Grain Biology

Worth knowing about Grain Biology
What's happening in your Grain Storage?

KONGSKILDE

Grain biology

To understand the rationale concerning the handling and processing of grain, it is necessary to understand the nature of the kernel and its environment.

The newly harvested grain kernel is a living entity. Grain which is to be used for seed must be kept alive and capable of reproduction. Although non-germinative grain can maintain nutritional value, the grain trade prefers germinative grain also for food and feed purposes. This indicates, that the grain is healthy and well preserved.

Maize, rice, sorghum, wheat, and millet are all cereal grains which belong to the same grain family. These grains do not look alike.

Maize is a large kernel with a triangular shape; it has a hard coat and a large, oily germ which is easy to see in one end of the kernel. Sorghum, on the other hand, is a round seed in a brittle seed coat. The germ is very hard to see.

Although they look different, the grains all share three basic parts: The seed coat, the endosperm, the embryo (germ).

A Wheat Kernel

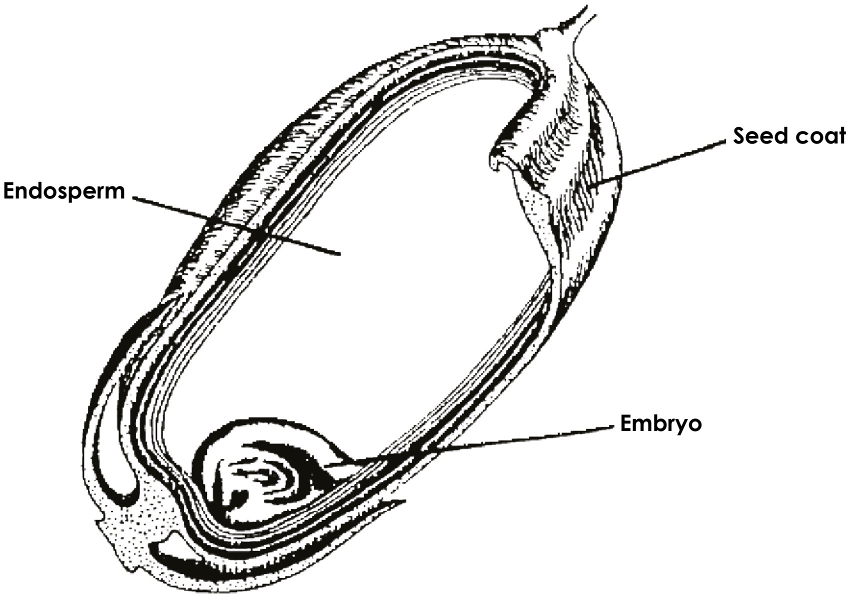

Fig. 1.03

The seed coat

- Surrounds the embryo and the endosperm
- Protects the grain from attack by certain insects if it is dry and uncracked
- Cannot withstand attack by moulds and some insects. Those insects which attack the embryo are most dangerous because the seed coat in the area of the embryo is weak.

The endosperm

- Takes up the largest part of the kernel and makes up 80% of the kernel volume in most grains
- Is mostly starch and protein
- Provides food for the developing seed when planted and food for the seed in storage
- Provides food for humans and others if the grain is not being used as reproductive seed

The embryo

- Is the part of the seed which can develop into a new plant
- Contains most of the protein, fat, and vitamins of the grain
- Is attacked easily by some insects and by moulds. Seed grain which is attacked will not grow into strong plants or will not grow at all. Food grains without embryos do not provide as much nutrition as grains with embryos

Life Activity Respiration of Grain

Germinative grain breathes. Each kernel gets oxygen from the air and burns food from its endosperm. This process gives off heat, water, and carbon dioxide. This process in grain is called respiration.

In many countries, respiration during the storage period is causing a dry matter loss of 1% or more.

1% dry matter loss in 1 ton grain produces:

- 37.600 kcal increasing temp. by 65°C, (if heat is not transmitted).

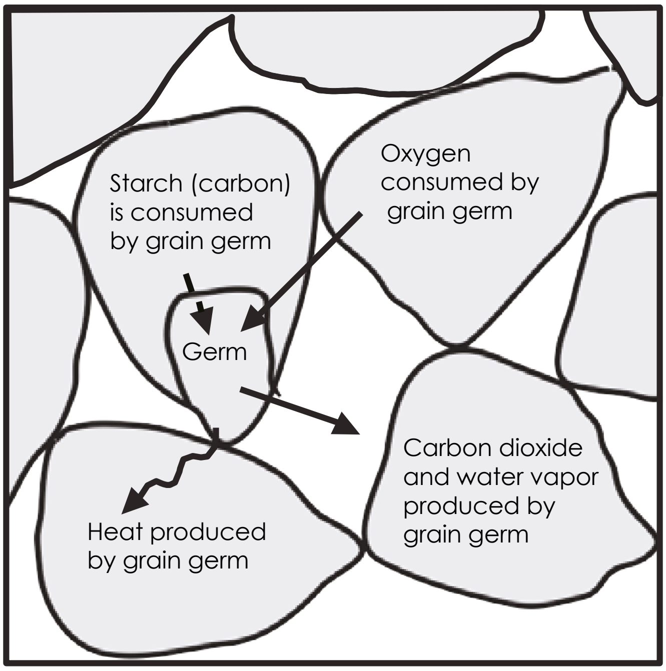

Fig. 1.04: Respiration of grain.

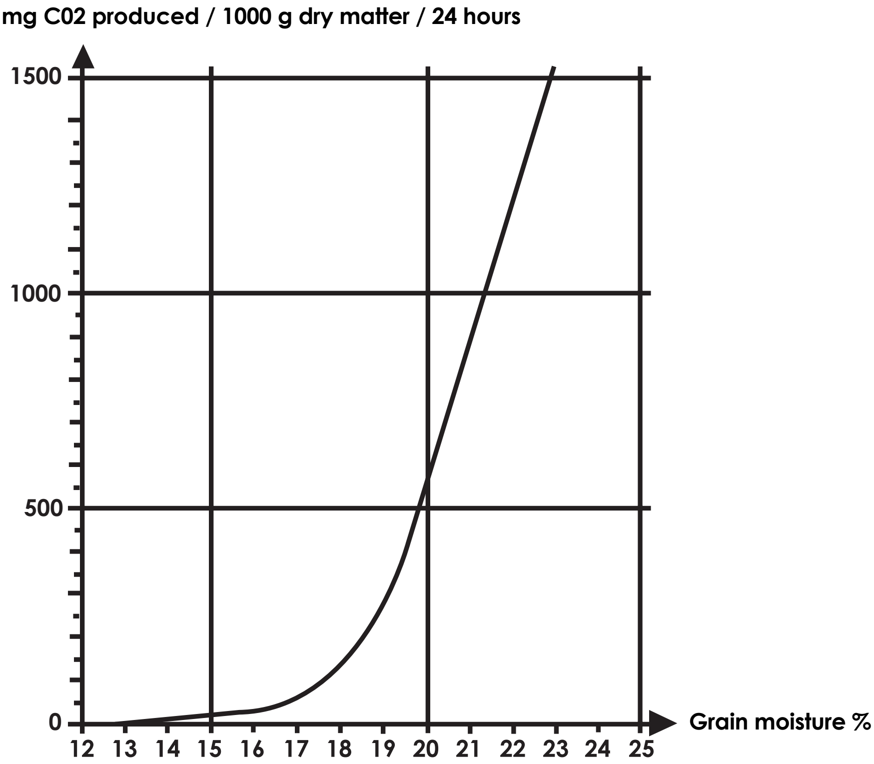

Fig. 1.05: Respiration of wheat and barley.

From fig. 1.05 it can be seen how life activity is increased at higher moisture contents (m.c) at a definite temperature. At higher temperatures the curve is more steep, - at lower temperatures less step, see fig. 1.06.

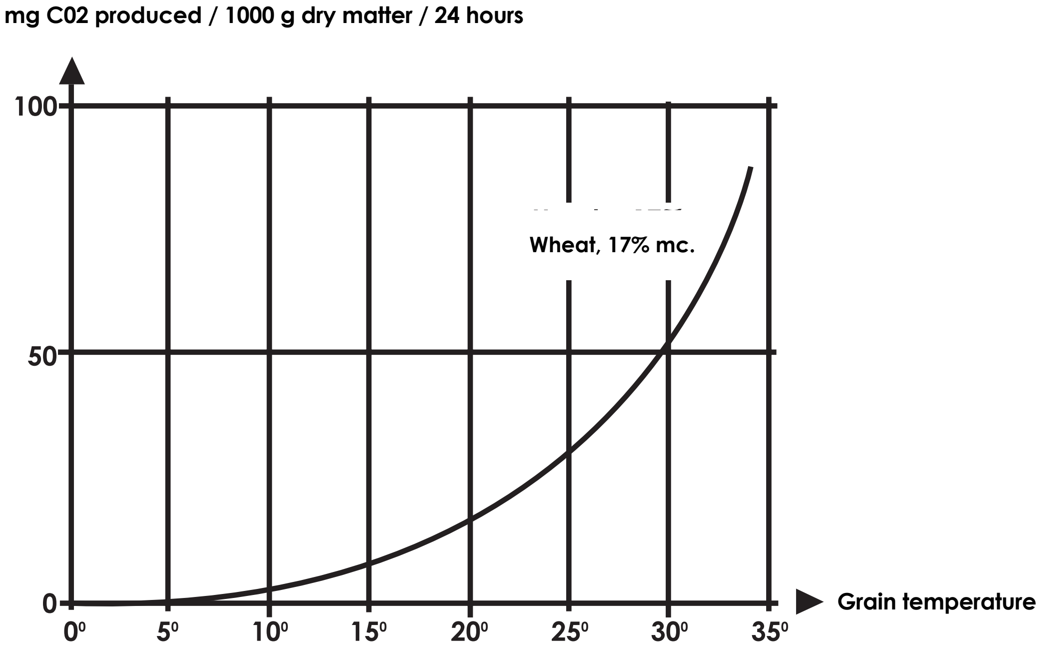

Fig. 1.06: Respiration depend on temperature

From fig. 1.06 it can be seen how life activity is increased at higher grain temperatures for a definite moisture content (m.c). At higher m.c. the curve is more steep,- at lower m.c. less steep.

Respiration of grain produces heat, water and carbon dioxide. This process consumes dry matter from the grain.

Heat and carbon dioxide are also formed by the activity af bacteria, fungi and insects.

Heat and water resulting from the respiration of the grain as well as the activity of bacteria, fungi and insects cause an increase in moisture content and temperature, which again increases the life activity.

The curve in fig. 1.05 have a breaking point at which life activity increases rapidly.

Enemies of Grain

The life activity/respiration producing water, heat and carbon dioxide is in itself harmfull due to the consumption of valuable dry matter.

The real damage to the grain is caused by fungi, insects and mites which thrive under warm and humid conditions.

Therefore, moist grain with a high life activity, producing water and heat, form ideal conditions for fungi, insects and mites, and leads to a fast deterioration if it is not kept under powerfull ventilation or dried immediately.

Fungi
Fungi are small plants without roots, leaves and chlorophyll, therefore they have to live of other materials such as grain. Fungi reproduce by small airborne spores which are spread everywhere by the wind.

There are two basic types: field fungi and storage fungi. Field fungi deteriorate wet crop in the field but die as soon as the grain is brought to the indoor storage.

Storage fungi are found everywhere on farms, grain stores, elevators, etc.

As seen in fig. 1.07, fungi not only kill germination but also produce dangerous toxins; - this is not possible when seed is dried to the below stated minimum moisture content and stored at a low temperature.

Because so much seed and grain in around the world is stored with too high moisture content under inadequate condi tions, storage fungi are considered the major reason for the loss of seed and grain in the world.

Grain with even a minor content of toxins produced by fungi presents a major health risk to humans and animals and is thereby reduced in value.

Fungus	**Crop**	**Minimum m.c. for growth at 20° C**	**Damage**
Aspergillus restritus (species)	Corn, wheat sorghum soybeans	13.5 % 14% 12%	Kills and discolours germs damages germs that it doesn't kill.
Aspergillus glaucus (species)	Corn, wheat sorghum soybeans	14% 14.5 % 12.5 %	Same as above, plus mustiness and caking.
Aspergillus candidus	Corn, wheat sorghum soybeans	15% 16% 14.5 %	Kills and discolours germs very rapidly, heats the grain up to 55°C, discolours entire kernel, spoilage follows almost immediately.
Aspergillus flavus	Corn, wheat sorghum soybeans	18% 19% 17%	Same as above, plus production of "insignificant" amounts of cancer-producing toxin.
Aspergillus ochraceus	Corn, wheat sorghum soybeans	15% 16% 14.5 %	Kills and discolours germs, produces "insignificant" amounts of cancer-producing toxin
Penicillium (species)	Corn, wheat sorghum soybeans	16.5 % 17% 16%	Kills and discolours germs and whole kernels, probably (but not proven beyond question) highly toxic to animals, especially poultry.

Note 1. The most favourable temperature for the above fungi is between 26° and 30° C. Minimum temepratures are as follows:
A. restrictus 5°C, A. glaucus 0°, A. candidus 10°, A. flavus 10°, and Penicillium - 5°C.

Note 2. The toxins mentioned above, and all other fungi toxins, have only been known during the past 50 years, - the toxin from A. flavus was the first economically important toxin chemically identified, when, in 1961, it killed (and caused to be slaugtered) hundreds of thousands of turkeys in England. It is interesting to observe, that scien tific books published as late as 1974 still list as "insignificant" the toxin that killed the turkeys.

Fig. 1.07: Minimum m.c. of various seeds and grains to make growth of fungi possible.

Fungi-attacked kernel

Insects
Attack of insects is another major source of seed and grain losses, especially in tropical countries. In warm climates insects are often joining the grain on its way from the field to storage.

Under favourable conditions, - temperatures between 28°C - 38°C and grain with a high moisture content, which makes the kernels soft and easy to attack and giving an ideal food mixture of dry matter and water for insects to thrive on - each female can produce up to 400 eggs within a couple of months.

Under such conditions insects and their larvae can consume considerable amounts of dry matter and seriously spoil germination capacity.

Such insect-attacked kernels are with their holes left com- pletely open to attacks of fungi.

It is obvious, that the lower the moisture content and the storage temperature, the smaller the problem of insects will be.

Still, it is not normally economical to dry the grain to the minimum moisture content for reproductions of insects - this would takes too much energy and cause too much cracking of the grain during the handling and cleaning process.

The fact that most insects, eggs and larvae are killed at temperatures above 42°C gives some kind of protection when grain entering an installation passes through a hot air drier.


Granary Weevil
(Sitophilus Granarius)

Insect	Minimum moisture necessary for reproduction	Minimum m.c. for growth necessary for survival	Damage
Rice Weevil (Sitophilus Oryzae)	9%	8%	Drills holes in and eats germs of rice and corn causes serious losses of weight, quality and nutrition.
Maize eevil (Sitophilus Zemais)	9%	8%	Eats rice and corn, spoils whatever it touches.
Granary Weevil (Sitophilus Granarius)	9%	8%	Eats and contaminates every kind of grain
Pulse Beetle (Callosobrushus Maculatus)	Not certain	Not certain	Eats a large part of the bean harvest every year.
Grain Moths (Ephestria Cautella, Corcyra Cephalonica, Silotraga Ceralella)	Not certain	12%	All 3 eat all kinds of grain leave much debris, cause serious loss of weight and quality.
Grain beetle (Tribolium Castaneum)	Not certain	10%	Severely damages all stored grain.
Khapra Beetle (Trogoderma Granarium)	Not certain	Not certain	Eats every kind of grain, spoils the oil from ground nuts and oil seeds.
Note 1. Many other equally destructive grain insects have been omitted because of lack of space, - the list goes on indefinitely.			
Note 2. Grain insects die at temperatures above 42° C. Experts disagree whether they also die below 16° C or are just made inactive.			

Fig. 1.08: Minimum moisture content of the grain for the survival of insects.

Mites
Although more than 80 species of grain mites are known, these have never received the same attention as e.g., insects, because they are more difficult to see and they eat less grain than insects.

Especially in temperate climates mites are a serious pest. They need a grain m.c. of min. 14-15% and can survive at temperatures down to 5°C.

Existence of mites indicates too high grain m.c. for safe storage. This also means that fungi is active. Even a small number of mites can damage the grain by spreading fungi and toxins.

The best way to control mites is to dry the grain to 13-14% m.c.

GRAIN STORAGE

Grain storage methods rely on controlling the relevant critical level of one or more of the following three main factors:

a) oxygen availability; b) temperature; c) water (grain moisture content), as shown in fig. 1.09.

Factor	Controlled	Method
a) Oxygen	Until absent	Seal grain in airtight container; initial respiration absorb oxygen supply; further activity prevented
b) Temperature	To low level depending upon moisture content	Chill by refrigerated air: or ventilate with low rates of air flow (10-20 m^3/h/t)
c) Water (grain m.c.)	To around 14% depending upon future use and period to be stored	Variuos: Bulk ventilation using low to moderate temperature rise; or high temperature drying air.

Fig. 1.09: Factors affecting life activity and grain storage.

Today, on grain producing farms and in the grain industry, the most common method of grain preservation in use is by far to dry the grain to a suitably low moisture content (m.c.). All systems rely on the same basic principle, viz., air of suitable quality when passed through the grain will absorb and carry away moisture.

To obtain a safe storage of grain the moisture content must be reduced to the point giving a low level of respiration and fungi and insect activity. Please see fig. 1.05, fig. and fig. 1.08.

This manual will only deal with the principles for preservation of grain by drying to a safe m.c. followed by ventilation cooling the grain.

The influence of grain temperature and moisture content on storage ability is shown principally in fig. 1.10.

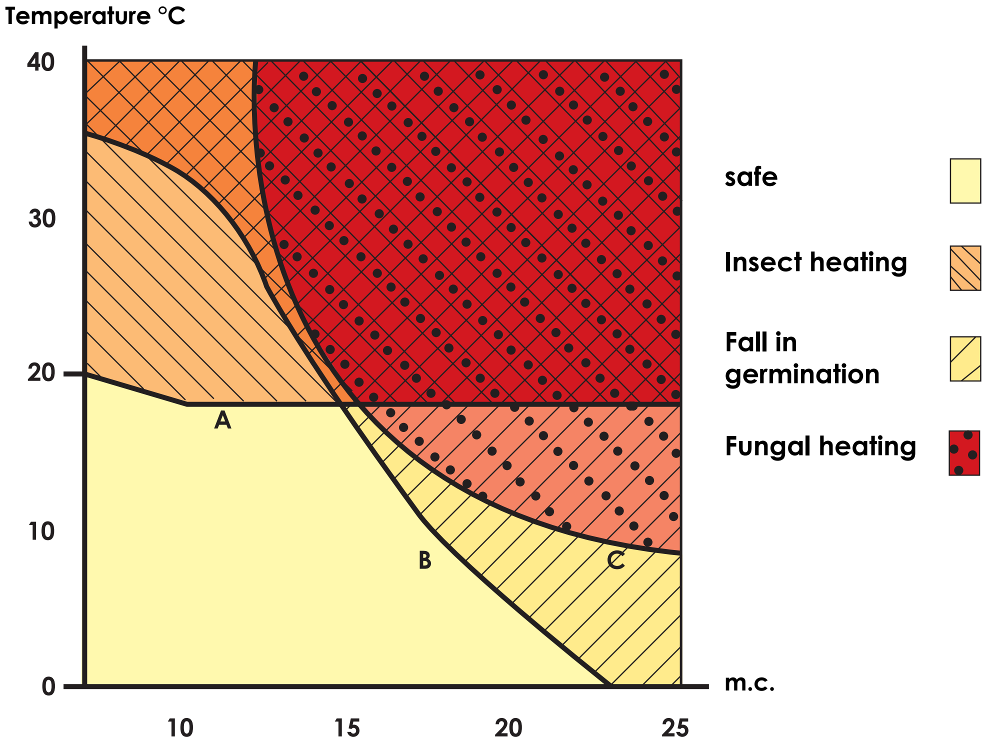

Fig. 1.10 Values of grain temperature, relative humidity and moisture content for safe storage, insect and fungal heating, and fall in germination.

A) Lower limit for insect heating.
B) Lower limit for germination.
C) Lower limit for fungal heating.

Looking at the figure the following points emerge:

1. The general information given in fig. 1.10 is, that the higher the storage temperature, the lower the moisture content must be, and the lower the storage temperature, the higher the moisture content can be before grain deterioration.

2. Even at 16 per cent moisture content, quite low temperatures are necessary [<4°C (40°F)] for completely safe storage through the winter.

3. No grain should be stored warmer than 15°C (59°F) - the need to cool grain which is dry enough to store directly from the combine becomes obvious. A good ventilation system can cope with this in temperate climates.

4. To be absolutely free of mite risk, a moisture content of 12 % or less and a temperature not exceeding 3°C (37°F) are indicated. Since the average farm storage conditions are likely to be at a higher moisture content and temperature level, the need for good store hygiene and regular disinfestation measures is emphasized.

5. Not all damage to grain is visible to the eye. When storing seed grain, malting- or bread grain, the closest watch on conditions during storage should be maintained by frequent inspection.

6. Fig. 1.10 is based on work carried out under laboratory conditions using clean, undamaged grain. In practice, combined grain contains fragments of green material, also damaged and broken kernels whose presence must tend to further reduce the actual margins of safety.

Some important issues

Before discussing drying principles some important issues must be kept in mind:

Grain moisture content (m.c.)

Due to the hygroscopic nature of grain, moisture will be absorbed or released from the kernel when it is exposed to humid or dry conditions.

In the seed and grain trade, moisture content is defined on wet basis, as follows:

$$\text{Moisture content} = \frac{\text{water weight}}{\text{(water + dry matter) weight}} \times 100\ \%$$

Moisture content of grain can be accurately determined by the "Oven Method". A sample is placed in a hot oven, normally with forced air circulation, long enough for all moisture to evaporate. On the basis of weight of dry matter and initial weight the moisture content can be determined.

Loss in weight on drying grain

If 100 kg of grain at 20% m.c. were to be dried to 15% m.c., the weight loss would be not 5 kg but in fact 5.88 kg. The reason is that before drying, the 100 kg of grain consist of 80% dry matter and 20% water. After drying, 85% of the weight is the same dry matter and only 15% is water.

Fig. 1.11 allows a direct reading of the amount of water to be evaporated from 1 ton of damp grain at various moisture reductions.

Initial Moisture Content %	**Final Moisture Content %**									
	19	18	17	16	15	14	13	12	11	10
30	136	146	157	167	176	186	195	205	213	222
29	125	134	145	155	165	174	184	193	202	211
28	111	122	133	143	153	163	172	182	191	200
27	99	110	120	131	141	151	161	170	180	189
26	86	98	108	119	129	140	149	159	169	178
25	74	85	96	107	118	128	138	148	157	167
24	62	73	84	95	106	116	126	136	146	156
23	49	61	72	83	94	105	115	125	135	145
22	37	49	60	71	82	93	103	114	124	133
21	25	37	48	60	71	81	92	102	112	122
20	12	24	36	48	59	70	80	91	101	111
19		12	24	36	47	58	69	80	90	100
18			12	24	35	47	57	68	79	89
17				12	24	35	46	57	67	78
16					12	23	35	45	56	67
15						12	23	34	45	56

Fig. 1.11: Weight in kg of water lost when one ton of damp grain is dried.

It is important to remember, that the weight loss in fig. 1.11 is for water only as other losses occur during drying. Harvested grain contains field dust, grain fragments and also green material and, on drying, these break down to small lightweight material which is lost during handling, when extracted by the grain drier fans or during cleaning. The dirtier the ex-field sample, the greater the loss, and because of this variability, there is no accurate way of calculating weight loss from drying other than that from evaporation of water.

Relative humidity (RH)

The amount of moisture which a volume of air can absorb is determined by its RH. At any given temperature, air cannot carry more than a fixed amount of water in the form of vapour.

When it is carrying this amount, the air can be regarded as "full" of water vapour and is usually described as being "saturated" or "at 100% RH". During fog or rain, the RH of the atmosphere will approach 100% whereas, on a bright summer day, the RH may fall to 40% and occasionally below. Air which is not saturated, i.e., less than 100% RH, can absorb moisture and thus exert a useful drying effect on the crop being exposed to the air. Technically speaking, such air will absorb moisture from the crop provided the vapour pressure of the air is less than the vapour pressure within the crop: the greater the difference, the greater the absorption capacity or drying potential of the air.

Example:

1 m^3 of air of 20°C contains 5.25 grams of water.
1 m^3 of air of 20°C can, at the saturation point, contain 17.5 grams of water.

The RH is: $\frac{5.25\ \text{g}}{17.50\ \text{g}} \times 100\% = 30\%$

This means, that one m^3 air with a RH of 30% and a tempera- ture of 20°C has a capacity to take up (17.5 - 5.25) = 12.25 grams of water before the saturation point is reached.

When air is heated, the RH will go down - it means the capacity to take up water is increased. This is the principle upon which all hot air drying is based.

Exact data on air RH versus temperature changes can be obtained from a psychrometric chart.

An extract useful for grain drying is given in fig. 1.12.

Temperature increase, °C	0	6	11	17	22	28	33	39	45	50	55	61
Air temperature °C	**Percent**											
43	95	72	55	42	33	26	21					
38	95	71	53	40	31	24	19	15				
32	95	70	52	40	30	23	18	14	12			
27	95	70	50	38	29	22	17	13	10	8		
21	95	69	49	36	27	21	16	12	9	7	6	
15	95	67	49	36	26	19	14	11	9	7	5	4
10	95	66	47	32	24	18	13	10	8	6	4	4
4	95	64	45	31	22	16	12	9	7	5	4	4

Source: Dr. S.M. Henderson, University of California.

Fig. 1.12: Reduced relative humidity resulting from an increase in temperature

For low temperature grain drying, an average change in RH of 4,5% per 1°C change in air temperature is a useful rule of thumb.

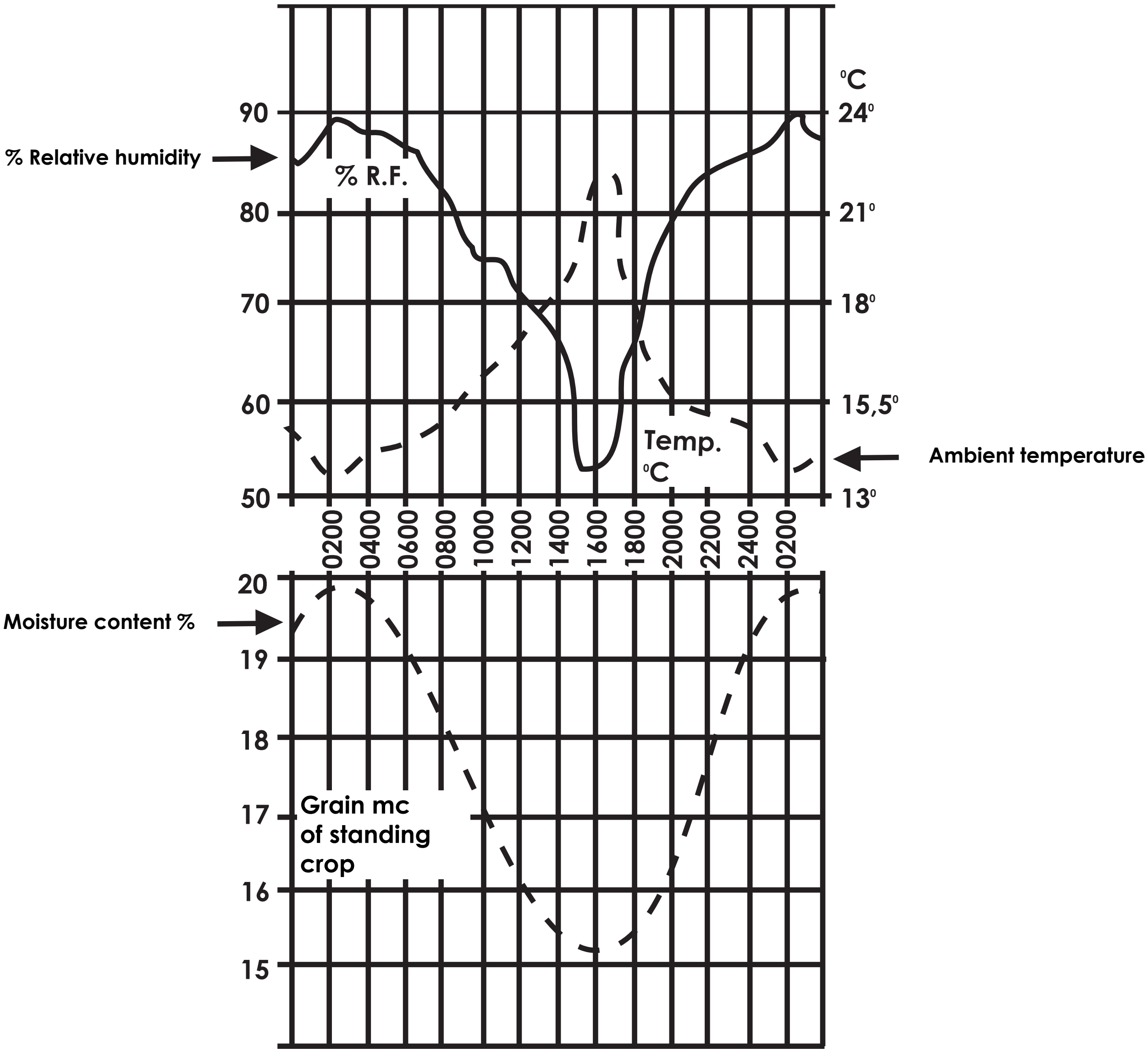

Fig. 1.13: Variation of temperature, relative humidity and m.c. of standing grain on a typical August day.

From a psychrometric chart it can be seen, that one % decrease in RH increases water absorption capacity many times more at high temperatures than at low temperatures. It means, that drying at an air temperature of less than 10° C is almost impossible, and that continuous-flow driers at an air temperature of 100°C have a tremendous absorption capacity. As a rule of thumb you can say, that the same kcals of heat give a much higher water absorption capacity at higher than at lower temperatures.

Grain drying

The drying mechanism is based on the fact, that all granular materials exposed to air will after some time reach a moisture content in equilibrium with air RH.

Ambient air % RH	40	50	55	60	65	70	75	80	85	90
	Grain equilibrium m.c. %									
Barley	10.1	11.8	12.6	13.4	14.3	15.2	16.5	17.8	19.4	21.9
Wheat	11.0	12.2	13.0	13.5	14.3	15.2	16.3	17.3	19.0	20.5
Oats	10.0	11.3	12.0	12.5	13.3	14.0	15.4	17.0	19.3	22.6
Rye	10.7	11.6	12.4	13.2	14.0	14.8	15.8	17.0	19.0	21.5
Rape	5.7	6.6	7.0	7.5	8.0	9.0	10.0	11.3	12.7	14.3
Peas	10.3	11.9	12.7	13.5	14.3	15.0	16.0	17.1	19.0	22.0
Maize	9.8	11.3	12.1	12.9	13.5	14.2	14.8	16.2	17.7	19.1
Paddy rice	9.2	10.5	11.2	11.8	12.5	13.3	14.0	15.2	16.4	17.6
Sorghum	9.9	11.1	11.5	12.0	13.1	14.1	15.2	16.4	17.6	18.8
Grass seed*)	9.2	10.5	11.1	11.8	12.8	13.8	15.4	17.0	19.4	22.5
Hay *)	8.0	11.0	12.8	15.0	17.0	19.5	24.0	29.0	-	-

*) Some variation according to quality.

Fig. 1.14: Grain moisture content in equilibrium with air relative humidity, 15°C.

To have a drying effect of the air, it is necessary to have RH values somewhat lower than the equilibrium figures indicated in fig. 1.14.

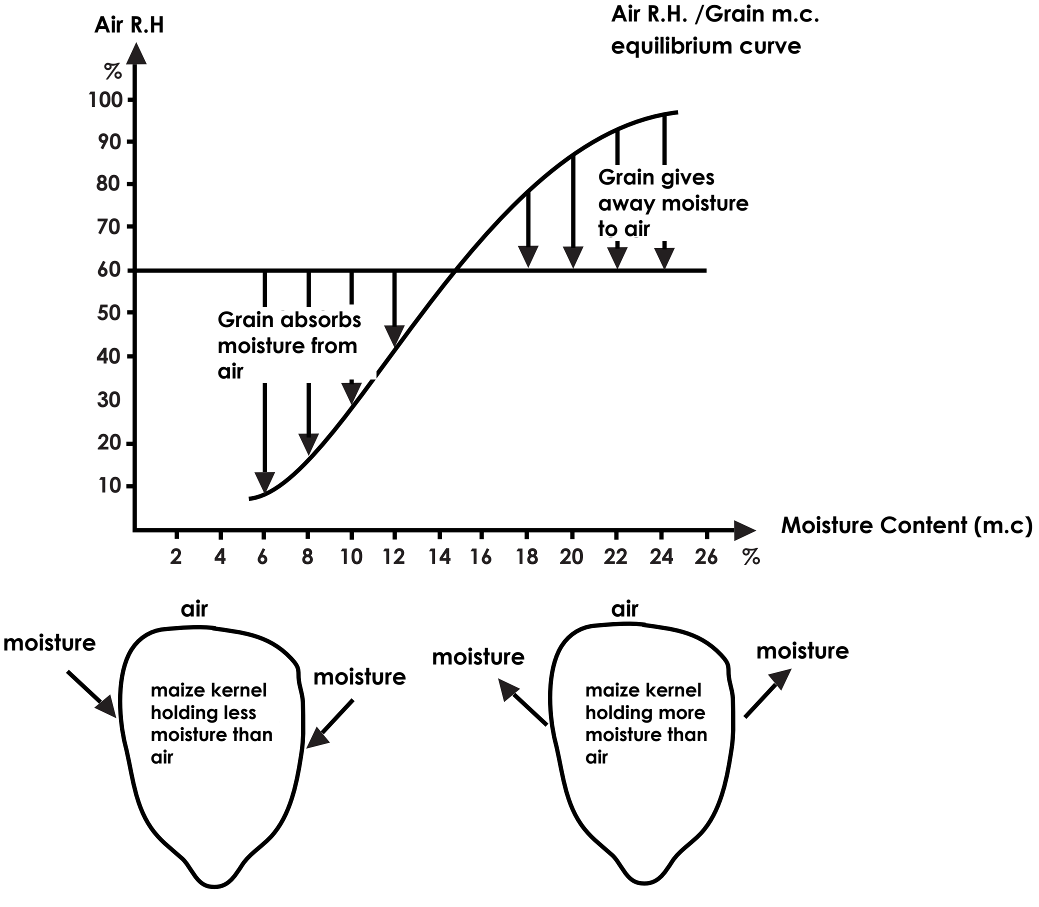

Fig. 1.15: Exchange of moisture between air and grain.

The lower the RH value of the drying air compared to the equilibrium RH corresponding to the desired m.c. for the grain, - the faster the drying will proceed.

When air is heated up the RH will go down, - it means the capacity to absorb water is increased. This is the principle upon which all warm air drying is based.

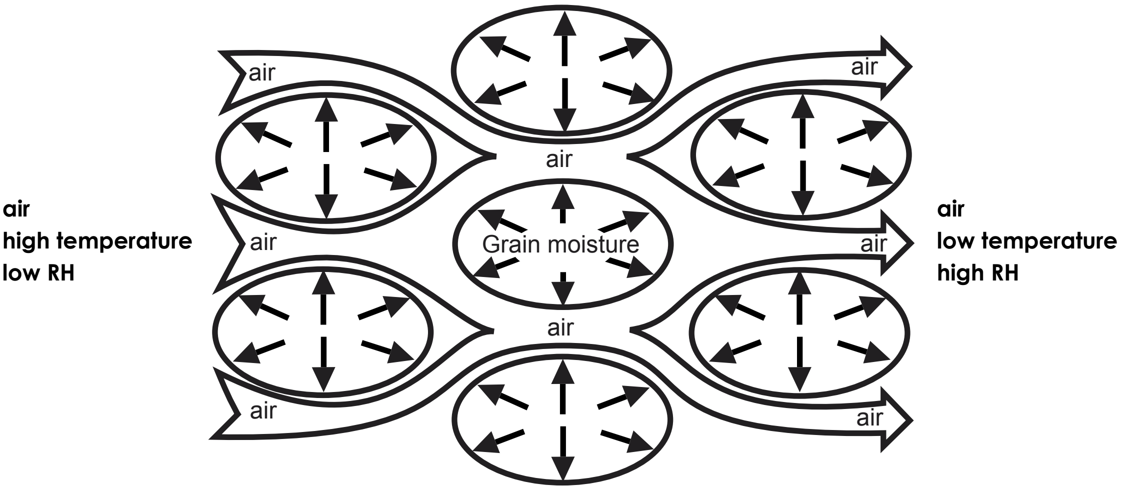

Fig. 1.16: Exchange of heat and moisture between air and grain.

When heated drying air passes around a kernel, some heat will be absorbed by the kernel giving energy to evaporate water from the surface.

It means, that the drying air after the passage has a slightly lower temperature and a higher moisture content.

The kernel has lost water and has been heated up slightly.

It is only very close to the end of the drying sequence that the kernels obtain a temperature close to the drying air temperature, because the evaporation of water consumes most of the heat.

The capacity of the air to take up moisture is much higher at high temperatures and, also, the internal transfer of water inside the kernel takes place faster at high temperatures.
Therefore, high temperature drying gives high capacity and low specific energy consumption and only has limitations, if grain cracks are to be avoided and germination maintained.

The internal transportation of water inside a kernel should take place almost as fast as the evaporation from the surface of the kernel, - otherwise there will be a dry shell around the inner part. Such a shell can slow down the drying, and the outer layers can shrink so much that cracks will develop all over the surface.

Such cracks may be microscopic but can lead to complete breaks at a later stage, e.g., during conveying.

Note! It is very difficult to determine what process actually causes cracks as these microscopic cracks often start in the field. In many climates, the sun is so powerful that the change from night to sunny day will develop such cracks - also, the threshing often creates cracks.

As drying capacity increases drastically with increase in dry- ing air temperatures, it has always been desirable to design driers to work at high temperatures.

The biological qualities such as germination, content of vitamins, baking quality and the fact, that cracking of grain should be avoided, - since whole grain are much better protected against attacks of fungi and insects, - set certain limits on how much the grain kernels can be heated. As seen in fig. 1.17, this temperature sensitivity depends upon the grain moisture and the time the grain is exposed to the temperature.

Exposure Time	**Moisture Content (m.c)**			
	15 %	20 %	25 %	30 %
	Max. grain temperature °C			
15 min.	59	55	52	50
30 min.	56	52	49	47
1 hour	53	49	46	44
2 hours	50	46	43	
8 hours	44	40		
24 hours	39			

High grain temperatures kill the germination and may crack the grain

Fig. 1.17: Max. grain temperature versus exposure time and m.c. for seed and bread grain.

It is important to distinguish between drying air temperature and grain temperature.

High air temperatures may cause high grain temperatures as done in static batch driers, or only result in rather low grain temperatures as done in contiuous mixed flow or recirculating driers where grain is continuously moving from hot air zones to less hot air zones, and on to hot air zones, etc..

Recommended drying air temperatures depend totally on the design of the drier.

E.g., in a static batch drier, where grain is constantly exposed to the hot air for several hours, the drier has a limit of app. 43° C drying air temperature for seed grain.

In a continuous flow drier with lateral ducts, a drying air temperature of 65° C often results in a grain temperature of 40° C and the drying sequence lasts only for app. 1 hour. Such a high drying temperature is no more harmful to the grain than the low temperature in the static batch drier.

The maximum drying air temperature from a specific drier depend upon the use of the grain; - e.g. for consumption, a higher air temperature can be used; or for seed grain, a lower air temperature must be used to preserve germination.

Generally, grain with a high moisture content should be dried at a lower air temperature than grain with a low moisture content.

Various grains give off moisture at different speeds according to the size, kind of kernel structure and initial moisture content.

Species of Plant	**Percentage of Moisture Content (m.c)**				
	22 %	20 %	18 %	16 %	14 %
Broad bean	70	40	25	15	8
Lupine, Peas	165	95	55	35	20
Wheat	210	150	100	65	35
Rye	225	175	115	70	35
Oat	450	250	150	100	60
Rye grass	750	400	250	160	100

Fig. 1.18: Relative factors for moisture evaporation (Laboratory data).

More about our automatic dying control system for on floor storages.

Principle of PST
The PST system consists of a special automatic star/delta starter, which should correspond to the size of the blower, an outside humidistat, and a humidistat placed in the main channel. The PST star/delta starter is equipped with a main switch and a switch for blower and heater, which permits selection between manual and automatic operation through humidistats. Operation hours for blower and heater can be monitored in order to permit keeping continuous control of the energy consumption.

Function
When handling grain with high moisture content, the natural air most commonly has sufficient drying ability and the blower is therefore only controlled by an outside humidistat.

When handling grain with lower moisture content, it is profitable to add heat to obtain the desired final moisture content as soon as possible. The heat source is controlled by a humidistat placed in main channel. This humidistat is to be adjusted to a relative humidity, which corresponds to the desired final moisture content of the grain.

The outside humidistat can, furthermore, be adjusted in a manner so the blower-/heat source is switched off automatically if the natural air has an extremely high relative humidity.

Using the PST system ensures that the blower and heater are controlled in a manner that carries out the correct drying process in the shortest possible time with a minimum consumption of energy.

Grain Quality

Purity
It is essential that grain used for human and animal consumption is free from sand, stones, poisoned weed seeds, dust and trash, which will spoil the basis for an attractive and healthy food.

For seed, it is of utmost importance that different species and varieties are not mixed thus degrading the genetic purity.

A High purity level requires good system planning and good equipment making an effective clean-up of conveyors, driers and storage equipment possible.

Moisture content (m.c.)
As grain with high m.c. rapidly deteriorates and cannot be stored safely and some very dry grain tends to crack, it is important to be able to measure and control moisture content.

Grain trade is based on weight basis with some adjustments for m.c. and purity. Economically, it is important to supply grain with the right m.c.

All grain growers and people in the grain trade should have easy access to a reliable moisture-meter for repeated checking of their grain.

Larger grain growers should have their own drier so, if neces- sary, they can reduce the m.c. immediately after harvesting.

Grain weight
The grain weight is different for different species of grain.

For specific varieties of grain, the weight gives an indi- cation of the quality. Grain weight can be given in two different ways:

a) **Weight per volume**

Weight per hectolitre or weight per bushel gives an indication on content of light immature kernels, dust and trash. When calculating grain storage and conveying systems, the weight per volume data is transformed into kg/m^3, t/m^3 or lbs/bushel figures and called bulk density or specific weight. (See Appendix 1)

b) **Weight per grain**

Random samples of 1000 grains are weighed. The 1000 grains' weight indicates the size of grain. The size of grain gives information on content of various feed components and the number of seeds for planting per kilo of seed.

Weight per hectolitre and 1000 grains can vary a great deal from year to year and from one variety/grower to another.

Germination
From nature, grain has germination, which must be maintained for seed purposes. Grain for food/feed production may have lost germination without reducing the feed value, - e.g., due to high drying temperatures.

Germination power is a universal indicator for grain health, and it is widely accepted, that high germination power indicates that grain is free from fungi and insects, dried properly, etc.. Therefore, grain with germination power is preferred to grain without germination in the grain trade.

Feed components

Grain consists of a very complex combination of compo- nents. A great deal of research has been carried out as to the role these components play foodwise, but it is not yet fully understood, since many components are difficult to check with todays technology. However, some information exist on the following components:

A. Starch

Starch exists as:

Simple starch molecules diluted in water (types of sugar).

Complex rather high starch molecules undilutable in water (dextrine, cellulose).

Starch provides the main bulk component for food and feed production.

B. Protein

Proteins are complicated molecules. The proteins are normally mixed with the starch in a kernel. Protein is a necessary component for the growth and life of all animals and human beings.

For malting barley, starch is the most important component in the processing into alcohol. As starch and proteins share the same part of the kernel, malting barley with a low content of protein is preferred.

Small kernels tend to have high percent-content of protein and are therefore carefully screened off from the malting barley.

C. Fat

Grain contains important nutritional fat components.

Free Fat Acid (FFA) is part of the fat content. FFA is not poisonous or harmful itself, but tie up with and destroy vitamins A, D, E, and K. This reduces the feed value, and the reduction of vitamin E means reduced resistance to rancidity.

High content of FFA indicates poor handling and storage.

D. Vitamins

Vitamins are necessary components for all humans and animals, but the daily need is rather low; e.g., with some of the vitamins,- the vitamin B group - you are to a high degree covered via food grain products.

Vitamin E protects grain from rancidity.

E. Basic components

A large group of grain components e.g., bran, husk, hair and skin is now recognized as very important for the digestive function.

Testing feed components is fairly complicated and not particularly widespread in the grain trade. Protein tests are well established with many grain companies as this is important data for malting barley.

Testing for vitamins and FFA normally takes place in laboratories.

Baking quality

The baking quality deteriorates with a high content of grain which has already sprouted.
Rye will often start sprouting in the field before harvest, if the weather is rainy.
Baking quality of rye and wheat can be checked by the “Falling Number” test.

Milling quality

The milling quality is expressed by such factors as:

- amount of pure flour
- grain structure
- power consumption

Many factors like variety, size of kernel, climatic and soil conditions, amount of fertilizer, etc., influence the milling quality.

Bulk densities af grain

No.	English name	Latin name	Kg/m³
1	Alfalfa	Uledicago	770
2	Barley	Hordeum	670
3	Cocksfoot, orchard grass	Dactylis Glomerata	300
4	Coffee, pulped, fermented washed, 55 m.c.		650
5	Coffee, skindry, 45% m.c.		520
6	Coffee, dry parchment 11% m.c.		350
7	Coffee, green hulled 11% m.c.		620
8	Cotton seed, dry, delinted		560
9	Cotton seed, dry, undelinted		350
10	Cowpeas		770
11	Flax, Linseed	Linum Ussitassimum	720
12	Fescue, meadow	Festuca, elatior pratense	300
13	Lentils	Ervum lens	500
14	Maize, on the cob, husked 35% m.c.	(in USA earcorn)	450
15	Maize, dry, shelled	Zea mays	800
16	Meadow grass	Poa pratensis	375
17	Millet	Panicum nutiacum	620
18	Mustard, yellow	Sinapis, alba	700
19	Oats	Avena	500
20	Pea, field	Pisum, arvense	800
21	Peanut, unshelled, Virginia	Arachis hypogaea	280
22	Peanut, unshelled, Runner		350
23	Peanut, unshelled, Spanish		290
24	Peanut, shelled		650
25	Rape	Brassica napus	700
26	Red clover	Trifolium pratense	800
27	Rough rice, paddy	Oryza sativa	580
28	Rice, hulled, polished		750
29	Rye	Secale oerale	700
30	Sesame		590
31	Sorghum	Sorghum	650
32	Soybean	Soya hispida	800
33	Sugarbeet, unpolished	Beta vulgaris saccharifera	330
34	Sunflower	Helianthus annuus	400
35	Timothy	Phleum pratense	550
36	Wheat	Triticum	800
37	White clover	Trifolicum repens	800
	In Denmark:		
	Wheat, 16% water		750
	Rye, 16% water		700
	Barley, 15% water		670
	Oat, 15% water		500

Below list of literature does not refer specially to the text of this cahpter but is generally recommended for more in depth study of this subject.

List of literature
D. W. Hall Handling and Storage of Food Grains FAO, Rome 1970
Clyde M. Christensen Storage of Cerial Grains and Their Products St. Paul Minn. 1974
Oren L. Justice and Louis N. Bass Principles and Practices of Seed Storage Agricultural Handbook no. 506 U.S. Department of Agriculture 1978
H. Toftdahl Olesen Korntørring Innovation, Development, Engineering Thisted 1982
Carl Lindblad and Laurel Druben Preparing Grain for Storage, Small Farm Grain Storage VITA Publications 1980
Carl Lindblad and Laurel Druben Enemies of Stored Grain, Small Farm Grain Storage VITA Publications 1980
Learning to Save More of Our Harvest Kongskilde 1978

Kongskilde offers expertise in project planning and execution of complete grain handling and storage facilities. All equipment can also be purchased as single stand alone units for integration/ expansion in existing facilities.

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