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Full Length Research Paper

Comparison of three methods of weight loss determination on maize stored in two farmer environments under natural infestation

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Common methods of weight loss assessment in stored grain include the standard volume weight (SVW), count and weigh (C&W), the thousand grain mass (TGM) and the indirect with a conversion factor (CF) which have been used in varying storage environments. Apart from accuracy and reliability, practical application may limit their use in rural areas. Three of the methods: (SVW) or Bulk density (BD), C&W and CF were evaluated on maize stored in two farmer environments exposed to natural infestation. Baseline damage parameters: bulk density, grain moisture, sieved dust, weevil damage and insect pests per kilogram were established and again after 24 weeks. Weight loss was calculated using Equations 1 to 3. Percent weight loss varied by wide margins between treated and untreated maize: 4.4 to 12.3% (in Crib) and 0.3 to 9.9% (in house) for BD; 2.3 to 5% (in Crib) and 2.2 to 13.4% (in house) for C&W and 2.5 to 6.6% (in Crib) and 2 to 7% (in house) for the CF method. Generally, the house environment favoured pest establishment resulting to higher sample and cumulative weight loss in untreated maize. All the three methods had closely related weight loss figures in the same storage environment suggesting the need for careful selection of the preferred method based on practical application. C&W and CF provided the lowest results for the crib storage, but the ease in BD made it the preferred method in both environments.

Key words: Grain loss, assessment methods, bulk density, rural conditions.

INTRODUCTION

The need to reduce post harvest food loss in developing countries was first debated by the 7th Special Session of the United Nations General Assembly of 1975 (Harris and Lindblad, 1978). However, a sub-committee on methods observed that “There was no agreed methodology of loss assessment ….” Showing how hard it was to come up with a single figure for an area, country, region or global. It appears that the most important consideration is for the loss assessment method to yield realistic results which can justify loss reduction methods envisaged. But which method would work best under rural farm conditions? The main methods used for determining storage losses include the standard volume weight (SVW) (Golob, 1981) and thousand grain mass (TGM) (Proctor and Rowley, 1983). Harris and Lindblad (1978) have given detailed accounts of the count and weigh (CW) and % damage and conversion factor (CF) in addition to the SVW. Others like Irshad and Javed (1990) have used derivatives giving rise to the multiple thousand grain mass (MTGM), multiple count and weight (MCW), indirect by weight (Ind. Wt.) and indirect by number (Ind. No.). For simplicity, Tiongson (1992) grouped the methods into: SVW; C&W; indirect (CF) and thousand grain mass (TGM). However, using one or a combination of the aforementioned methods, variable weight loss results have been reported but the main concern has been the rising trend from about 5% (De Lima, 1979) to over 30%, Golob (1981a), Muhihu and Kibata (1985). To give the monetary worth, a study on the impact of *Prostephanus truncatus* on stored grain found30% weight loss where the pest was endemic and 20% where it was not, a

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difference worth over Kshs 2.8 billion at the then market price of Kshs 1000 per 90 kg bag (Mutambuki and Ngatia, 2006).

Few comparisons between the loss assessment methods have been made. Golob (1981) compared the SVW and the C&W and found the former to give higher weight loss estimates. Irshad and Javed (1990) evaluated seven methods against the standard weighing (STD) but found most to be tedious and time consuming. Alonso-Amelot and Avila-Nunez (2011) found the modified standard volume/dry weight ratio and % damaged grains converted to weight loss were the most practical for wheat and barley under rural conditions. The afore-mentioned studies appear to point at the need for further refining of the methods, if farmers and traders can be expected to work with them. Farmers in rural areas know the damage caused by the maize weevil *Sitophilus zeamais,* Angoumois grain moth *Sitotroga cerealella* and even the larger grain borer *P. truncatus* but their knowledge on losses is limited. Lack of understanding robs them of the bargaining power on prices and the situation provides a rich ground for exploitation by the middlemen who buy grain in kilograms while farmers are used to trade in volume. A simplified method on loss assessment could be all the rural farmers need to understand the relationship between volume and weight before they can be expected to institute loss reduction measures.

Of the documented procedures, a few can be adapted to suit the level of understanding of the rural populations. Batch weight loss is common in central storage system where grain is weighed at the entry and again as it is disbursed. Any discrepancy is taken as the weight loss. The weight of a standard volume measure, preferably using containers commonly used in grain trade is one method that can be used. A difference in weight between original and final weight after storage could be regarded as the weight loss (Neto et al., 2006). Farmers view damaged grain in terms of “the inability to use it”, and the C&W which takes into account the weevil eaten portion could be another appropriate method. Compton and Sherington (1999) adopted farmers’ view to classify weevil damage on cobs using a 1 to 5 categorical scale from slightly damage (10 to 20%) to heavy damage (90 to 100%) and then applied C&W method for weight loss. The indirect method which uses the percent damage multiplied by a conversion (CF) is also suitable when the cause of damage is either *S. zeamais,* or *S. cerealella*. These appear to fit farmers’ rural storage environment.

Surveys have established that maize in rural districts in Kenya is stored both as cobs in traditional outside cribs and as shelled grain in bags in the living house (Mutambuki et al., 2010). While the crib provides continuous ventilation thereby aiding drying and quality maintenance, the warm conditions in the living house could in a way, favour rapid proliferation of storage insect pests. To verify whether the conditions in the house lead to more damage and hence weight loss, a simulation trial on farmers’ storage practices was set up where maize was stored in exactly the same way farmers did, with and without any chemical protection. Samples were taken on a monthly basis over a six month period and subjected to the identified three methods of weight loss assessment and the results compared with the baseline.

MATERIALS AND METHODS

Storage structures

The common maize storage practice in Bungoma were the outside crib for cobs and in-house stores after shelling and treating with dilute chemical dusts. Three traditional outside cribs were constructed in the selected homestead, one for cobs and the other two for shelled grain in bags. The farmer at the homestead also provided space in the house where experimental bags were laid on wooden logs.

Maize treatments

Eight bags of 90 kg of shelled grain were locally purchased. Two bags were treated with 1.6% pirimiphos methyl + 0.3% permethrin at the recommended rate of 50 g / 90 kg bag. These were placed upright in one of the outside cribs while the other two bags were stored untreated in the next crib. The same treatment was repeated for the in-house trial but treated and untreated bags were separated by 1 m space. The 60 kg of untreated cobs were loaded into the third crib to monitor infestation development. Farmer maize stocks were also monitored in six homesteads close to the site for comparison. Farmers’ uses were not controlled and about half exhausted their stocks before end of trial, so data was pooled and the average used in the subsequent comparison.

Infestation

Infestation was left to set in naturally just as it happens in farmer stores. Pest identification was done to confirm the most prevalent storage insect pests and whether the newly introduced larger grain borer *P. truncatus* Horn had set in.

Sampling and analysis

Farmer’s consumption pattern was calculated from the quantity cooked daily which translated to between 12.3 and 14.5 kg for the six farmsteads, average 13.4 kg per month. Because of handling logistics, a compromise 10 kg sample was close to farmers’ consumption rate and convenient for our purpose. The 10 kg sample was reduced through conning and quartering and the 1 kg taken to designated site for analysis. After sieving and grain moisture determination, the grain was sorted into weevil damage, dust, broken pieces and mould infection.

Subsequently, regular sampling and analysis were done at 4-weekly intervals until the final at 24 weeks. In the cob store, between 9 and 17 cobs (depending on size) were picked along the 8 compass directions and shelled to give about 1 kg of grain. For subsequent sampling, the depth of cobs was visually assessed to determine the number of cob layers to be removed every month, so as to sample on the top layer left. The final sampling was from the bottom few layers.

Percent weight loss methods

Weight of standard volume method

The 1 kg sample was first sieved to remove dust, foreign matter and free living insects which were collected for identification. Grain moisture was determined using a Dickey John moisture meter. Three test weights for a 440 ml capacity glass jar was taken and average used for bulk density calculation. The results were compared with the baseline figure at 0 weeks using the formula as follows:

$$\% \text{ Weight loss} = \frac{W1 - W2}{W1} \times 100 \quad (1)$$

Where, W1 = weight of baseline sample, W2 = subsequent sample weight at different storage intervals.

Count and weigh method

The same sample was passed through the riffle divider to reduce to ⅛ for ease of handling. Grain in three ⅛ sub-samples were sorted into damage categories: insect damaged (weevil damage), mould damage, broken pieces and undamaged grains. Because the interest was on the weight loss caused by storage insect damage, only the weevil damaged grains were compared with undamaged lot in the equation as follows:

$$\% \text{ Weight loss} = \frac{(UNd) - (DNu)}{U(Nu + Nd)} \times 100 \quad (2)$$

Where, U = weight of undamaged grain, D = weight of damaged grain, Nu = number of undamaged grains, Nd = number of damaged grains.

Conversion factor method

The method has been found useful where the infestation consists mainly of the maize weevil, *S. zeamais* and the Angoumois grain moth, *S. cerealella*. The percent weevil damaged grains in Equation 2 were multiplied with ⅛, the conversion factor given in Harris and Lindblad (1978) as shown:

$$\% \text{ Weight loss} = \frac{(Nd) \times 100}{(Nu + Nd) \times 8} \quad (3)$$

Where Nd = number of damaged grains; Nu = number of sound grains.

Statistical analysis

Data was subjected to statistical analysis using the statgraphic software and the Duncan's multiple range test (DMRT) which separated the treatment means for the crib and the in-house trials as well as the methods of weight loss assessments.

RESULTS

Baseline information

The maize used was purchased locally and it was at different levels of moisture content and insect damage. Table 1 shows no statistically significant (P>0.05) differences in the bulk density (BD) for both crib and in-house at the initial stage of trials. However, weevil damage and amount of dust in 1 kg samples were significantly higher in treated maize, a reflection of the differences in farmer storage conditions. Differences in the level of grain moisture for untreated and treated maize were significant at P>0.05 level.

Infestations build up and grain damage

Infestation build up was very slow during the first three months with about one live weevil per kg at the start, which increased gradually to 112 and 150/kg in untreated samples in the two environments (Table 2). At 24 weeks, more than half (53 to 56%) of the untreated grains were weevil damaged compared with 16 to 20% in the treated maize. Dust generated as a consequence of the weevil damage increased to 20 g/kg in untreated maize compared with 5 to 7 g/kg in treated samples. Grain moisture had little variation while BD varied from 0.7407 to 0.6734, indicating a drop from the original weights. The main storage insect pests were *S. zeamais, S. cerealella* and *Tribolium castaneum.*

Percent weight loss

Data in Tables 1 and 2 was applied to Equations 1, 2 and 3 for the respective assessment methods. The results are shown in Table 3. ANOVA for the storage period and assessment methods were highly significant (P=0.0000) followed by store environment (P=0.006). Weight loss varied widely from a low 0.3% for BD to 13.4% in the C&W method for the two environments. In the crib at P =0.05 level, weight loss in BD was twice that of the C&W and CF respectively. Weight loss differences between BD and C&W were not statistically significant in the in-house trial. But C&W had twice that of the CF for untreated maize. Grain treatment was more effective in in-house storage, but more weight loss occurred in untreated maize in the same trial.

Cumulative weight loss

Cumulative weight loss (CWL) show the long term effect of infestation for farmers who do not apply any protectants. Figure 1 shows that farmers were likely to loose between 23 and 27% of their harvest after six months of storage in the two environments. The benefit of

Table 1. Maize conditions (parameters ± SE) before simulation trials.

	Simulated farmer storage environment			
Parameter	**Crib treated***	**Crib untreated**	**House treated***	**House untreated**
Initial				
Bulk density	0.7632±1.2[a]	0.7677±0.2[a]	0.7432±5.0[a]	0.7652±2.1[a]
% Grain moisture	13.3±0.0[b]	14.0±0.0[d]	13.0±0.0[a]	13.8±0.0[c]
Wt of dust (g/kg)	1.3±0.0[ab]	0.6±0.4[a]	2.1±0.3[b]	0.6±0.6[a]
% weevil damage	3.5±0.2[b]	0.9±0.4[a]	2.7±0.3[b]	0.3±0.1[a]
Live insect pests/kg	1.0±0.0[a]	0.0±0.9[a]	1.0±1.0[a]	0.0±0.5

Each datum is a mean of three readings, row means followed by the same letter are not significantly different (P<0.05).
* = Analysed before chemical application.

Table 2. Maize conditions (parameters ±SE) after 24 weeks exposure to natural infestation in a simulation trial.

Parameter	Simulated farmer storage environments			
	Crib treated	**Crib untreated**	**House treated**	**House untreated**
Final				
BD	0.73±2.9[a]	0.6734±3.0[b]	0.7407±1.9[a]	0.6893±3.0[b]
% Grain moisture	12.7±0.1[c]	12.6±0.0[bc]	12.4±0.2[ab]	12.2±0.0[a]
Wt of dust (g/kg)	6.5±0.8[a]	22.0±2.7[b]	5.1±1.7[a]	19.8±2.7[b]
% weevil damage	19.9±6.0[a]	52.9±3.6[b]	15.7±4.5[a]	55.8± 5.0[b]
Live insect pests/kg	12.6±6.5[a]	112.5±34.5[b]	15.0±1.0[a]	150.5±5.5[b]

Each datum is a mean of three readings, Row means followed by the same letter are not significantly different (P<0.05).

Table 3. Calculated percent weight loss in treated and untreated maize after 24 weeks of simulation as assessed by the three methods.

Equation	Method	Simulated farmer storage environments			
		Crib treated	**Crib untreated**	**House treated**	**House untreated**
1	BD	4.4[b]	12.3[b]	0.3[a]	9.9[ab]
2	Count & weigh	2.3[a]	5.0[a]	2.2[a]	13.4[b]
3	CF x % damage	2.5[a]	6.6[a]	2.0[a]	7.0[a]

Column means followed by same letter are not significantly different (P>0.05) DMRT. CF x % damage = Conversion Factor x % damage.

treating maize was a reduction in cumulative loss to between 10 and 13% in the in-house and the crib trials respectively. Figure 2 shows the influence of the storage environment on the cumulative weight loss by methods of assessment on untreated maize. BD had the highest (>34%) in both storage environments. C&W and CF had the lowest (15 to 20%) for untreated maize in the crib but recorded between 23 and 27% for untreated maize in the in-house trial. On cob maize storage (Figure 3), BD recorded higher cumulative weight loss (34%) while CF had 9%, the least. On farmer stored maize (Figure 4), BD and C&W methods had higher (18%, 20%) and similar pattern while CF had the lowest cumulative loss at 11%.

DISCUSSION

The simulation trial was carried out to determine the level of weight loss on farm stored maize, with and without any protection. Weight loss is defined as the difference in food stocks between two successive storage periods. The comparison between baseline and subsequent weights after 4-week intervals for 24 week storage period was the preferred approach. Weight loss determination could be influenced by the availability of the requisite equipment, methods used and the storage environment. Tiongson (1992) has outlined requisite equipment for SVW, C&W and CF. However, the listed equipment could

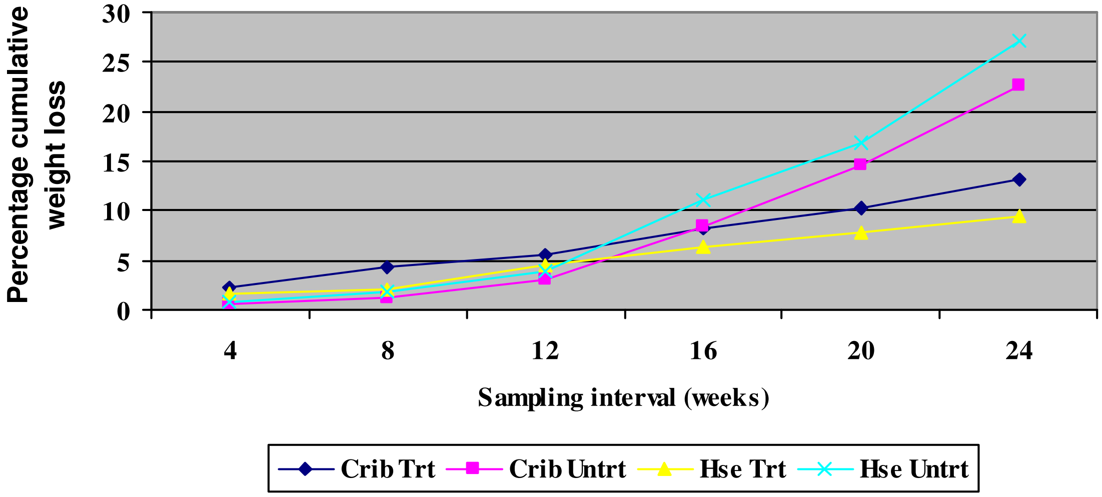

Figure 1. Influence of the two storage environments on cumulative weight loss in treated and untreated maize.

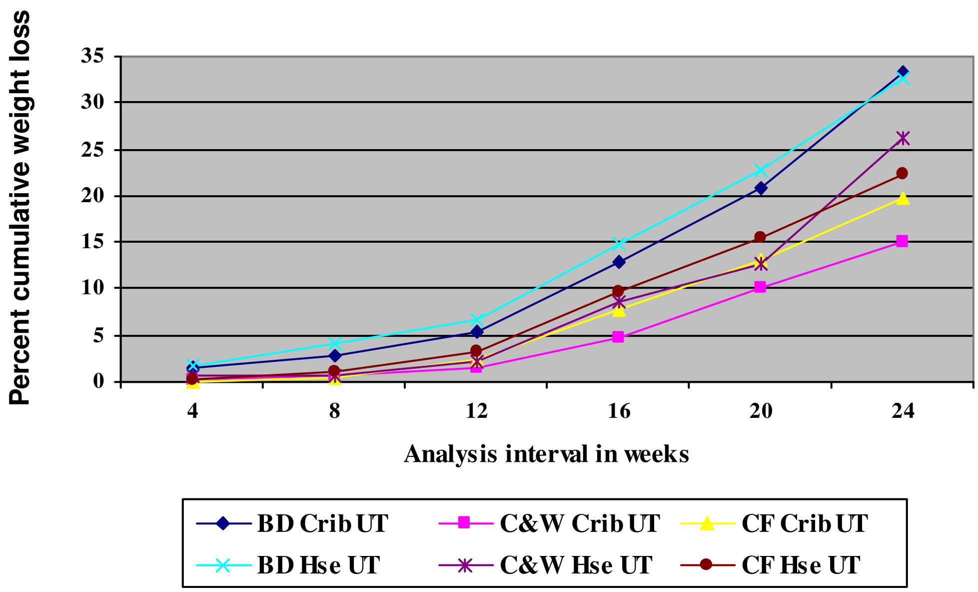

Figure 2. Mean cumulative weight loss in untreated maize in two storage environments as assessed by three methods.

be hard to find under many rural situations, making it necessary to consider the minimal that would enable the application of three methods. These could be a weighing balance for the C&W and a standard volume container for the BD methods. In this trial, the CF method utilised the results from the C&W method. All the three methods evaluated produced results in the range of 0.3 to 13.4%, which agrees with Hodges' (undated) weight loss range of 0.3 to 13.3% in maize and (Alonso-Amelot and Avila-Nunez, 2011) weight loss of 2.2 to 14.5% in wheat. The storage environments appear to have some influence with the average 8.0% weight loss in untreated maize in the crib, compared to 10.1% for the same in the in-house storage.

The results thus confirm the house environment to have favoured insect pest damage which translated to a higher cumulative weight loss if no control was done. However, with intervention, the scenario was different as cumulative weight loss in farmer stored maize was markedly lower than in both cob and simulation trials, as a result of different interventions used. Therefore, the aforementioned losses can be regarded as being within

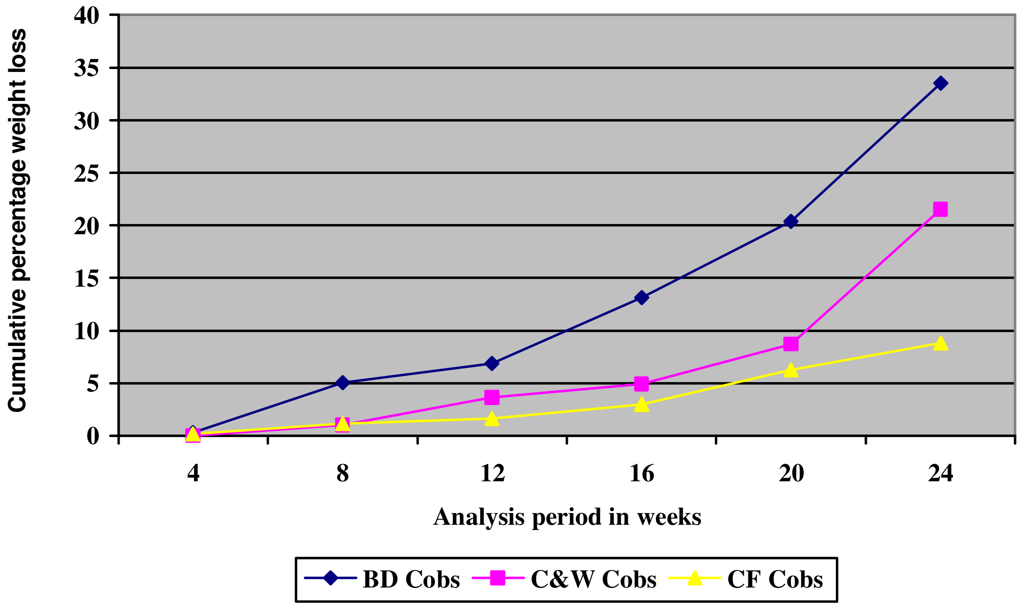

Figure 3. Cumulative weight loss on cob stored maize as assessed by three methods.

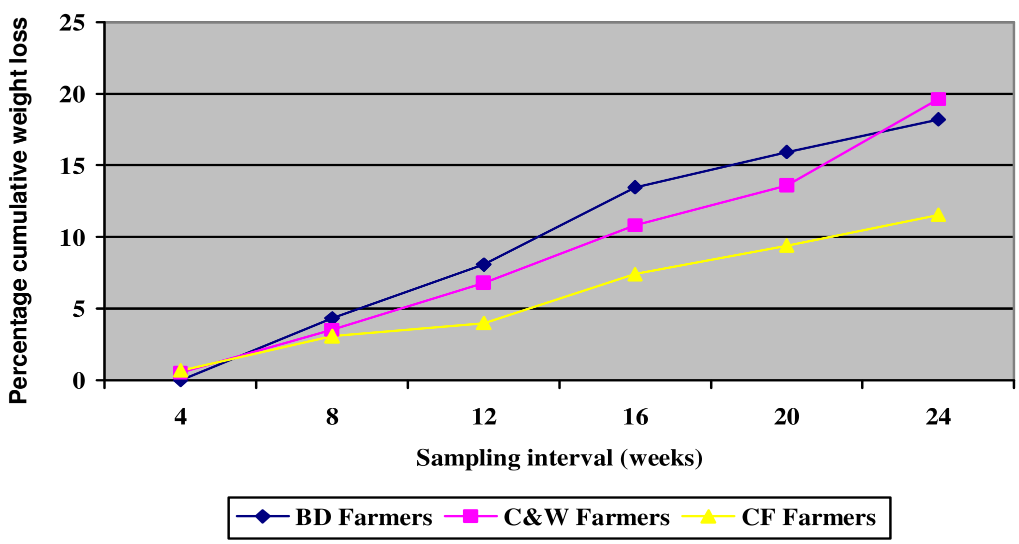

Figure 4. Cumulative weight loss in farmer stored maize as assessed by three methods.

the acceptable level for a storage period of 24 weeks. Apart from the storage environment, variation in weight loss could be due to the method of analysis. Harris and Lindblad (1978) noted that acceptable post harvest grain loss assessment methods should yield realistic results. In both the crib and in-house trials, CF results were somewhere between the BD and C&W, with the former consistently giving a higher percent sample and cumulative losses (Table 3). BD also maintained higher cumulative weight loss on cob and farmer stored maize, a fact Golob (1981) described as weight loss exaggeration.

On the other hand, the C&W method gave consistently low weight losses compared to the other methods confirming Alonse-Amelot and Avila-Nunez (2011) notion that the method grossly under estimated the losses when compared with thousand grains mass (TGM). The discrepancies between methods are not uncommon and must therefore be accepted. Miguel and Jorge (2011) reported percent weight loss of 2.3% for C&W compared with 14.5% by visual method. Braga-Caneppele et al. (2003) found 2.3, 4.7 and 21% as percent losses following three methods in Harris and Lindblad (1978).

Grain size and hidden infestation are some of the factors causing variation of the results and sorting by size could overcome the problem but can frustrate rural population because it is tedious and time consuming. One method could act as the check for another. In the simulation trial, when CF was applied to the C&W data with 13.4% weight loss, the resultant figure was 6.4% lower than in the preferred method confirming Alonse-Amelot and Avila-Nunez (2011) observation that CF was a more practical and an expedite means to evaluate losses in individual farms. The fact that BD involved only weighing makes it more attractive for both traders and farmers interested in ascertaining weight loss, but like visual inspection, BD is likely to unfairly keep prices artificially low (Miguel and Jorge, 2011). This could be one of the trade-offs between accuracy and speed.

Conclusion

The importance of weight loss at farm level cannot be ignored any more. Farmers know the causes and even the benefits of treating grain. Treated maize is of good quality and attracts premium prices. The house environment has a role to play in aggravating losses as both sample and cumulative losses showed. Simple weight loss assessment methods, like the ones evaluated were all acceptable based on level of losses found. This puts the farmers at dilemma on which to choose among them. A look at the influence of the storage place does not appear to be helpful, leaving farmers with the requisite equipment as the criterion for choice rather than weight loss levels. On this alone, BD appears to be the method of choice.

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