Weight losses in maize stored on the cob in cribs: Some preliminary investigations

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SUMMARY

Weight losses suffered by maize stored on the cob in three rectangular and five circular cribs were measured under various storage conditions. In rectangular cribs, improved maize with husks intact and not treated with insecticide suffered a weight loss of 38.4 per cent after 29 weeks. Similar maize stored for 28 weeks in two separate circular cribs suffered losses of 26.3 and 21.9 per cent. Untreated local maize, also with the husks intact, stored in circular cribs for 40 weeks suffered a weight loss of 25.0 per cent. When the outer surfaces of rectangular cribs were sprayed at monthly intervals with a 7.5 per cent solution of pirimiphos-methyl, weight loss in maize stored without husks was 38.8 per cent after 25 weeks. Maize with husks intact lost 31.1 per cent after 29 weeks. When pirimiphos-methyl was applied to maize with husks intact at a rate of 27 ppm before storage in a circular crib, the loss after 28 weeks was 13.1 per cent. Similar maize cobs treated with permethrin at the same rate suffered a loss of 10.7 per cent after 28 weeks.

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RÉSUMÉ

OFOSU, A.: *Une étude préliminaire sur les pertes du poids du maïs mise en stockage avec l'épi dans des coffres.* Les pertes du poids du mais mise en stockage avec l'épi dans trois coffres rectangulaires et cinq coffres circulaires ont été mésurées dans plusieurs conditions de stockage. Dans des coffres rectangulaires, le maïs amélioré équi a eu des enveloppes qui n'étaient pas perturbées et aussi n'étaient pas traitées avec l'insecticide a eu une perte du poids de 38.4% après 29 semaines. Le maïs similaire mise en stockage pour 28 semaines dans deux coffres circulaires a eu des pertes du poids de 26.3 et 21.9%, respectivement. Le maïs locale non-traité, avec des enveloppes qui n'étaient pas perturbées et mise en stockage dans des coffres circulaires pour 40 semaines a eu une perte du poids de 25.0%. Lorsque les surfaces exterieurs des coffres triangulaires ont été traitées mensuellement avec 7.5% de produit chimique pirimiphos-méthyl, la perte du poids du maïs mise en stockage sans les enveloppes était 38.8% après 25 semaines. Le maïs mise en stockage avec des enveloppes qui n'étaient pas perturbées a perdu 31.1% de son poids après 29 semaines. Lorsque le pirimiphos-méthyl a été appliqué aux maïs avec des envelopes qui n'étaient pas pertubée à un taux de 27 ppm avant le mise en stockage dans le coffres circulaire, la perte du poids après 28 semaines était 13.1%. Des épis du maïs traités avec perméthrin au même taux ont eu une perte du poids de 10.7% après 28 semaines.

Introduction

It is now accepted that an increase in the amount of food available to man and his animals cannot be achieved solely through increase in crop production. Attention must be paid to the development of efficient post-production systems and to the reduction of losses which occur after harvest. However, to be able to take correct decisions about the allocation of resources to programmes that aim at preventing food loss, policy makers need to know the magnitude of food losses.

In Ghana, estimates by knowledgeable people put cereal storage losses at between 5 and 20 per cent. While such estimates might have served some purpose in the past, obviously they cannot be used as a basis for important policy decisions on post-production programmes. There is, therefore, the need to accurately determine the magnitude of food losses as they occur at the various stages of the post-production system.

In the present study, storage losses in maize stored in cribs under various storage conditions

were measured to show what losses may be expected under similar storage conditions. Percentage dry weight loss was used as a measure of storage loss suffered by stored maize.

Materials and methods

General methods

Dry weight losses in maize stored in rectangular (Ashanti) and circular (Ewe) cribs were measured in three separate experiments, two at the Food Storage Section of the Crops Research Institute, Pokoase, and one on a farm about 20 km from the Pokoase laboratory. The rectangular cribs, each 1.0 m wide, were constructed specifically for the experiment. The circular cribs were of two designs. The first consisted of a rectangular wooden platform about 1.0 m above the ground. The circular cribs at Pokoase were of this design. The second consisted of a wooden framework in the shape of an inverted cone with the apex about 30 cm above ground level. Maize was stored in two cribs of this design on the farm 20 km from Pokoase.

To conform to the traditional method of storing maize in cribs, maize cobs were either stacked neatly in the rectangular cribs or arranged to form a solid cylinder on the platforms of the circular cribs. All damaged cobs including those with damaged husks were also discarded according to traditional practice. Before storing, approximately 50 cobs were selected at random, weighed, dehusked and re-weighed. The dehusked cobs were carefully shelled by hand, sieved and weighed. The weight of shelled maize was expressed as a percentage of the weight of cobs, both with and without husks. Using this information, the weight of cobs stored in each crib was converted to a shelled grain equivalent at 13.0 per cent moisture content.

A baseline condition of the stored maize was determined to serve as a reference point with which to compare losses incurred during storage. This involved the determination of the weight of a standard volume of undamaged grain at seven different moisture contents within the range 29.0 -13.0 per cent and the preparation of a graph to establish the relationship between dry weight of undamaged grain contained in the standard volume vessel and grain moisture content (Adams & Schulten, 1978). Dry weight/percent moisture content graphs were prepared separately for the maize stored in the three experiments.

Experiment 1

The maize used was Composite 4, a white-grained improved variety with an initial moisture content of 28.6 per cent. Shelled maize formed 68.8 per cent of the weight of cobs with husks and 80.2 per cent of cobs without husks.

Rectangular crib 1. The crib contained 365 kg of cobs with husks, equivalent to 206.1 kg of shelled maize at 13.0 per cent moisture content. The cobs were stored for 29 weeks (2 Aug 77 to 21 Feb 78).

Rectangular crib 2. 454 kg of cobs with husks, equivalent to 256.3 kg of shelled maize at 13.0 per cent moisture content were stored in the crib for 29 weeks (9 Aug 77 to 28 Feb 78). Five weeks after the beginning of the storage period and at subsequent 4-weekly intervals, pirimiphos-methyl was applied to the outside of the crib according to the recommendations of Boshoff (1977).

Rectangular crib 3. The crib contained 275 kg of cobs without husks, equivalent to 181 kg of shelled maize at 13.0 per cent moisture content. The cobs were stored for 24 weeks (5 Sep 77 to 22 Feb 78). Five weeks after the beginning of the storage period and at subsequent 4-weekly intervals, pirimiphos-methyl was applied to the outside of the crib according to the recommendations of Boshoff (1977).

Experiment 2

A mixture of white-grained Composite 4 and La Posta varieties were used. Initial moisture content of the maize was 24.3 per cent. Shelled maize

formed 69.9 per cent of the weight of cobs with husks.

In the traditional method of storing maize in a circular crib, water is sprinkled on the cobs as they are stacked neatly on the wooden platform. Wetting is claimed to help stabilize the stack of cobs. In this experiment, cobs were wetted with water at the rate of approximately 30 ml/ kg of cobs with husks. Where stored cobs were treated with insecticide, this was added to the water used in wetting the husks. Wetting did not cause a significant increase in grain moisture content.

Circular crib 1. 175 kg of cobs with husks, equivalent to 106.4 kg of shelled maize at 13.0 per cent moisture content, were sprinkled with 5 *l* of water during stacking and stored for 28 weeks (26 Jul 78 to 7 Feb 79).

Circular crib 2. The crib contained 250 kg of cobs with husks, equivalent to 152.1 kg of shelled maize at 13.0 per cent moisture content. The cobs were wetted with 7 *l* of water during stacking and stored for 28 weeks (1 Aug 78 to 15 Feb 79).

Circular crib 3. The crib contained 222 kg of maize with husks, equivalent to 135 kg of shelled maize at 13.0 per cent moisture content. The cobs were sprinkled during stacking with 6 *l* of water containing 12 ml of pirimiphos-methyl (50 % e.c.) at the rate of 27 ppm and stored for 28 weeks (28 Jul 78 to 9 Feb 79).

Experiment 3

Maize stored during this experiment was a local variety. Shelled maize formed 69.0 per cent of the weight of cobs with husks. The experiment was started 8 weeks after the maize had been stacked in two circular cribs by the farmer. It was, therefore, not possible to determine the volume of water used in wetting the cobs during stacking, the initial moisture content and the actual weight of cobs stored. The weight of cobs stored in the two cribs was, however, determined by calculation based on the volume of cobs in relation to volume of cobs in the circular cribs of Experiment 2 for which actual weights were available. The calculated weight was 1300 kg, equivalent to 883.6 kg of shelled maize at 13.0 per cent moisture content. Moisture content of the stacked maize at the beginning of the experiment was 14.3 per cent.

Sampling procedure

Traditionally, maize cobs are removed for sale or for consumption at intervals throughout the storage period. There is no set pattern of removal and the quantity removed is likely to vary on each occasion. The procedure for removing maize from cribs for the determination of percentage dry weight loss was based on this traditional practice. At 4-weekly intervals, between one and eight baskets full of cobs were removed from cribs. The actual number of baskets of cobs removed from each crib at each sampling time was determined at random.

Measurement of dry weight loss

For the measurement of dry weight loss, the whole batch of cobs removed from each crib at each sampling time was used as the working sample. Cobs removed from each crib were first weighed. Cobs stored with husks were dehusked and re-weighed. Cobs were then classified into three groups as undamaged, completely damaged, and partly damaged cobs. Undamaged cobs with grains declared fit for human consumption were completely without mouldy, germinated or extensively damaged grains. Cobs with all the grains mouldy, germinated, mouldy and germinated or extensively damaged by insects were the completely damaged cobs that were declared unfit for human consumption. Partly damaged cobs had both types of grains.

Completely damaged and undamaged cobs were shelled carefully by hand, sieved and put into Containers A and B respectively. Grains that were unfit for consumption on the partly dam-

aged cobs were carefully removed with a sharp-pointed stick, sieved and added to the grains in Container A. Grains left on the cobs were shelled, sieved and added to the grains in Container B. The weight and moisture content of the maize in the two containers were determined. The dry weight of the shelled grain in each container was then calculated.

Dry weight losses suffered by samples removed from cribs were assumed to consist of two parts. The first part resulted from shelled grains rejected as unfit for human consumption and was calculated from the following equation:

$$l_1 = \frac{W_1}{W_1 + W_2} \cdot 100$$

where l_1 is the percentage dry weight loss due to rejected shelled grain, W_1 is the dry weight of shelled grain rejected as unfit for human consumption, and W_2 is the dry weight of shelled grain judged to be fit for human consumption.

The second part of the loss (l_2) consisted of the dry weight loss suffered by shelled grain judged to be fit for human consumption. l_2 was determined by a method based on a comparison between the dry weight of a fixed volume of grain and the dry weight of the same volume of grain calculated from a baseline drawn for that particular sample of grain (Adams & Schulten, 1978).

To obtain a use-weighted percentage dry weight loss suffered by maize over a given storage period, the percentage of the total quantity of stored maize lost at each sampling time (L) was calculated and then summed. L was calculated from the following equation (Schulten, 1982):

$$L = \frac{(q/100 - x).100 - q}{Q} \cdot 100$$

where L is the dry weight loss at a given sampling time expressed as percentage of total maize stored in each crib, Q is the dry weight of shelled maize equivalent stored as cobs in each crib, q is the dry weight of shelled maize equivalent removed as cobs from cribs at a given sampling time, and x is the percentage dry weight loss suffered by samples removed from cribs at each sampling time ($l_1 + l_2$).

Results and discussion

Experiment 1

Table 1 shows the percentage dry weight losses suffered by samples removed from each of the rectangular cribs at various sampling times and the use-weighted percentage dry weight losses suffered by maize during a 24- or 29-week storage period. The total dry weight loss suffered by maize stored with husks for 29 weeks was 38.4 per cent of the total stored. During the same storage period, the total dry weight loss suffered by maize stored with husks in a rectangular crib whose outside walls were sprayed with a 7.5 per cent solution of pirimiphos-methyl at 4-weekly intervals was 31.1 per cent of the total stored. Total dry weight loss suffered by dehusked maize stored for 24 weeks in a rectangular crib similarly treated with pirimiphos-methyl was 38.8 per cent of the total stored. In these trials, this method of applying pirimiphos-methyl to maize in cribs (Boshoff, 1977) was not effective.

The major component of the percentage dry weight loss suffered by stored maize was the dry weight of shelled maize rejected as unfit for human consumption (l_1). It constituted between 100 and 81 per cent of dry weight loss suffered by samples of maize stored with husks and between 76 and 56 per cent in samples stored without husks. In cobs stored with husks, grains rejected as unfit for consumption were either germinated or damaged by moulds and larvae of *Mussidia nigrivenella, Ephestia cautella* and *Corcyra cephalonica*. Grains damaged by *Sitophilus* spp., *Sitotroga cerealella* and the other insects usually found in crib-stored maize in Ghana (Forsyth, 1962) were usually fit for consumption. In the third crib where maize was stored without husks, grains rejected as unfit for consumption were damaged mainly by the insects mentioned and a few by moulds.

Experiment 2

Table 2 shows percentage dry weight losses suffered by maize samples removed from the four

TABLE 1

Percentage Weight Losses by Maize Stored on the Cob in 1 m-Wide Rectangular Cribs

Storage conditions	*Storage period (weeks)*	*Moisture content of maize (%)*	*Weight removed as shelled grain at 13 % m.c. (kg)*	l_1 *(%)*	l_2 *(%)*	*Weight loss in sample* ($l_1 + l_2$) *(%)*	*Weight loss as % of total stored (L)*	*Cumulative weight loss as % of total stored*
Crib 1	5	26.0	7.0	0	0	0	0	0
	9	18.4	9.0	33.3	0.2	33.5	2.2	2.2
Maize	13	16.1	8.6	22.8	0.8	23.6	1.3	3.5
stored with	17	15.3	11.8	17.2	2.8	20.0	1.4	4.9
husks	21	14.1	18.6	40.4	4.1	44.5	7.2	12.1
	25	15.0	51.8	23.0	3.8	26.8	9.2	21.3
	29	14.8	50.0	38.2	3.1	41.3	17.1	38.4
Crib 2	5	27.6	8.4	17.4	0	17.4	0.7	0.7
*Maize	9	18.6	9.1	15.1	0	15.1	0.6	1.3
stored with	13	15.2	9.5	16.1	0	16.1	0.7	2.0
husks	17	15.2	13.5	29.4	0	29.4	2.2	4.2
	21	14.3	21.1	34.6	1.6	36.2	4.7	8.9
	25	14.8	51.6	19.4	4.4	23.8	6.3	15.2
	29	15.2	82.0	27.6	5.6	33.2	15.9	31.1
Crib 3	5	16.4	9.2	2.7	1.3	4.0	0.2	0.2
*Maize stored	9	15.7	11.8	3.2	2.5	5.7	0.4	0.6
with husks	13	14.5	16.9	6.8	4.2	11.0	1.2	1.8
	17	13.5	20.0	14.4	6.8	21.2	3.0	4.8
	21	14.8	46.4	22.2	9.5	31.7	11.9	16.7
	24	14.6	52.9	33.0	10.1	43.1	22.1	38.8

* External surfaces of crib sprayed with 7.5 per cent solution of pirimiphos-methyl monthly.

circular cribs at various sampling times and the use-weighted percentage dry weight loss over a 28-week storage period. Total dry weight loss suffered by maize stored with husks and without treatment with insecticide in two circular cribs were 26.3 and 21.9 per cent of the total stored. Total dry weight loss in maize with husks stored in two circular cribs after treatment with pirimiphos-methyl and permethrin at 27 ppm were 13.1 and 10 per cent respectively of the total stored in each crib. Treatment of husked maize with such high concentration of insecticide reduced percentage weight loss by about 50 per cent. Giles & Leon (1974) also applied pirimiphos-methyl at 27 ppm to maize stored with husks and controlled insects satisfactorily. Moreover, after 16 weeks, the insecticide residue on grains was less than 0.1 ppm. Since the subsistence farmer in Ghana is likely to consume some stored maize within the 16-week period, there is the need for further study to determine the point at which insecticide residues fall to the tolerance limit within the 16-week period. Since the husk is an important wrapping material for a Ghanaian food (kenkey), the level of insecticide residue on the husk must also be within the tolerance limit.

The dry weight of shelled maize rejected as unfit for consumption (l_1) was again the major component of weight loss in maize removed from all cribs at all sampling times. It constituted between 100 and 69.8 per cent of dry weight loss suffered by samples. Factors contributing to the rejection of maize as unfit for consumption were, in order of decreasing importance, damage by moulds, damage by the insects listed under Experiment 1 and germination of grains.

Experiment 3

Percentage dry weight loss suffered by local

TABLE 2

Percentage Weight Losses by Maize Stored on the Cob in Circular Cribs

Storage conditions	*Storage period (weeks)*	*Moisture content of maize (%)*	*Weight removed as shelled grain at 13 % m.c. (kg)*	l_1 *(%)*	l_2 *(%)*	*Weight loss in sample* ($l_1 + l_2$) *(%)*	*Weight loss as % of total stored (L)*	*Cumulative weight loss as % of total stored*
Crib 1	12	13.3	14.0	4.3	0.4	4.7	0.6	0.6
Maize	16	14.3	25.0	14.6	2.8	17.4	4.9	5.5
stored with	24	13.4	18.0	25.2	7.4	32.6	8.2	13.7
husks	28	14.4	19.6	33.6	7.0	40.6	12.6	26.3
Crib 2								
Maize	12	13.1	15.5	5.7	1.2	6.9	0.7	0.7
stored	16	13.2	29.9	9.8	1.7	11.6	2.6	3.3
with husks	24	13.2	36.6	19.4	5.9	25.3	8.1	11.4
	28	13.2	29.7	25.8	9.1	34.9	10.5	21.9
Crib 3								
Maize with								
husks treated	12	13.8	15.6	12.1	0.7	12.8	1.7	1.7
with	16	12.8	28.4	14.5	0.0	14.5	3.6	5.3
pirimiphos-	24	13.0	24.6	14.8	1.1	15.9	3.4	8.7
methyl at 27	28	13.5	39.2	10.0	3.2	13.2	4.4	13.1
ppm								
Crib 4								
Maize with	12	13.0	15.0	2.2	0.9	3.1	0.5	0.5
husks	16	13.3	23.8	6.1	1.8	7.9	2.1	2.6
treated with	24	13.3	13.7	10.0	3.2	13.2	2.1	4.7
permethrin	28	12.8	33.3	10.4	4.5	14.9	6.0	10.7
at 27 ppm								

maize stored in two circular cribs on a farm for 40 weeks and the use-weighted percentage dry weight loss are shown in Table 3. During sampling, cobs were removed from both cribs and bulked before analysis for dry weight loss. The results are, therefore, presented as if all the maize cobs were stored in a single crib. The maize was stored with very little simulated use during the 40-week period. After 34 weeks' storage, 93 per cent of the original weight of maize stored remained in the cribs. Total dry weight loss under this pattern of use was 25.0 per cent of the total stored.

The contribution of rejected maize to dry weight loss suffered by samples removed at various sampling times was of the same importance

TABLE 3

Percentage Weight Losses by Local Maize Stored in Circular Cribs on the Farm

Storage conditions	*Storage period (weeks)*	*Moisture content of maize (%)*	*Weight removed as shelled grain at 13 % m.c. (kg)*	l_1 *(%)*	l_2 *(%)*	*Weight loss in sample* ($l_1 + l_2$) *(%)*	*Weight loss as % of total stored (L)*	*Cumulative weight loss as % of total stored*
Crib 1	8	14.3	19.1	5.1	0.0	5.1	0.0	0.1
	14	14.4	7.9	4.3	1.5	5.8	0.1	0.2
Maize	21	15.2	16.2	11.3	3.1	14.4	0.3	0.5
stored with	25	15.8	8.8	13.4	1.5	14.9	0.2	0.7
husks	34	15.9	23.0	23.7	0.0	23.7	0.7	1.4
	40	15.2	687.5	23.3	0.0	23.3	23.6	25.0

as in the two previous experiments. Between 100 and 74 per cent of the dry weight loss was due to dry weight of shelled maize rejected as unfit for human consumption. The grains rejected were damaged mainly by the insects already listed.

The results of this experiment confirm the author's observations on the storage of local maize with husks intact. Generally, as the storage period increases, cobs are either completely damaged by insects or not damaged at all. This makes it possible to obtain grains with little or no damage from a sample of cobs with a high level of damage. The weight loss suffered by maize considered to be fit for consumption (l_2) decreased after 21 weeks' storage in spite of the increase in weight loss in samples withdrawn from the stored maize.

The weight of shelled grain equivalent stored in both rectangular and circular cribs ranged between 97 and 883 kg (a little less than one 100-kg bag to about 9 bags). This range is representative of the quantity of maize usually stored by subsistence farmers in Ghana.

Majority of farmers do not store the major season's maize crop (harvested from the beginning of August to mid-September) beyond February of the following year, a storage period of between 24 and 30 weeks. With the exception of Experiment 3, the storage periods over which percentage dry weight losses were determined were representative of the subsistence farmer's storage period. Using patterns similar to those of these experiments, farmers who cultivate Composite 4 or La Posta may lose about 30 per cent of their harvests in the absence of effective and affordable methods of weight loss reduction. Though the application of high concentrations of some insecticides could reduce weight losses by about 50 per cent, further work in relation to insecticide residues is needed before such treatments could be widely recommended. The increase in dry weight loss beyond the 16-week storage period suggests, however, that if maize is not stored on the cob beyond this period but is shelled and protected against insect damage with pirimiphos-methyl (Ofosu, 1977), percentage dry weight losses could be reduced considerably.

The percentage weight loss (l_1+l_2) in local maize stored for 25 weeks (with no removal for consumption) was less than 15 per cent (Table 3). Even after 40 weeks storage, the farmer who cultivates local maize loses less than 25 per cent of the harvested crop. If because of low yields the subsistence farmer is to replace his local maize varieties with new high yielding varieties, care must be taken to ensure that effective and affordable post-harvest technologies are introduced at the same time.

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