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PHYSICAL AND MICROBIOLOGICAL QUALITY OF MAIZE STORED IN SILOS AND WAREHOUSES IN GHANA

A PROJECT REPORT

BY

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PHYSICAL AND MICROBIOLOGICAL QUALITY OF MAIZE STORED IN SILOS AND WAREHOUSES IN GHANA

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Abstract

Maize samples from warehouses and silos of the Ghana Food Distribution Corporation from various locations in Ghana were assessed for their physical and microbiological qualities. All the samples had normal levels of moisture content, none exceeding 13.5%. Levels of extraneous matter were also very low with a maximum of 1.4%. Percentages of broken grains from silos ranged from 4.0 to 4.9% whilst that from the warehouses ranged from 0.8 to 11.1%. Most of the samples had low levels of insect damaged grains, the highest level of 9.4% being found in only one warehouse. On the other hand levels of discoloured grains were quite high for both silos and warehouses. Also samples from the warehouses were found to have higher levels of total blemished grains than those from the silos. However, because the initial qualities of grains stored were not known, it cannot be inferred that warehouse storage practices promote grain quality deterioration than what obtains in the silos. In general six main types of fungi were found on the samples, four of these namely, *Aspergillus flavus* Link, *Aspergillus ochraceus, Penicillium expansum* and *Fusarium* species are known to cause discolouration of grains. None of the samples examined had more than 20% of the grains infected with the fungi isolated.

Introduction

The Government of Ghana has initiated a programme to invest in long-term infrastructure to hold large stocks of grain for prize stabilization and food security purposes. This has been found necessary to reduce post-harvest losses, which have been estimated as high as 30% of total annual crop harvest (Adams, 1977). Earlier estimates of post-harvest grain losses in Ghana ranged from 12% to 20% Nyanteng, (1972) estimated losses of 12% for grains and rice while Rawnsley (1969) gave estimates of 15% for maize and 20% for the pulses. Hall (1970) also reported estimates of 20% for maize stored over a period of eight months. Recent measurements of weight loss in maize stored in cribs in Ashanti, Volta and Central regions by Crops Research Institute/Food Research Institute and the FAO Project indicated a range of 1% to 10% losses over a storage period of seven to eight months.

The main factors responsible for post-harvest losses of grains are insects, moulds and rodents. The most important of these is insect infestation. Beetles and moths are the main insect pests in Ghana. Insect pests break down cereals and oilseeds into smaller particles leading to increased chemical activities such as oxidation and loss of essential nutrients. Moths and beetles feed only on the germ of cereals and thus cause considerable loss in nutritive value.

The activity of infesting insects makes metabolic water available, which goes to effect marked increases in moisture content of grains consequently encouraging mould growth. The main insect pests of grains in Ghana have been listed by Forsyth (1966) as *Sitophillus zeamais, Sitotroga cereallela, Tribolium casteneum, Prostepharus truncatus* and *Oryzaephilus surinamensis.*

Next to the insects, fungi are almost exclusively responsible for the decay of dry grains and seeds. Grain storage moulds are primarily those capable of growth at minimal water activity (Aw) levels. Moulds often encountered in storage are *Aspergillus, Penicillium, Fusarium, Rhizopus* and *Mucor*.

In line with the Governments objective to invest in long-term infrastructure to hold large stocks of grain, the long-term plan is to build adequate silos and warehouses for storing food grains such as maize, rice, sorghum and millet. During the first phase of this programme a number of aluminium metal silos of 250-ton capacity were erected for bulk storage of grains in the country. However, a number of problems may be encountered with such silos particularly if they are not well insulated.

In a tropical country such as Ghana, moisture migration may be a serious problem. Spoilage of grain can occur as a result of the existence of temperature gradients within the bulk of the grain. Differences between the temperature of the grain and the outside air temperature can be communicated through the silo walls. Transmission of heat through the grain is however slow due to the low thermal conductivity of grains. Thus, temperature at the centre of the bulk may rise due to presence of insects but the heat cannot be easily communicated to the outside. As the air cools, the relative humidity rises and may reach saturation point when excess water is deposited on the surface of the cooler grains (Joffe, 1958). Localized increases of moisture content can therefore occur giving conditions favourable for development of fungi. Aeration is normally sought to as an answer to this problem. This is a high-energy process and may be costly under the practical conditions presented by average temperatures of the country. The need for it would have to be assessed in terms of the extent of losses and general conditions prevailing in the silo and warehouse storage in Ghana.

The purpose of this study was to determine the efficiency of silo and warehouse storage of maize as practiced in Ghana. Maize storage operations of the Ghana Food Distribution Corporation were also assessed for product quality preservation.

Materials and Methods

Sample collection

Visits were made to Ghana Food Distribution Corporation Head Office in Accra to collect relevant information on sites and location of Warehouses and Silos in Ghana. Subsequently, all the silo sites and some warehouses scattered throughout the country were visited.

Samples were taken from all storage sites, which had maize in store. Several samples were drawn from various sections of the bulk. Samples taken from each section of a silo such as the peripheral core, the middle core and the central core were pooled together such that for each silo there were three samples.

At the warehouses, samples were taken from the sides and tops of stacks using sampling spears. Several samples were taken and pooled to obtain a minimum of 500 g sample for each warehouse and silo.

Quality assessment

Physical characteristics

Moisture content of all samples was determined by oven-drying method (A.A.C.C. Method 44 – 15A). Bulk density (kg/m^3) measurements were done by taking weights of a standard volume of grain.

Percentages of insect damaged grains, discoloured grains and broken or chipped grains were determined based on sample units of 500 g weights. Presence of foreign matter including materials mixed with the grain which do not answer to the type description of grain, i.e. seed coats, parts of stem, dead insects, dust, earth, sand and stones, was also determined as a percentage out of a 500 g sample.

Microbiological analyses

Five hundred grams of grains of each sample were taken for determination of grain microflora, using the solid medium method. Sub-samples were taken from each sample of grain by the coning and quartering method. Out of this sub samples, five hundred grains were taken and plated on solid agar plates. Ten surface sterilized (sodium hypochloride solution) grains were placed on Malt agar containing 20% sodium chloride in 9.0 cm petri dishes without any further treatment. There were 5 replicates for each treatment and plates were incubated at 26 ± 3°C (ambient temperature) until fungi grew. Sodium hypochloride treatment was used for surface sterilization with the aim of removing completely external saprophytes, which compete with pathogens.

Results

Silos

Tables I and III show the results of samples taken from the silos at different locations. The moisture contents of samples taken from various sections of each silo, (Table I) i.e. periphery, middle core and central core showed no significant differences. The means of moisture content from the three sections of each silo ranged from 11.3 percent in Techiman to 13.0 percent in Abofour. Levels of insect damaged grains found were quite low ranging from 1.2 per cent (Techiman) to 3.2 per cent for silos at Nkoranza and Abofour. Apart from the silos at Techiman, there were higher percentages of insect damaged grains in samples taken from the peripheral and middle core sections of each silo than at the central core.

There were also high levels of discoloured grains for all the silos except at Mampong with a mean of 4.1 percent discoloured grains from the three sections of the silo.

The percentage of total blemished grains i.e. both insect damaged and discoloured grains, ranged from an average of 6.5 percent for Mampong to 13.6 percent for Techiman.

Broken grains found in the samples ranged from 4.1 percent for Techiman to 4.9 percent for Mampong. Levels of extraneous matter were low in all the silos examined.

Microbiological analysis gave six main types of fungi on the grains (Table III) namely, *Aspergillus flavus* Link, *Aspergillus ochraceus, Aspergillus* sp.1, *Aspergillus* sp.2, *Penicillium expansum* and *Fusarium spp.* Generally, the percentages of surface disinfected grains yielding fungi were low for all the samples. *Penicillium expnsaum* and *Aspergillus* sp.1 were the only fungi isolated from a maximum of 18 to 20 percent of the grains.

Warehouses

Tables II and III show the results of physical and microbiological analysis of samples taken from warehouses.

The moisture content of the samples ranged from 12.4 per cent in Wenchi Warehouse (1) with a mean of 12.75 ± 0.39.

The range of insect damaged grains for samples was 1.3 per cent to 9.4 per cent (mean = 5.3 ± 2.97). The highest percentage insect damaged grains was observed in Abuakwa warehouse where the maize was bought from several small scale farmers. The insect damaged grains from commercial private farms i.e. Ejura Farms and KIFCOM Farms were low, 1.3 and 2.5 per cent, respectively.

Most of the samples collected from the warehouses had high levels of discoloured grains, ranging from 7.8 per cent from mixed farms in Abuakwa. The levels of discoloured grains from the private commercial farms were also high. Percentage of total blemished grains was high for all the samples from the warehouses. The range was from 11.0 from Ejura Farms (Abuakwa Warehouse) to 31.6 from mixed farms.

The level of broken grains ranged from 0.8 to 11.1 per cent. The highest level of 11.1 per cent was obtained from the sample taken from Balduzzi warehouse.

The microbiological analysis of samples showed growth of five species of *Aspergillus* one *Penicillium* and *Fusarium.* These were *Aspergillus flavus* Linki, *Aspergillus ochraceus, Aspergillus* sp. (1), *Aspergillus* sp (2), *Aspergillus* niger, *Penicillium expansum* and *Fusarium* spp.

Two main fungi i.e. *Penicillium expansum* and *Aspergillus* sp (1) were found to be predominant on the samples. These were isolated from 10 to 20 per cent of the grains.

Discussions

During production, harvesting, drying, shelling, cleaning, handling and storage, grain almost invariably acquires a number of qualities. The importance of these depends on the nature and extent of their occurrence. Generally, they are detrimental to the overall quality of the grain concerned.

One such characteristic is foreign matter or extraneous matter. This includes organic and inorganic materials such as seed coats, parts of stems, pods, weed seeds, sand, stones dust, metal etc. Organic foreign matter is ideal food for many insect pests and microorganisms and may shorten the storage life of the grain through the translocation of heat or moisture generated by its own infested condition.

All the samples of grain taken from both silos and warehouses in this study had very low levels of extraneous matter. Only the sample taken from Abuakwa warehouse where the maize originated from Ejura farms had a high level of 1.4%

extraneous matter. Even this value is slightly less than the 1.5% proposed Codex limit for Ghana WHO/FAO, 1978).

Another characteristic quality parameter for assessing grain is moisture content. Abnormal moisture content may occur if grain has been excessively dried or if it has been exposed to rain and condensation. High moisture content encourages infestation by insects and microorganisms, particularly microorganisms if grain is kept under poorly ventilated conditions. Abnormal low moisture content often present loss problems.

In this work, all the samples had normal moisture contents required for safe storage of maize i.e. a maximum of 13 per cent as given by Davey and Elcoate, 1965.

Physical damage or breakage is another characteristic considered. Breakage, splitting or cracking of grain, render grain more prone to infestation by insects and microorganisms. An example is the production of free fatty acids, which may develop to the point of rancidity (Pingale, Rao and Swaminathan, 1954). The levels of breakage found in all the samples from the silos were low except in two warehouses, Balduzzi and Abuakwa (Ejura Farms), which had values above the maximum limit of 5% (FAO/WHO, 1978).

As regards insect damage, insects eat up grain by chewing, usually starting at the embryo end. As mentioned in the introduction, beetles and moths are the main insect pests of cereals in Ghana. They feed only on the germ of cereals causing considerable loss in nutritive value.

The analytical results however showed low levels of insect damage for grains from both the silos and the warehouses. This may be attributed to good insect control measures practiced in both warehouses and silos examined.

The levels of discoloured grains on the other hand were rather high. The maximum permitted percentage discolouration, according to proposed standards (FAO/WHO, 1978), is 2%. Discolouration of grains particularly the germ and embryo can be caused by both field and storage fungi. Field fungi are the fungi, which invade the kernels before harvest, while the plants are growing in the field or after the grain is harvested but before threshing. Maize stored moist on the cob in cribs, may be attacked and decayed by typical field fungi such as *Alternaria, Fusarium, Helminthosporium* and *Cladosporium*. These require high moisture levels to grow usually 28 to 33%, (Christensen and Kaufmann, 1974). When the grains mature their water content drops and growth of these fungi ceases. If grain remains moist as in the case of moist maize on the cob in cribs, growth of these fungi will continue and discolour the grains.

During storage of grain containing 13% moisture or less, the field fungi slowly die, the rate of which depends on the moisture content and temperature of the grain (Christensen, 1965). The grains may therefore be discoloured even before they are shelled. However data was not available on the initial quality of grains stored. The storage fungi on the other hand are capable of growth at lower water activities such as are encountered in storage. These are members of 10 to 15 groups of fungi especially *Aspergillus* and several species of *Penicillium*. The sources of these moulds are trucks, the storage bins and warehouses, etc.

The principal strains are *A. glaucus, A. restrictus, A. Falvus, A. ochraceus, A. candidus* and *Penicillium.* All of these are capable of discolouring the kernel. Also, for each of the common species of storage fungi, there is minimum moisture content in grains below, which the fungus cannot grow. These minimum moisture contents have been determined for most of the common storage fungi growing on starchy cereal grains (Christensen, and Kaufmann. 1974). Davey and Elcoate (1965) put the safe moisture content for storage of maize at 13 per cent. Lutey and Christensen (1963) also suggested that viable field and storage fungi may be generally reduced or eliminated from grain lots stored at moisture contents of 12-14 per cent and temperatures of 20 to 30°C. In this study a few of the species identified were storage fungi such as *Aspergillus flavus* Link, *Aspergillus ochracaus* and *Penicillium expansum.* A field fungus was also isolated (*Fusarium* spp.) which can also discolour grains.

Generally, the initial quality of grains before storage is very important. This is because, the tendency for grain to deteriorate in storage is affected by the soundness of the grain initially put in storage. Unfortunately, in Ghana at present, there is no official legislation and grade specification for maize and other grains. The Ghana Food Distribution Corporation has very little control on the quality of maize bought from farmers. Except for obviously damaged grains which are sometimes rejected, the bulk of the maize bought from farmers are of varied quality with varying degrees of moisture levels depending on the time after harvest. However, with efficient cleaning operations which ensure that foreign matter is removed from the grain followed by immediate drying down to safe moisture level for storage, it is ensured that chemical changes within the grains are negligible and respiration of the grains are minimized. Thereafter, control of insects and rodent and maintenance of appropriate storage conditions, e.g. constant turning over of the grain from one silo to the other and aeration help maintain satisfactory quality. On the whole grains stored in both warehouses and silos in Ghana at the time of the study had moisture levels within limits for safe storage. This may account for the low mould infestation observed in this study. However, the levels of total blemished grains were higher in warehouses than the silos, because the initial qualities of grains stored were not known it cannot be inferred that warehouse storage practices promote grain quality deterioration more than what obtains in the silos.

References

1. Adam, J.M. 1977. A review of the literature concerning losses in stored cereals and pulses published since 1964. Trop. Sci. (19) 1:1-28.

2. American Association of Cereal Chemists. 1955.
St. Paul, Minnesota, U.S.A

3. Christensen, C.M. 1965. Fungi of cereal grains and their products.
In: Mycotoxins in Food Stuffs (G.N. Wogan, Ed.) pp. 9-14
M.T. Press, Cambridge Massachusetts.

4. Christensen, C.M. and Kaufmann, H.H. 1974. Microflora. In: Storage of Cereal Grains and their Products. Monogr. Ser. Vol.5 (revised), pp. 158-192. Am. Assoc. Cereal Chem. St. Paul, Minnesota

5. Davey, P.M. and Elcoate, S. 1965. Moisture content/relative humidity equilibra of tropical stored produce. Part 1. Cereals. Trop. Stored Prod. Inf., (11), 439-467.

6. FAO/WHO. 1978. Proposed Draft Standard for Maize (Corn). In: Report of the third session of the Coordinating Committee for Africa. Accra, 26-30 September 1977, pp. 25-28. Joint FAO/WHO Codex Alimentarius Commission, Rome.

7. Hall, D.W. 1970. Handling and Storage of Food Grains in Tropical and Sub-tropical Areas. FAO, Rome.

8. Joffe, A. 1958. Moisture migration in horizontally stored bulk maize: The influence of grain infesting insects under South African conditions. S. Afr. J. Agric. Sci. 1: 175-193.

9. Lutey, R.W. and Christensen, C.M. 1963. The Influence of moisture content, temperature, and length of storage on survival of fungi in barley kernels. Phytopathology 53, 713-717.

10. Pingale, S.V., Rao, M.N. & Swaminathan, M. Effect of insect infestation on stored wheat. I. Studies on soft wheat. J. Sci. Fd. Agric., 5: 51-54.

11. Frosyth, J. 1966. Agricultural insects of Ghana. Ghana Univ. Press. 163 p.

12. Rawnsley, J. 1969. Crop storage. Technical report No.1. (PF:SF/GHA/7). Accra, Ghana: FAO Food Research and Development Unit.

13. Nyanteng, V.K. 1972. Storage of foodstuffs in Ghana. ISSER Technical Publication No. 28. Univ. of Ghana, Legon.

TABLE I: PHYSICAL PROPERTIES OF SAMPLES OF MAIZE COLLECTED FROM GHANA FOOD DISTRIBUTION SILOS (Capacity of each silo = 250 metric tonnes)

Location	Silo Section	% Moisture Content	% Insect Damaged Grains	% Discoloured Grains	% Total Blemished Grains	% Extraneous Matter	% Broken Grains	Bulk Density K760 kg/m³
	Periphery	10.8	1.1	14.0	15.1	0.4	4.7	760
	Middle Core	11.0	1.5	15.1	16.6	0.6	3.5	767
Techiman	Central Core	11.6	1.1	8.1	9.2	0.8	4.0	760
	Mean	11.3	1.2	12.4	13.6	0.6	4.1	762.3
	STDEV	0.4	0.2	3.8	3.9	0.2	0.6	4.0
	Periphery	12.5	4.0	6.4	10.4	0.2	4.3	758
	Middle Core	12.6	3.8	6.4	10.2	0.4	5.8	782
Nkoranza	Central Core	12.4	1.9	13.5	15.4	0.3	2.7	767
	Mean	12.5	3.2	8.8	12.0	0.3	4.3	769
	STDEV	0.1	1.2	4.1	2.9	0.1	1.6	12.1
	Periphery	12.2	3.8	2.2	6.0	0.1	4.3	774
	Middle Core	12.4	1.4	7.0	8.4	.02	4.8	784
Mampong	Central Core	12.3	2.1	3.0	5.1	0.2	5.6	783
	Mean	12.3	2.4	4.1	6.5	0.2	4.9	780
	STDEV	0.1	1.2	2.6	1.7	0.1	0.7	5.5

TABLE II: PHYSICAL PROPERTIES OF SAMPLES OF MAIZE COLLECTED FROM GHANA FOOD DISTRIBUTION CORPORATION (GFDC) WAREHOUSES

Description of Samples	**% Moisture Content**	**% Insect Damaged Grains**	**% Discoloured Grains**	**% Blemished Grains**	**% Extraneous Matter**	**% Broken Grain**	**Bulk Density Kg/m³**
Wenchi (1)	12.4	6.8	7.8	14.6	0.2	1.2	774
Wenchi (2)	12.6	5.1	12.7	17.8	0.2	0.8	769
Balduzzi	13.5	6.5	14.4	20.9	0.3	11.1	738
Abuakwa (from Ejura Farms)	12.8	1.3	9.7	11.0	1.2	7.6	745
Abuakwa (from Kofoom Farms)	12.5	2.5	12.0	14.5	0.3	4.7	761
Abuakwa (mixed Farms)	12.7	9.4	22.2	31.6	0.6	3.5	746
Mean	12.75	5.3	13.1	18.4	0.5	4.8	756
Standard Deviation	0.39	2.97	5.0	7.3	0.4	3.9	14.6

TABLE III: PERCENTAGE FREQUENCY OF FUNGI ISOLATED FROM MAIZE SAMPLES COLLECTED FROM SILOS AND WAREHOUSES IN GHANA

(+ = silo site; - = Warehouses)

	FUNGI						
Location	***Aspergillus Flavus* Link**	***Aspergillus* Sp .1**	***Aspergillus* Sp.2**	***Aspergillus ochraceus***	***Aspergillus niger***	***Penicillium expansium***	***Fusarium* spp**
+Nkoranza	5.3	8.5	1.3	5.5	0.0	7.3	1.0
+Mampong	3.7	11.0	2.3	2.0	0.0	8.5	3.0
+Abofour	8.0	12.0	2.0	7.0	0.0	9.0	2.0
+Techiman	4.0	9.0	2.0	2.0	0.0	11.0	0.0
-Wenchi (1)	3.0	12.0	2.0	4.0	0.0	8.0	2.0
-Wenchi (2)	7.0	17.0	2.0	7.0	0.0	10.0	2.0
-Balduzzi	4.0	20.0	1.0	0.0	0.0	110.	3.0
-Abuakwa (Ejura farms)	5.0	10.0	2.0	0.0	0.0	14.0	2.0
-Abuakwa (Kifoom farms)	4.0	6.0	1.0	5.0	2.0	14.0	0.0
-Abuakwa (mixed farms)	4.0	11.0	4.0	0.0	0.0	18.0	6.0