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THE REAL MEANING OF HIGH-TEMPERATURE/LOW-HUMIDITY TO GRAIN STORAGE IN THE SAHELIAN ZONE.

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By a low humidity/high-temperature area I consider :

a) mean maximum temperature to 45C

b) average yearly temperature above 25C

c) strong sunlight during the day

d) cloudless skies during the day and night leading to high earth-to-sky radiation at night.

e) temperature range between day and night is high (can be to 25C)

f) low humidity during the day

g) dew point seldom reached at night.

If we look at the different factors we find they either are related to temperature or moisture or an interrelation between the two.

This paper will look at how these factors can influence storage and what changes can be brought about by the farmer to improve storage conditions.

MOISTURE IN GRAIN STORAGE

In the Sahel, high moisture levels are seldom a problem in grain stores if the grain is put into storage in a dry state.

The traditional varieties grown by the farmers of the region usually mature after the end of the rainy season. Certain new varieties that have been introduced from other regions may mature before the end of the rainy season. The harvest from such a variety needs to be dried before it is put into storage.

Apart from climate, this drying may be further complicated by the plant structure. Traditional varieties were generally open-panicle types which made them easier to dry.

In the case where the grain is in storage in a dry state it can still be wetted by :

1) moisture migration due to temperature gradients (moisture moves from the warmer to cooler areas through convection currents)
2) by a change in relative humidity

There is a constant interchange of the moisture in the grain and the moisture in the air surrounding the grain. When the partial pressure of the water vapor in the air and in the grain are equal, this state is known as the equilibrium moisture content (emc). For sorghum a relative humidity of 70 % is equal to an emc of 12 %. This means that at 70 % R.H. the grain is higher than 12 % m.c. it can be dried to 12 %, while if it's lower than 12 % it may pick water until it reaches 12 %.

3) by the use of poor structures - i.e. leaky roof
4) by poor location of the bin - i.e. placing the bin in a hollow so that it is flooded after so heavy rainfall

In the high temperature zones the different biological agents must have a certain relative humidity in the air (or corresponding emc) before they can multiply. Most moulds need at least 70 % R.H. although some can develop at 60 %/ %. Mites can reproduce when the R.H. is 60 %. Bacteria require at least 90 %. Insects, excluding Trogoderma, require at least 30 % R.H. Trogoderma appear to thrive on very dry grain. At an R.H. of 95 % or higher germination is likely to take place. I will not discuss the losses due to these agents but will assume that these topics will be covered by others.

- The converse of storing grain that is too wet is of course that of storing grain that is too dry. This cannot be helped in a low humidity area.

In the region the farmers often store their grain in the unthreshed form. When they thresh their grain they usually consume it immediately. For the grain that is sold we have two problems :

1) Very dry grain tends to be very brittle and when moved from one container to another cracks easily, thus allowing secondary species of insects such as Tribolium to attack the broken kernels.

2) very dry grain experiences a weight loss which is an economic disadvantage to the farmer

Suppose we have weight of grain, at mc x, and we want to know weight of grain W2 at mc X2

Thus W2 $= W_1 \left(\dfrac{100 - X_1}{100 - X_2} \right)$

For example if we have 1000 kg of sorghum at 12 % mc and we dry to 6 % mc we have

$$1000 \left(\frac{100 - 12}{100 - 6} \right) = 936 \text{ Kg}$$

Assuming this grain is worth 30 F CFA per Kg, his monetary loss would be 1.920 F CFA. Although this over-drying represents a monetary loss, it would be foolish for us to suggest that farmers wet their grain to make it weight more. In fact a suggestion such as that would be hazardous to the food policy of the country.

CONTROL OF MOISTURE

Drying can be achieved by stacking the heads into racks that are elevated off the ground. This allows air to pass through the pile of grain and reduces the losses due to mice, rats and insects. The rack is best designed as a rectangle that is long and narrow. The wind should blow through the short distance since it is the wind that carries away most of the moisture. In this area there is a hight incidence of solar radiation, however this heat removes very little moisture from the grain unless there is some wind to carry away the moisture removed.

Rather the heat from solar radiation heats up the ambient air and reduces the relative humidity. This reduction in relative humidity then gives the wind a larger carrying capacity to remove moisture from the grain.

Before every rainy season the farmer should make certain that the bins walls and roof are repaired to keep out water. In the construction of new bins, low areas that may flood during the rainy season should be avoided.

TEMPERATURE IN GRAIN STORES

Temperature of grain stores are important for several reasons

1) temperature gradients within solid walled bins cause convective air currents which may transfer moisture from one part of the bin to another

2) Grain, being a ~~is~~ living organism, has a certain respiration rate. This respiration rate doubles with each 10C rise in temperature. Thus the respiration rate at 40C would be 8 times that at 10C.

The respiration of grain produces heat, carbon dioxide and water. The process is self-accelerating since an increase in moisture content increases the rate of respiration. Similarly due to the low thermal conductivity and low thermal diffusivity the heat generated does not dissipate. Rather the temperature of the produce is increased with a corresponding increase in respiration rate. The grain will eventually germinate. and spoil

In a non threshed state the grain is not as compact and if there is even a slight breeze the grain that is dry will seldom encounter the problem of weight loss by respiration due to the day and night fluctuations.

3) The temperature has an effect on the number of insects and mites and the level of fungal activity.

Each species has different temperature requirements for optimum growth.

Molds can develop from about 2C to about 63C. Bacteria will develop up to a temperature of 71C while mites prefer temperatures less than 30C. Grain will germinate between 15-42C if the humidity is high enough. The temperatures we find in our region nearly optimum for many of the species we encounter. The question then becomes, What are some control methods we can employ ? These we will discuss next.

CONTROL OF TEMPERATURE IN GRAIN STORES

Grain has a low thermal conductivity as well as a low thermal diffusivity. This means that a mass of grain that is warm may remain that way for a long time. The temperature of the grain is due largely to the thermal properties of the bin, the size and type of bin and initial temperature of the grain as well as incidence of solar radiation, wind speed and ambient temperature.

In the case of greniers the temperature wawe within the bin follows closely the ambient temperature. When it is hot outside, the grain temperature is high. In the evenings the grain temperature is cool. The time lag can be only a few minutes or it can be a few hours. Tightly packing the heads increases the density and thus may cut down on the amount of diurnal temperature change.

In the case of a grenier, storing threshed grain or a solid-wall bin, the situation is different. During the day the bin may not heat up as fast due to the bin wall or the grain bulk or both. During the evening the cooling off may be less than in a grenier. Table 2 shows the effect of different wall thicknesses on the lessened effects by the outside environment both over the periods of a day and a year. How can we use this knowledge.

A. For farm stores In the case of unthreshed grain in a solid wall container we can

1) have a thicker bin wall to reduce effects of air temperature

2) Use shading to protect the bin from direct rays of the sun.

3) have a bin with a larger diameter

4) aerate during the evening

In the case of threshed grain we can

1) have a bin with a large diameter

2) have thicker bin walls

3) Use shading of the bins

4) fill the bins early in the morning rather than the heat of the day

5) aerate during the evening.

B. For large stores

1) store bags at least 1 metre away from the wall so that there is no contact between the grain and the bin wall.

2) aerate and ventilate the store during evenings

3) Stores should be designed to obtain maximum shading. This is generally done by having an overhanging roof and by having the long wall facing south.

4) Fill stores during the cool part of the day or on cooler days.

I enjoyed talking with you about what I consider an important subject. You realize that much of what I said can be shown theoretically or has been discussed by other scientists. For those of you interested in this subject I would like to suggest your obtaining the FAO publications on storage and fumigation. They are available in both English and French and I am sure you would find them of value.

I hope that if you have questions we discuss them during this meeting or that you contact me at Dakar.

I wish you every success with your seminar.

Thank you.

Some weather data from low humidity/High-temperature zones *

Quelques données du temps dans les zones de basse humidité/Haute température

		J	F	M	A	M	J	J	A	S	O	N	D	Year
amey	T	24.7	27.1	31.0	33.6	33.4	30.9	28.3	26.8	28.0	30.1	28.1	24.7	28.9
	R.H	22	17	18	26	42	55	68	77	72	54	33	26	43
gadez	T	20.1	22.7	27.1	30.7	33.0	33.0	31.3	29.8	30.7	29.2	24.4	20.7	27.7
	R.H	26	20	19	17	23	29	46	57	42	26	27	27	30
amba-ounda	T	24.9	27.1	29.8	31.8	32.6	30.0	27.2	26.5	26.9	27.7	27.8	24.4	28.0
	R.H	28	26	25	29	39	59	75	82	83	76	59	37	52
akar	T	21.1	20.4	20.9	21.7	23.0	26.0	27.3	27.3	27.5	27.5	26.0	23.2	24.3
	R.H	69	75	76	77	78	76	76	78	79	79	73	64	75
aga	T	25.4	27.6	30.8	32.6	31.0	28.7	26.9	26.0	26.6	28.9	28.4	25.6	28.2
	R.H	27	23	24	34	53	64	72	79	77	62	41	29	49

* ~~From~~ du OMM publication 117, normales climatologiques relatives aux stations climat et climat ship pour la période 1931-1960.

TABLE 2

Depth at which temperature wave is reduced to 1C (thermal diffusivity = .115 um ^{2}/ s)

Profondeur à laquelle les ondes de température sont réduites à 1C (diffusion thermale = 115 um^2 /s

	Daily Amplitude / Amplitures journalières		Yearly Amplitud / Amplitude annuel	
Amplitude / Amplitude	Depth / Profondeur	Time lag / Retard	Depth / Profondeur	Time L / Ret
5	9.05 cm	6.14 Hr.	1.73m.	93.53
10	12.94 cm	8.79 Hrs	2.47 m.	133.55
15	15.23 cm	10.34 Hrs	2.91 m.	157.34
20	16.85 cm	11.44 Hrs.	3.22 m.	179.09
Time lag per Unit depth / Retard par unité de profondeur		.678 Hrs. / 678 heures		54.06 / 54.C6 jou