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Storage of cereals and pulses —

Part 1:
General recommendations for the keeping of cereals

Stockage des céréales et des légumineuses —

Partie 1: Recommandations générales pour la conservation des céréales

Reference number
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Foreword

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Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

International Standard ISO 6322-1 was prepared by Technical Committee ISO/TC 34, *Agricultural food products*, Subcommittee SC 4, *Cereals and pulses*.

This second edition cancels and replaces the first edition (ISO 6322:1981), which has been technically revised.

ISO 6322 consists of the following parts, under the general title *Storage of cereals and pulses*:

— *Part 1: General recommendations for the keeping of cereals*

— *Part 2: Essential requirements*

— *Part 3: Control of attack by pests*

Annexes A and B of this part of ISO 6322 are for information only.

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Introduction

The seasonal nature of cereal production, in conjunction with year-round consumer requirements, has always made it necessary to store grain for short or long periods.

However, the caryopsis of cereals, like all plant life with a reduced metabolic rate, undergoes an unavoidable physiological development which can have beneficial effects (breaking of dormancy, improved baking quality, quality for making pasta, cooking quality), but which leads to ageing and, after a time, to changes which are detrimental and of a nature and intensity which are dependent upon the storage environment.

When considered on a worldwide scale, these various changes result in very substantial qualitative and quantitative losses.

Storage losses have been estimated as being an average of 5 % but sometimes as much as 30 %, especially in countries with climates favourable to the rapid development of agents of deterioration and where storage techniques are poorly developed, such as developing countries in the damp tropics. The principal causes of loss of quantity and quality are metabolic changes in the grain and the attacks of microorganisms (bacteria and moulds) and of vertebrate and invertebrate animals.

The magnitude of these figures highlights the need for promoting throughout the world a rapid improvement in techniques of conservation.

Storage of cereals and pulses —

Part 1:
General recommendations for the keeping of cereals

1 Scope

This part of ISO 6322 gives general guidance related to the problems of keeping cereals. Other aspects of the storage of cereals and pulses are dealt with in ISO 6322-2 and ISO 6322-3.

2 Normative reference

The following standard contains provisions which, through reference in this text, constitute provisions of this part of ISO 6322. At the time of publication, the edition indicated was valid. All standards are subject to revision, and parties to agreements based on this part of ISO 6322 are encouraged to investigate the possibility of applying the most recent edition of the standard indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 5527:1995, *Cereals — Vocabulary.*

3 Definitions

For the purposes of this part of ISO 6322, the definitions given in ISO 5527 and the following definition apply.

3.1 relative humidity: Ratio of the vapour pressure in a sample of moist air to the saturation vapour pressure with respect to water at the same temperature.

4 Aspects of the problems

4.1 Technical factors

The problem of keeping cereals arises at two different stages, as discussed in 4.1.1 and 4.1.2.

4.1.1 Immediately after harvesting, the cereals may sometimes remain moist for periods of time ranging from a few hours to several months. The product is particularly unstable and as a rule it is at this stage that storage conditions are least favourable. It is frequently a question of storage on the farm or in small, not always adequately equipped, silos and storerooms, whilst awaiting the appropriate treatment.

4.1.2 Up to and including the international marketing stage, cereals are stored for anything from a few months to several years at or below a maximum moisture content, the level of which may be fixed in each country. Such storage can be handled by very large bulk storage organizations with modern, well-equipped silos, or other types of bulk storage facility. The type of problem arising varies with the type of store, its condition, location and expected period of storage.

4.2 Environmental and socio-economic factors

Problems peculiar to the keeping of grain vary greatly from one country to another. These variations depend upon the factors listed in 4.2.1 to 4.2.3.

4.2.1 Climatic conditions

Undoubtedly, climatic conditions are one of the most important factors affecting the quality of grain, from growth in the field to final animal or human consumption.

Geographical areas can be roughly divided into the following:

a) hot and damp tropical climates, where deterioration of the grain can be very rapid;

b) hot and dry climates, where cereals are harvested naturally dried and where, because of this, the problem is simpler (e.g. the southern United States of America and the Middle East); however, in these regions the grain can remain hot for long periods after harvesting, which exacerbates insect infestation problems;

c) temperate climates, where part of the harvest may be moist (e.g. Europe);

d) very cold regions posing very special problems such as cereals which have spent some time under snow.

It is frequently the case that some of the developing countries have less favourable climates and are therefore at a disadvantage in the fight against grain deterioration.

4.2.2 Importing/exporting activities of the country

All countries which produce cereals have storage problems at the farm level. Those which export and import grain have further problems. Exporting countries, in particular, have to use storage structures which make it possible to deliver cereals which comply with the often very stringent standards set by official organizations in those countries as well as by the importing countries (especially where microorganisms and insects are concerned). It should be remembered, however, that in many exporting countries it is important that any equipment used should be of low cost.

4.2.3 Technical management development

Some developing countries are not well informed about the many problems and are often ill-equipped to deal with them. On the other hand, the development of modern harvesting techniques (e.g. use of the combine harvester) considerably modifies the specific nature of the first storage (4.1.1) because of the potential influx of moist grain.

The organization of the storage system is very important because of size differences in the storage structures used; the presence of huge quantities of grain can present practical and logistical problems.

At the present time, varying types of more or less advanced storage systems (bulk or sack) exist side by side throughout the world and often in the same country.

It is desirable to segregate lots of grain on arrival at the bulk storage depot according to moisture content so as to avoid mixing damp and dry grain.

4.3 Qualitative factors

Whether or not a cereal is in good condition should be judged in relation to the ultimate use of the cereal: i.e. for human or animal consumption, in the natural state or after processing, or for non-edible industrial products.

The quality factors are usually laid down in regulations which, for each country, determine quality criteria, for example the quality of the grain itself and the permissible quantities of foreign substances (other varieties of grain, insect or rodent residues, residues of pesticides or toxins).

Mandatory quality standards set by importing countries obviously have an effect on the storage problems facing exporting countries. Countries with less advanced storage methods at their disposal may find difficulty in meeting these standards.

Thus, although each individual country may have its own problem, because of international trade there are very great overlaps and many problems which, at the technical and scientific level, are similar; present knowledge makes it possible to formulate guidelines for ensuring the safe storage of cereals.

5 Specific characteristics of cereals as products to be stored

5.1 Cereal seed as a living organism

The resting grain is a living caryopsis in which the germ and the aleurone layer have a reduced rate of metabolic activity which may accelerate very rapidly when the environment is favourable. The endosperm cells are composed essentially of reserve substances (carbohydrates, proteins and, in smaller quantities, lipids), which supply energy for the metabolic processes.

The fundamental metabolic activities of grain are of two kinds, as given in 5.1.1 and 5.1.2.

5.1.1 Respiration, which mainly affects carbohydrates and lipids, occurs under aerobic conditions if the moisture content and temperature of the grain are sufficiently high; the respiration produces carbon dioxide, water vapour and a considerable amount of heat (2 830 kJ per mole of glucose oxidized).

Under anaerobic conditions, a fermentative metabolic process occurs, producing less heat (92 kJ per mole of glucose). The fermented grain has a typical sour-sweet alcoholic smell and has undergone other changes that make it unsuitable for human consumption, although it is suitable for animal feeding.

Oxidation phenomena are normal in stored grain, but take place only at a low rate if grain is dry; care should be taken that no appreciable acceleration occurs, since this indicates that the grain is unsuitable for further storage.

5.1.2 Germination of the seed, which is the normal outcome of its metabolic activity in the presence of oxygen and optimum conditions of moisture and temperature, occurs in several successive stages: imbibition, activation of the enzymes, active cellular multiplication, soon accompanied by cell growth and followed by the development of the young plant; only the last stage is visible externally.

Germination, even in its initial stages, is a serious change in grain already stored or to be stored. It occurs most frequently in wet years, while the crop is still standing in the fields. There are two important practical consequences:

a) chemical change of the reserve substances;

b) increase of enzymic activities: wheat with high α-amylase content, harvested in northern Europe in wet years, is a well-known example.

Such cereals are often unfit for human consumption.

The germination potential, which determines the viability of the grain in general, has to be preserved if the grain is to be used in malting or for seed.

5.2 Microflora

The seed is permanent host to a considerable microflora; most of these microorganisms are cosmopolitan and innocuous, but some produce harmful by-products. Microflora communities present on freshly harvested grain include many types of bacteria, moulds and yeasts.

While the grain is ripening and its moisture content falling, the number of field microorganisms, mainly bacteria, diminishes. When the grain is harvested, it is invaded by storage microorganisms and the field microflora gradually dies out. If the moisture content is below 14 % on wet mass basis, the microflora does not multiply, whereas above 14 % on wet mass basis it does so rapidly. However, the moisture content limit is temperature-dependent (see 7.3).

Thus, at harvest, the qualitative and the quantitative compositions of the microflora depend more upon ecological factors than upon the species of cereal.

During transport and storage, additions to the microfloral population occur.

5.3 Weed seeds and other foreign matter

Most commercial bulks of grain, which have not been screened or aspirated, contain a proportion of other grains, weed seeds, chaff, straw, stones, sand, etc. The vegetable materials may have physical and biological properties that differ from those of the main constituent and may therefore affect the storage behaviour.

5.4 Important physical properties affecting storage

The most relevant physical properties affecting storage are the moisture and temperature conditions of the grain.

5.4.1 A bulk of cereal contains, besides the grains, a considerable interstitial volume of air; for example, in wheat, approximately 40 % of the total bulk volume is air.

The fluid-flow property of bulk grain is such that the grain can be fed into either hoppers or pipelines and makes it suitable for drying or cooling by blowing (or sucking) dry air through it.

5.4.2 Because of the very low thermal conductivity of the grain [0,125 W/(m·K) to 0,167 W/(m·K)], the heat resulting from metabolic phenomena, in the absence of ventilation, builds up locally, bringing about spectacular temperature rises, more especially as the specific heat capacity of grain is relatively low [approximately 1,88 kJ/(kg·K) for wheat with 15 % moisture content]; however, it increases as the moisture content of the grain increases. In addition to inherent metabolic activity, heat may be produced by the activity of microorganisms and insects.

5.4.3 Grain is hygroscopic and gives up or absorbs moisture so as to maintain an equilibrium with the concentration of moisture in the air surrounding it. The relationship may be expressed as a sigmoid curve, which is practically straight over most of the significant storage range between 20 % and 80 % relative humidity. There is some variation in the relationship between moisture content of the grain (usually expressed as a percentage on wet mass basis) and that of the air (usually expressed as a percentage as relative humidity) with temperature. As the temperature increases, the moisture content is lower at a constant relative humidity. There is also some difference between grain which is gaining moisture and that which is losing it; i.e. there is a hysteresis phenomenon in the relationship between the moisture content of the grain and the relative humidity of the intergranular atmosphere. Examples of adsorption-desorption isotherms are given in annex A.

Periodic changes in the relative humidity of the atmosphere only affect the surface layers of bulks of grain, the relative humidity of the interstitial air between grains below the surface being principally controlled by the original moisture content and temperature. Gradients of equilibrium relative humidity and moisture content may be set up by persistent differences in temperature between the surface and the interior of the grain bulk caused by changes in external temperature or heating within the grain mass. The moisture flows down the temperature and vapour pressure gradients to the coolest part of the grain and raises the moisture content there.

5.4.4 The terms "dry", "moist" and "safe" can be applied to grain in storage.

"Dry" or "safe" indicates that the grain has a moisture content at which, taking into account the likely range of temperature to be experienced during storage and transport, there is no risk of appreciable metabolic activity of the grain itself nor of attack by moulds and other microorganisms.

"Moist" grain is that whose moisture content is above that level. The range of "safe" moisture content varies with the crop and is dependent on the temperature (including artificial means of reducing temperature) and period of storage. As a general rule, a "safe" moisture content is one not exceeding that in equilibrium with 65 % relative humidity.

5.5 Preservation of grain quality

It is essential to retain certain indispensable properties in grain which is to be used for human or animal food, for malting or for seed:

a) a certain level of enzymic activity, especially α-amylase, in the case of cereals to be used for bread making;

b) the original nature of the various protein constituents, as these determine the rheological properties of dough;

c) the percentage germination and germinative energy, which should be kept very high for seed and malting barley.

These requirements preclude any intense heat treatment such as heat sterilization which denatures the proteins and limits the use of high-temperature drying systems.

For utilization in food (human or animal) it is obviously essential to maintain the food value of the product (flavour, nutritive elements, nutritious effectiveness) at the highest possible level. It is also necessary to safeguard product hygiene with regard to any possible toxic substances (toxins) and pesticide residues.

6 Deteriorative changes which occur in grain

Causes of changes which occur during storage can be divided into two quite distinct categories:

a) the immediate causes of the deteriorative changes;

b) the environmental factors affecting these causes.

6.1 Causes of change

6.1.1 Enzymic changes

Enzymic changes produced within the grain manifest themselves in a variety of ways. Such changes to proteins, carbohydrates and lipids may occur during storage, but these are insignificant unless the grain is moist.

However, some enzymes, for example the lipases, can be active in dry grain over a long period.

6.1.2 Other changes of biochemical and chemical origin

By their very nature, reactions of biochemical and chemical origin are varied. These reactions generally require fairly high temperatures such as are encountered during drying or as the result of "heating" caused by the activity of insects, moulds and other microorganisms:

a) Maillard reactions which produce many intermediate compounds, the physiological activity of which has been recognized, eventually lead to non-enzymic browning;

b) deterioration of the starch granule structure, which involves very substantial changes, for example damage to the granule and formation of dextrins at the time of drying;

c) denaturation of proteins, which leads to the loss of specific properties such as solubility, rheological properties in the hydrated state and enzymic activities;

d) diminution of the quantity of available lysine;

e) destruction of vitamins (B_1, E and carotenoids).

Some reactions, especially non-enzymic oxidation of lipids, may take place within the normal range of storage temperatures.

6.1.3 External causes: Living organisms

Deterioration may be caused by living organisms; i.e. vertebrate and invertebrate animals and microorganisms. Although the direct effects of attack by living organisms are important, certain indirect effects may be much more serious, especially heating due to the activity of insects and microorganisms and the production of toxic by-products by some of the latter.

The infesting organisms produce carbon dioxide and moisture but can also release enzymes and, thereby, give rise to considerable grain deterioration. Moulds and animals, however, are only active under aerobic conditions.

6.1.3.1 Animal pests: Rodents, birds, insects and mites

As a result of feeding on the grain, animal pests cause tainting and contamination and leave behind damaged grain. Heating caused by the activity of insects within bulks of grain sets up temperature gradients that can result in moisture migration and consequential damage due to development of microorganisms and even germination in extreme cases (usually at the surface of a bulk or the top layer of sacks in a stack).

6.1.3.2 Microorganisms: Moulds, yeasts and bacteria

The nature of damage caused by microorganisms depends on the action of the dominant elements of the microflora; there is often difficulty, however, in separating the effects of attack by microorganisms from inherent changes in the grain itself, both causes being encouraged by similar external factors.

The principal effects of attack by microorganisms are decomposition of the grain, heating and its consequential secondary effect, and the production of toxins and inhibition or loss of viability. There are also allergies produced in humans and animals that come into contact with grain infested with certain species of microorganisms.

6.1.4 External causes arising before storage

Grain can be broken or abraded during harvesting, transport and storage.

Grain harvested by combine harvester has a higher proportion of broken grains than that harvested by reaper binder. The proportion of broken grains is also a varietal characteristic.

Broken kernels of all grains, including those which are internally fissured, are more subject to attack by moulds and other microorganisms and by more species of insects and mites than are entirely sound kernels.

Broken grains are undesirable because enzymic and chemical changes are more likely to occur.

Grains such as rice, barley and oats, from which the husk has been removed, are deprived of protection and, in the case of oats, are more liable to become rancid and to suffer heat damage during kilning, and are very susceptible to insect attack.

Grains of other cereals, weed seeds and other material of vegetable origin may also be more liable to attack than the sound kernels of the main constituent grain.

6.2 Environmental factors affecting the causes of change

The environmental factors of temperature, relative humidity and composition of the atmosphere regulate the chemical and biological changes taking place during storage; their effects are influenced by the duration and nature of storage. Problems of storage and transport are dealt with in ISO 6322-2.

6.2.1 Operative factors in change

6.2.1.1 Time

The rates of reaction and development of the different factors of deterioration need to be known in order to determine the probable period of safe storage, taking into account the various operative causes.

In assessing the factors in relation to temperature and humidity, it should be emphasized that because of the physical properties of grain bulks, changes in temperature and moisture content normally take place slowly. Infestation by insects and microflora can cause a very rapid, possibly localized, rise in temperature and moisture content. It is important to measure the actual conditions in the bulk.

6.2.1.2 Temperature

Temperature influences practically all chemical and biochemical reactions according to a substantially exponential law. This explains the extreme importance of this factor. However, biological activity, especially of insects, mites and microorganisms, tends to be markedly limited within specific ranges of temperature. Thus, heating due to insect activity seldom causes temperatures to rise above 40 °C or that due to microorganisms to temperatures above 65 °C. Oxidative reactions can cause temperatures to rise to ignition point in some commodities but there is no evidence that whole cereals are subject to spontaneous combustion.

6.2.1.3 Relative humidity

Relative humidity is perhaps the most important factor to be considered. Extreme relative humidities (both low and high) can cause deterioration of the grain at a given temperature. The exact relative humidity at which deterioration occurs is temperature dependent.

6.2.1.4 Atmospheric composition

The relative proportions of oxygen and carbon dioxide in the intergranular air affect the nature of the metabolism of any microorganisms and animal pests and of the living cells of the grain. They also influence the level of non-enzymatic oxidation and certain enzymic reactions.

6.2.2 Combined action of environmental factors on the various causes of change

Although it is easy to distinguish between them in theory, in practice these various factors have an inter-dependent, closely linked action which makes their study a complex task. An examination is given in 6.2.2.1 to 6.2.2.8 of some examples relating to the combined action of such factors as causes of change.

6.2.2.1 Vertebrates

Birds and rodents can subsist and multiply on cereals stored under conventional aerobic conditions. The moisture content of the grain is not critical.

6.2.2.2 Invertebrates

Most invertebrate pests of stored grain cannot complete their life cycle at temperatures below 10 °C or much above 35 °C; for most of the serious pests the minimum is about 15 °C, and development is slow below 20 °C. Grain of less than 9 % moisture content is generally secure from attack except by *Trogoderma granarium* Everts (khapra beetle) and *Tribolium castaneum* Herbst (rust-red flour beetle), which breed at down to 3 % to 5 % moisture content. For each species of insect and mite there is a particular range of temperature and relative humidity (moisture content of grain) which is most suitable; *Acarus siro* L. (flour mite), for example, breeds at temperatures down to 3 °C, but needs an intergranular relative humidity of > 65 % (equivalent to 14 % moisture content in wheat).

The subject of attack by vertebrate and invertebrate pests is dealt with in ISO 6322-3.

6.2.2.3 Microorganisms: Aerobic conditions

Microorganisms, particularly moulds, in general do not develop below 65 % relative humidity[1], the equivalent for wheat of a moisture content of about 14 % on wet mass basis at 25 °C. However, the moisture content/relative humidity relationship alters with temperature in such a way that the higher the temperature, the higher the relative humidity corresponding to a particular grain moisture content. At relative humidities higher than 65 %, moulds continue to develop even at low temperatures; this is a particular problem with damp maize.

As with insects, moulds develop more rapidly as the temperature rises and the moisture content of the grain and the relative humidity of the immediate atmosphere increase. They can also cause grain to heat, being capable of raising its temperature to about 65 °C. A succession of different species of microorganisms is involved in this process.

1) However, certain important moulds, for example some species of *Aspergillus*, are able to develop at lower relative humidities.

Since all grain is exposed to mould spores, safe storage depends on preventing or delaying their germination and development.

For storage over an indefinite period and for safe transport, the moisture content in any part of a consignment should not be greater than the equivalent of 65 % relative humidity, at the temperature of the grain at the time of being taken into store or of commencing transportation.

However, the grain may be at a higher moisture content if the temperature is lowered, by aeration with atmospheric air or by refrigeration, to a level at which moulds will not develop to significant levels within the normal period of storage or transport.

6.2.2.4 Microorganisms: Airtight storage

As a general rule, the total bacterial population diminishes during storage, except in the case of very moist grain where such reduction is preceded by an increase in the number of bacteria, mainly lactic bacilli.

Airtight storage prevents the growth of moulds in grain of high moisture content, but certain yeasts are able to develop. Changes in quality at moisture contents above 18 % on wet mass basis make the grain unsuitable for human consumption.

Normally, the activity of the microorganisms produces low-oxygen conditions. These conditions may also be created artificially, for example by a vacuum or addition of carbon dioxide or nitrogen.

6.2.2.5 Enzymic reactions

Most enzymic reactions in grain which require water in the liquid phase occur at the moisture contents at which grain normally commences to germinate.

Certain enzymic reactions may take place during grain drying, their nature depending on the maximum temperature reached during the process and its duration.

6.2.2.6 Denaturation of proteins

The critical temperature at which this occurs during drying by hot air is dependent on the grain moisture content, the duration of drying and the temperature of the hot air applied.

6.2.2.7 Maillard reactions (see 6.1.2)

In general, Maillard reactions require a fairly high temperature, but can also occur at temperatures slightly above 20 °C during periods of prolonged storage. The reactions are inhibited by both high and low moisture contents in the grain but they proceed more rapidly in conditions of low humidity; rates of reaction will have an optimum at an equilibrium relative humidity of 60 % to 70 %.

6.2.2.8 Non-enzymic oxidation

Oxidative reactions limited by the presence of moisture occur mainly at equilibrium relative humidities of less than 20 %.

7 Tests designed to assess the condition of grain

Because numerous changes can occur, it is important to arrange tests to reveal and assess the sanitary condition of a consignment of grain. It will then be possible to forecast storage periods compatible with preservation of the technological and nutritional value of the grain.

7.1 Definition of fitness for storage

The general condition of a consignment of grain has two main aspects.

7.1.1 Current state

This results from changes which have already taken place. It represents the immediate utilization potential value of the grain for a given purpose.

7.1.2 Forecast state

This represents the potential risk of change to the consignment, for a given storage period and in view of its future use. It depends on the current condition of the grain and the risk of the introduction of further causes of change.

7.2 Criteria of acceptance

The criteria of acceptance, together with the corresponding analytical procedures, can be classified as given in 7.2.1 to 7.2.3.6.

7.2.1 Tests directly linked to industrial or nutritional use or use for malting or as seed

These tests are designed to establish whether the grain is suitable for its intended use. They may give information about the maximum time for which the grain can be kept.

7.2.2 Tests indirectly linked with ultimate use

These tests interpret the general condition of the grain by integrating the effects of multiple causes of change; in this category the following methods can be classified.

7.2.2.1 Methods for evaluating the viability of grain

Such methods involve measurement of the percentage germination and the germinative energy.

7.2.2.2 Methods for estimation of total fungal or bacterial microflora

At present, efforts are being made to finalize rapid methods for the evaluation of total microbial contamination.

7.2.3 Tests showing one particular aspect of change

Among such tests the following can be mentioned.

7.2.3.1 Determination of moisture content[2)]

The most important single immediate factor indicating potentiality for storage or immediate use is moisture content. Rapid and accurate determination in each lot is essential.

7.2.3.2 Special microbiological methods

The enumeration and identification of the species prevalent on grain and the characterization and determination of mycotoxins constitute very important tests of the fitness of the grain for human or animal consumption.

7.2.3.3 Measurement of extractable enzymic activity of grain

This includes, for example, activity of glutamic acid decarboxylase and of ribonuclease.

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2) A method is specified in ISO 712.

7.2.3.4 Measurement of results of enzymic action in grain

This includes, for example,

— presence of fatty acids;

— degradation of the complex lipids;

— presence of volatile organic substances;

— degradation of proteins;

— degradation of carbohydrates.

7.2.3.5 Measurement of apparent and hidden infestation by insects and mites

Populations of insects and mites (particularly of immature stages hidden within grains) may make grain consignments unsuitable for certain immediate uses and unsafe for storage.

NOTE — Methods for the determination of hidden infestation can be found in ISO 6639-3 and ISO 6639-4. These methods include a reference method by "breeding out", use of X-rays, measurement of carbon dioxide production, use of the ninhydrin reaction, and flotation.

7.2.3.6 Mechanical damage

This involves measurement of the extent to which grain has been damaged mechanically (broken grains, etc.).

7.3 Storage potential

In order to store grain correctly and with a sufficient degree of reliability, it is essential to be able to calculate the probable maximum period for which it can be kept, taking the following into consideration:

— the available storage conditions;

— the current condition of the grain;

— the ultimate use to which the grain will be put and the quality specifications.

Because of the wide variation in storage conditions and the difficulty, especially under tropical conditions, of predicting the incidence of infestation by insects, it is difficult to make exact predictions in the light of existing scientific knowledge.

However, subject to the provisos of 6.2.2.2 and 6.2.2.3, it may be stated that grainstocks (other than freshly harvested stocks) of which no part has a moisture content exceeding 14 % on wet mass basis remain in a substantially stable condition for periods of up to 12 months at a mean temperature of 18 °C. However, if the mean temperature is 27 °C, it is necessary to reduce the permissible moisture content of bulk grain to 13 % on wet mass basis for periods of storage of not more than 12 months. If the mean temperature is 9 °C, the permissible moisture content may be increased by 2 % on wet mass basis for periods of storage of not more than 12 months, but under these conditions insects and mites will not necessarily be controlled.

The surface of all grain bulks (except those in airtight storage) is in equilibrium with the ambient atmosphere. Thus, even if the bulk is dry (< 14 % moisture content), the surface layers of a few centimetres deep may exceed 16 % moisture content in European and humid tropical conditions.

8 Feasible keeping methods

Although the use of certain methods cannot be contemplated because the cost is too high, the means available are nonetheless varied and, quite often, entail a combination of various allied techniques.

8.1 Stabilization techniques

By modifying the environmental factors, stabilization techniques make it possible to reduce or inhibit the causes of change. Some of them prevent any development of insects or microorganisms; on the other hand, nothing can completely prevent chemical or enzymic changes.

Among possible stabilization techniques are the following:

a) drying, which reduces the moisture content of the grain to a level at which microorganisms cannot develop;

b) cooling of batches or consignments to about 5 °C to 7 °C without prior drying; if the grain moisture content is about 18 % on wet mass basis, this technique can be used only for relatively short-term storage, since grain so stored for a certain period of time (depending on the moisture content) may be attacked by moulds and mites;

c) ventilation by ambient air, which reduces temperature and moisture gradients and removes the heat and water vapour produced by respiration; the airflow can, all other things being equal, also reduce the development of those mites and microorganisms that prefer a draught-free environment; however, ventilation with ambient air may not prevent the development of moulds and mites if the moisture content of the grain is high;

d) airtight storage without drying; addition of carbon dioxide or nitrogen or creation of a vacuum may reduce aerobic respiration but it cannot eliminate fermentation, which may affect the properties of the grain; if the grain moisture content is over 18 % on wet mass basis, this technique can be used only for relatively short-term storage.

e) airtight storage of infested grain of moisture content not more than 14 % on wet mass basis; the respiration of insects causes an increase in carbon dioxide and depletion of oxygen and their eventual death. However, in practice, the artificial introduction of carbon dioxide may be necessary because the insects do not produce carbon dioxide rapidly enough (see 8.3.2.3).

8.2 Techniques for controlling or preventing attack by insects, mites or microorganisms

Methods for the control of insects and mites are given in ISO 6322-3.

Chemical substances which prevent the development of microorganisms are not used in practice for grain intended for human consumption, because of the hazards inherent in their use and the mammalian toxicity of most of them in effective doses. However, with moist grain intended for animal foodstuffs, certain metabolizable anti-microbial substances, such as propionic acid or other similar acids, can be used.

The destruction of microorganisms by heat is inadmissible because of the risk of damaging the proteins. Heat disinfestation for insect and mite control is permissible but should be undertaken with care. The possibility of prolonging the safe storage period of moist grain by gamma irradiation is being investigated.

It is undesirable to mix lots of contaminated grain with lots of uncontaminated grain.

Where wheat for flour milling and other cereals intended for human consumption are concerned, only certain forms of treatment for the destruction of insects and mites are used.

8.3 Combination of various treatments

As a rule, grain requires a certain amount of conditioning in conjunction with storage.

8.3.1 Preliminary treatments

8.3.1.1 Screening

Grain should be screened and/or aspirated to remove all straw, chaff and other leafy vegetable matter. Grains of cereals other that the main constituent grain, weed seeds, fine grain dust and inorganic particles should also be removed.

8.3.1.2 Drying

Grain may be dried in batch or continuously operated driers or *in situ* in the storage place.

Drying can be carried out using either unheated or heated air, taking account of the temperature and relative humidity of the drying air and of the grain to be dried.

If heated air is used for drying, the final operation should be cooling, which is most effectively carried out once the grain is in store.

8.3.2 Storage

There are two major types of storage as follows.

8.3.2.1 Storage under normal atmospheric conditions

This includes bulk storage and storage in bags. All such grain should be regularly examined or monitored for signs of obvious changes in temperature, moisture content and activity of invertebrate pests and microorganisms.

8.3.2.2 Airtight storage

In this type of sealed storage, carbon dioxide is increased and oxygen depleted by the activity of insects or microorganisms until further respiratory activity is stopped. Anaerobic activity may take place under high-moisture storage conditions.

Storage techniques are the subject of ISO 6322-2.

8.3.2.3 Controlled-atmosphere storage

In this type of storage the natural intergranular atmosphere is replaced artificially by carbon dioxide and/or nitrogen, to produce an oxygen-deficient atmosphere lethal to invertebrate pests.

Annex A
(informative)

Adsorption-desorption isotherms

Figures A.1 to A.7 show examples of plots of the moisture content of grain versus the relative humidity of air. These plots were provided by the Institut technique des céréales et fourrages (ITCF), Paris, France.

NOTE — On the figures, the moisture content of grain is given as a percentage on wet mass basis.

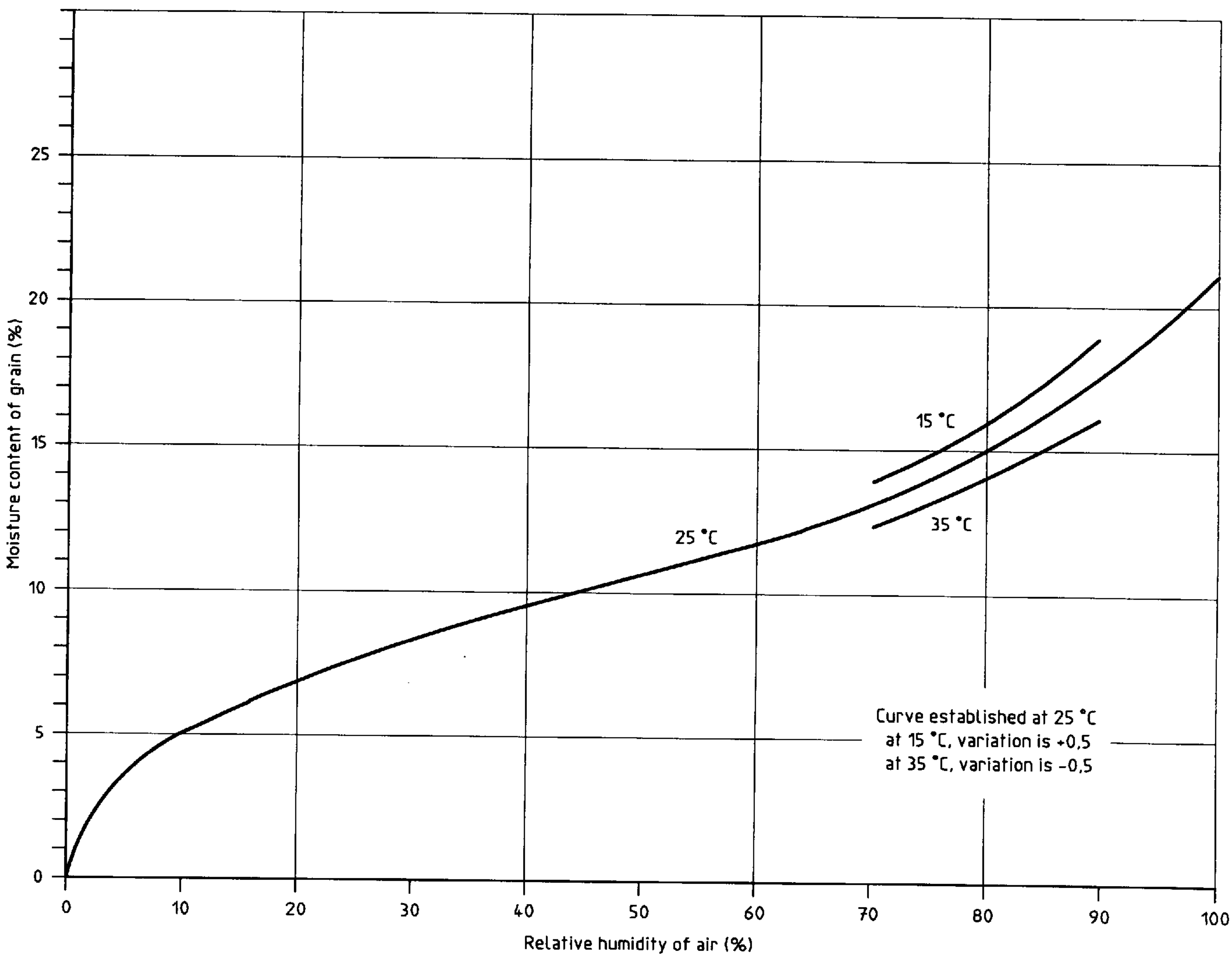

Figure A.1 — Wheat

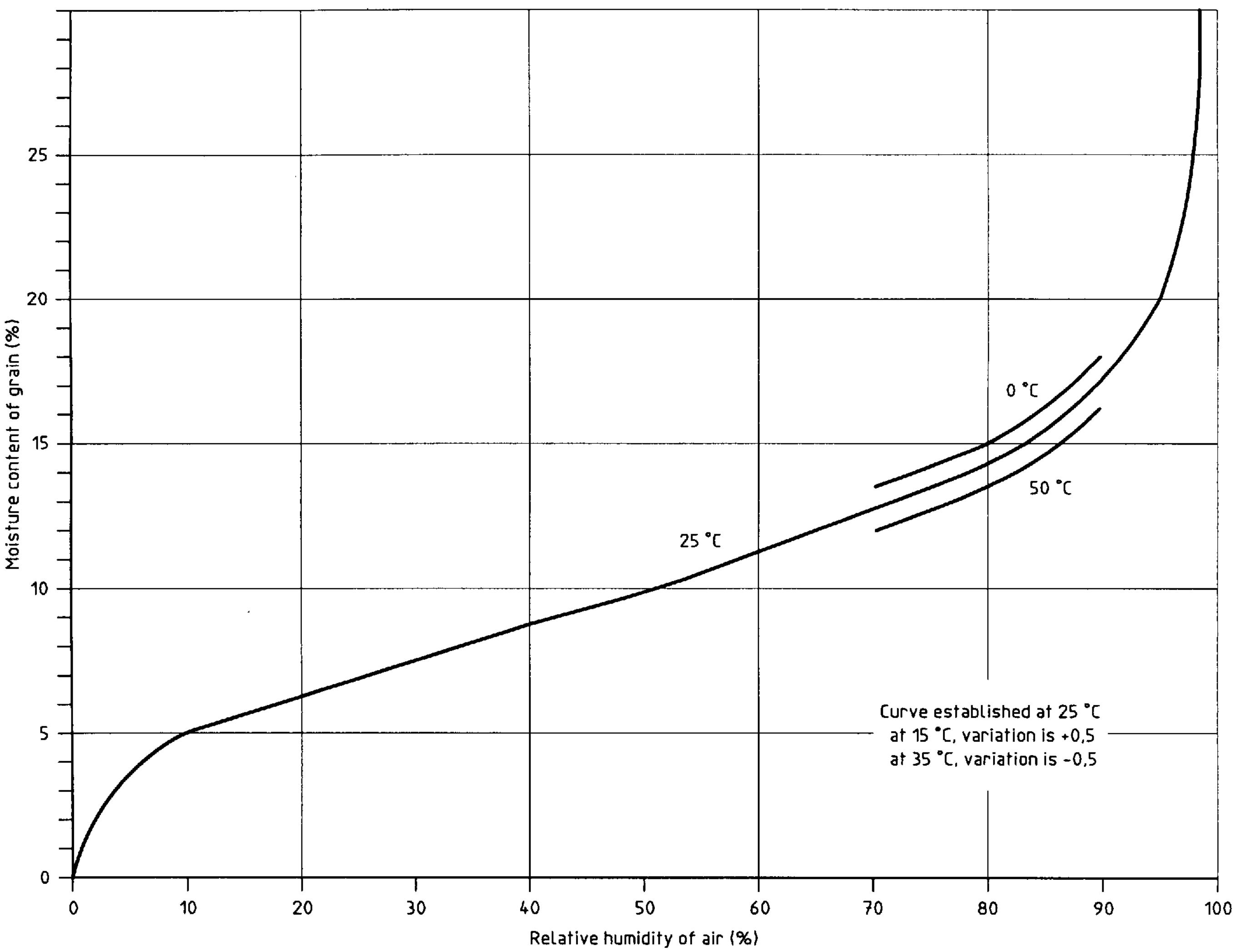

Figure A.2 — Barley

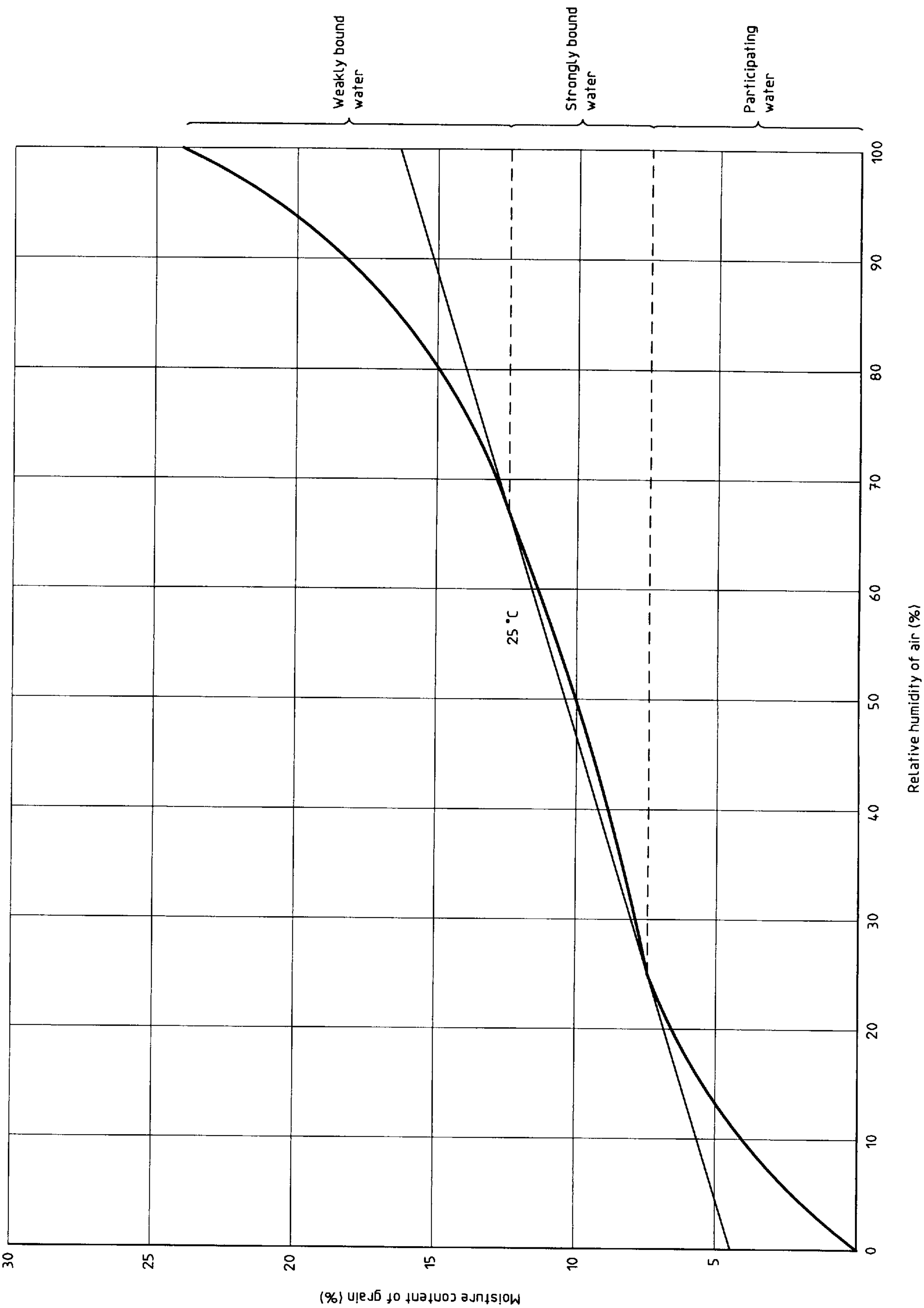

Figure A.3 — Oats

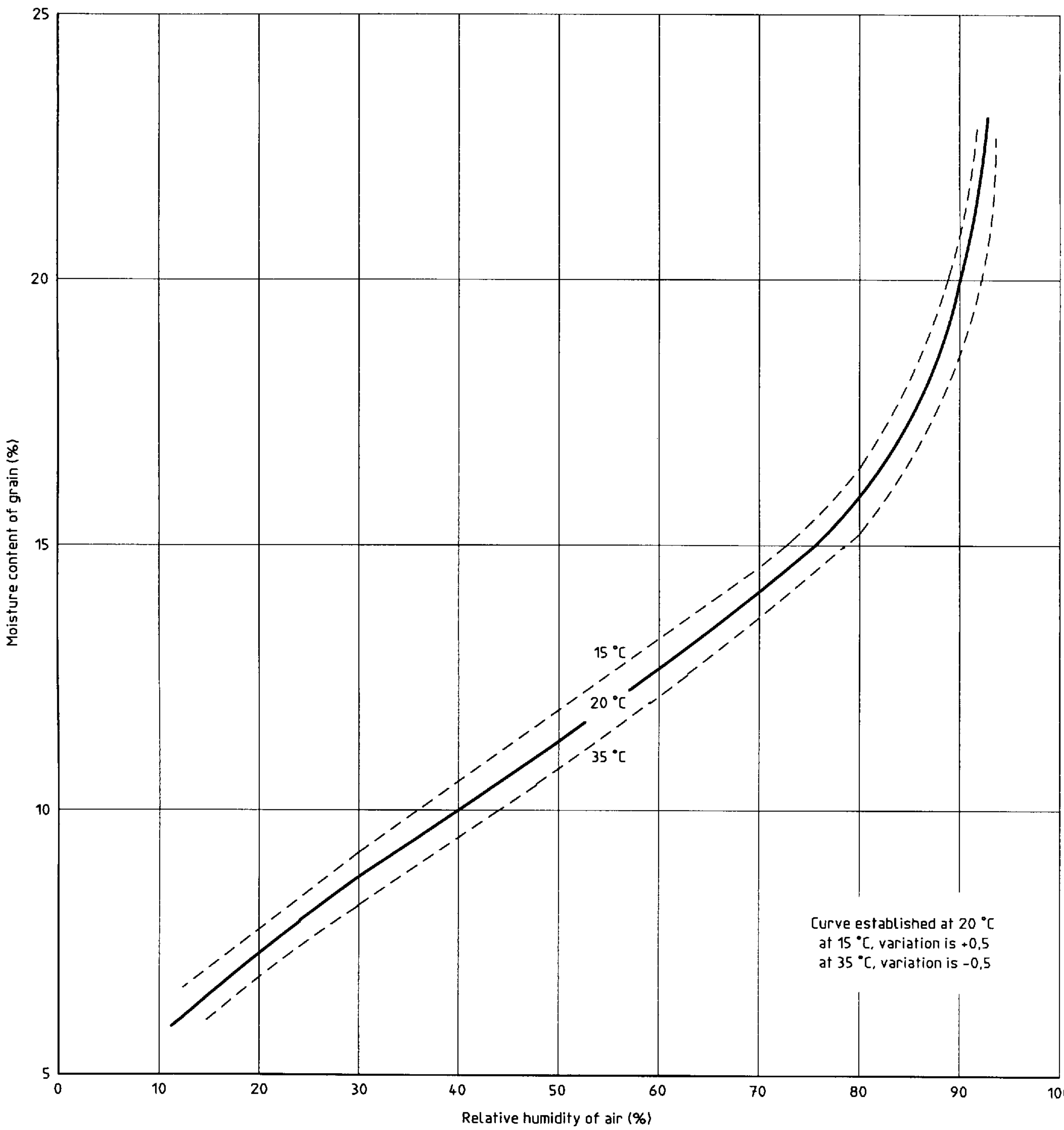

Figure A.4 — Maize

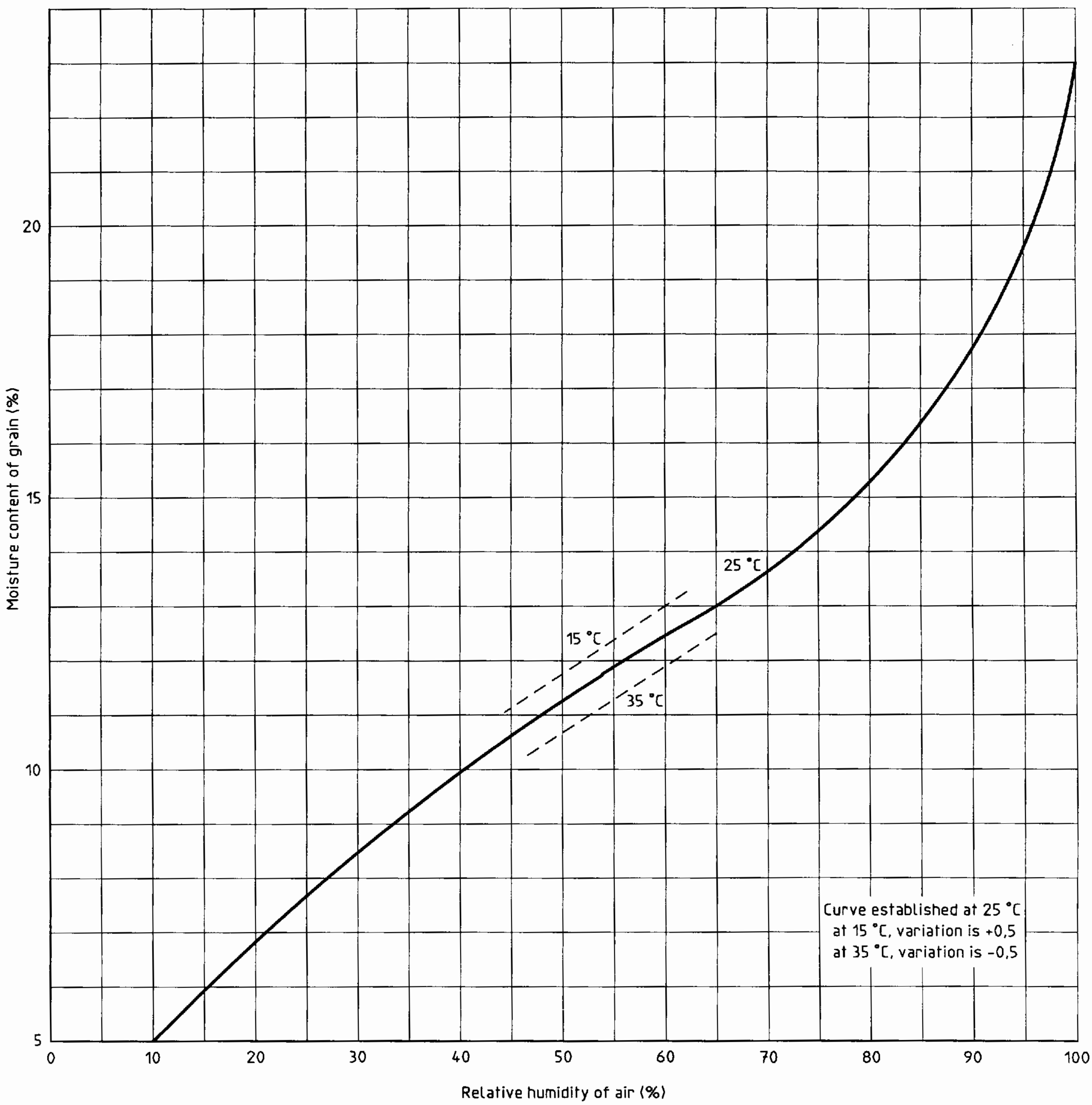

Figure A.5 — Rice

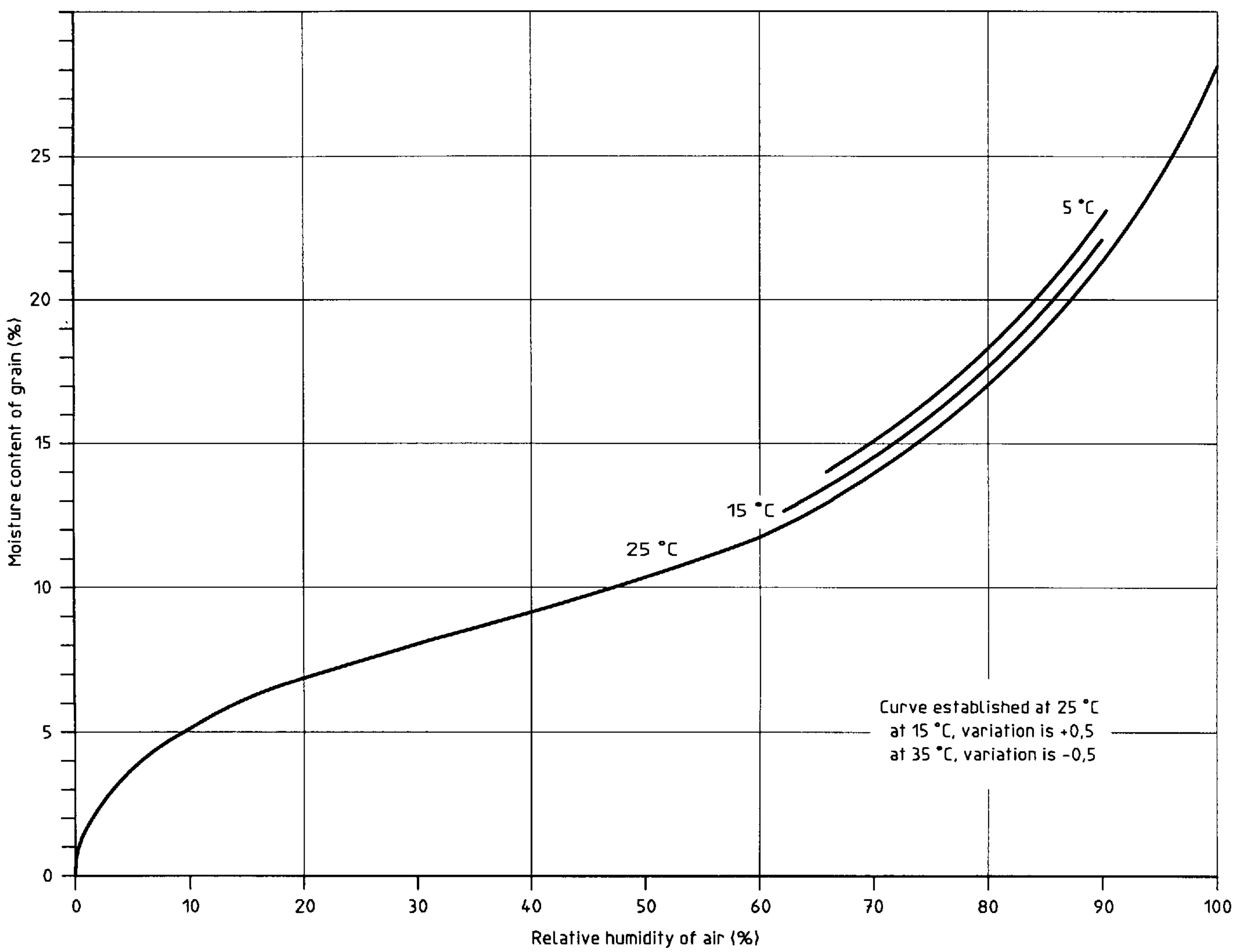

Figure A.6 — Peas

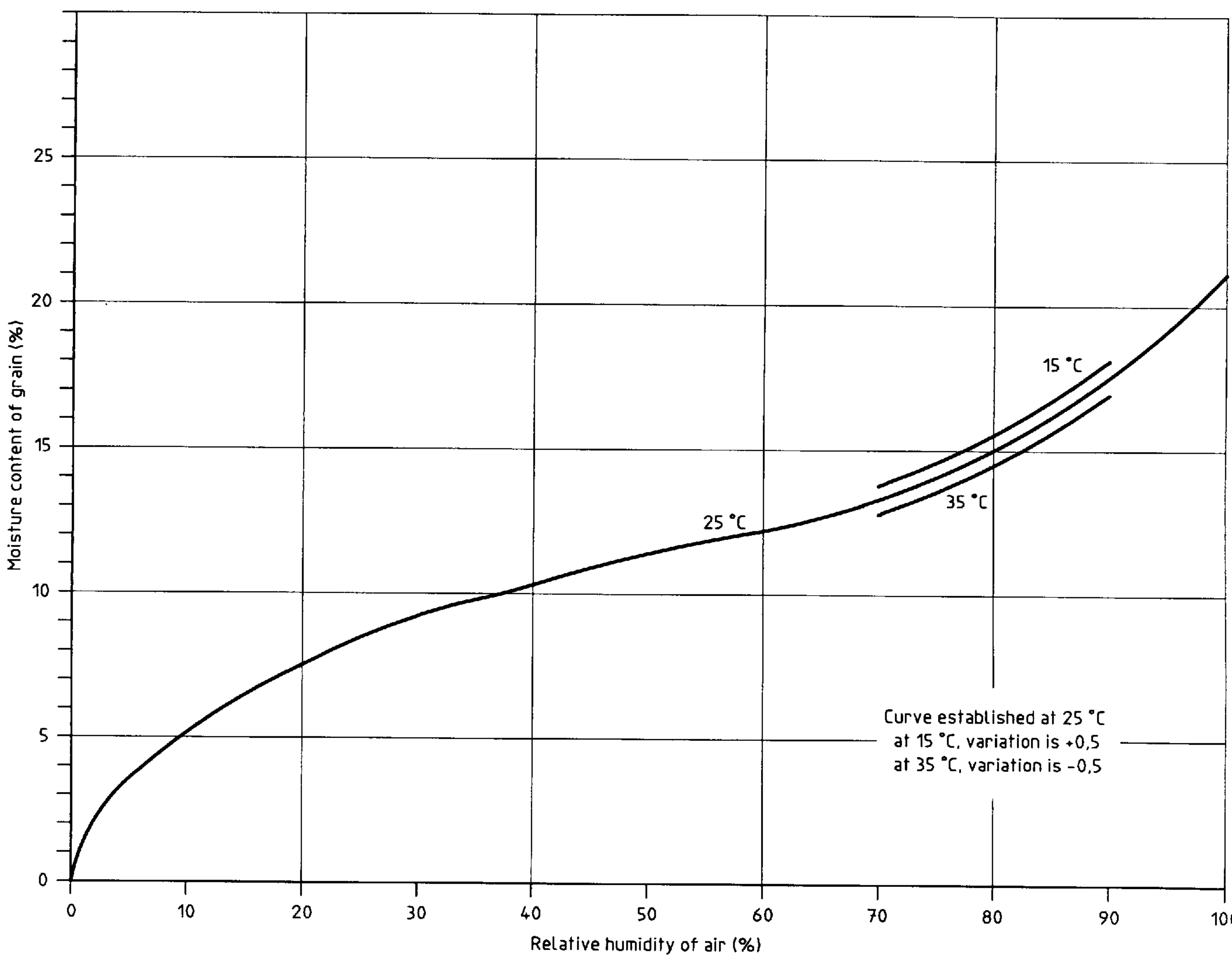

Figure A.7 — Sorghum

Annex B
(informative)

Bibliography

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3) To be published. (Revision of ISO 712:1985)

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