonneuve & Larose, Paris, 112 et 225 pp.

Christensen, C.M. (Ed.), 1982. Storage of Cereal Grains and their Products, American Association of Cereal Chemists, Inc., St. Paul, Minnesota, USA, 544 pp.

Hall, D.W., 1970. Handling and Storage of Food Grains in Tropical and Subtropical Areas, FAO, Rome, 350 pp.

Multon, J.L. (Ed.), 1982. Conservation et stockage des grains et graines et produits derivés, Lavoisier, Paris, Volume I, 576 pp.

Multon, J.L. (Ed.), 1988. Preservation and Storage of Grains, Seeds and their By-Products, Lavoisier, New York, 1095 pp.