ESTIMATING POST HARVEST LOSS: A CHALLENGE OF DEVELOPING NATIONS

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Abstract: This paper has highlighted the importance of reducing postharvest food losses as a necessary step in ensuring future global food security in a sustainable manner. Given the postharvest challenges posed by lack of understanding of postharvest losses, food safety and the non-controlling of aflatoxin cannot be achieved merely through increases in agricultural productivity. There have been very few past studies conducted to estimate food losses. The existing studies have been mostly one-off and do not adopt any consistent methodologies. Methodology assessment identified include-specific food loss assessment consideration-rapid laboratory based procedure, rapid judgement based procedure guesstimate, traditional local estimate, vissloss estimate and on-site expert judgements. Other loss measurement techniques include weight comparisons, separation of damaged kernels and percentage determination. While the African Postharvest Losses Information System has recently made an effort to provide a framework to calculate food losses using a common methodology for south and east Africa, the input used in this process is based on work which may be outdated or not directly relevant. Therefore, it is critical that a more broader and updated effort be implemented to improve the ability to estimate postharvest food losses. The paper outlines a framework which can be adopted for consistent estimation of postharvest losses.
Keywords: Developing, estimating, loss, nations, postharvest

Introduction

While planning to provide the basic needs of a people or improving their living standards, it hardly needs to be emphasized that the availability of sufficient and nutritionally balanced food is of the highest priority (notwithstanding the importance of suitable policies for adequate and suitable housing, education and health schemes). There is evidence that at the moment about 1 billion people in the world do not have enough to eat (NRC, 1996), and this number will increase with the increased world population (since, paradoxically, the areas of scanty food availability, have the greatest population explosions). Consequently, there will be a greater demand for food in future. Traditionally, increasing food production by increasing average yield per acre has always been a readily applied concept while reducing losses in order to increase food supplies was a less obvious strategy. This is hardly surprising because, all over the world, post-harvest technology has greatly lagged behind its preharvest counterpart in the attention it has received with the result that knowledge, experience, infrastructure and interest have been built up mainly in the pre-harvest area. It is only in recent years that widespread scientific interest in, and political concerns for post-harvest food loss reduction have arisen.

The United Nations predicts that 1.3 billion tons of food is lost globally every year (Gustavsson*et al*., 2011). Food losses in Europe and America range from 280-300 kgs/year, and are about 120-170 kgs/year in Sub-Saharan Africa and South/Southeast Asia (Gustavasson*et al*., 2011). With the current world population expected to reach 10.5 billion by 2050, this food loss, if properly managed and prevented, can feed future generations. This resolution was sequel; to the belief of many observers that a 50 – percent reduction in the post-harvest food losses in developing countries would greatly reduce, or even eliminate, the present need of some countries to import large quantities of food. It therefore hardly needs emphasis that post-harvest food loss reduction requires immediate and deliberately prejudiced attention.

Every year across sub-Saharan Africa (SSA) unacceptable levels of food losses continue to occur. Although these losses are being recorded at every stage in the supply chain, from production through to retail and consumer levels, the area of highest concern (where the greatest percentage of crop losses are recorded) are pre-farm gate, where poor harvesting, drying, processing and storage of crops occur. Postharvest management at farm level is the critical starting point in the supply chain. Current inefficiencies in this segment represent one of the largest contributing factors to food insecurity in Africa, directly affecting the lives of millions of smallholder farming families every year and impacting enormously on available volumes of food for consumption and trade in low-income, food-deficit countries (UN World Programme (2014)

Despite increased warnings regarding the planet's inability to feed the expected population growth beyond 2050, alarmingly little is being done to preserve existing food production in regions most vulnerable. Over recent decades, significant focus and resources have been allocated to increase food production (95% of all research investments over the past 30 years have focused on increasing productivity and only 5% directed towards reducing losses(UN World Programme, 2014). The solution, however, requires more than an expansion of agricultural production. Improving farm management practices will not only increase the available food for consumption annually by millions of tonnes, but will achieve this without incurring the additional labour, land, materials, resources and biofuel expansion required with increased production. A sustainable solution to global food shortages will rely heavily on the preservation of existing food production; a reduced loss of food.

Post-harvest challenges

Understanding post-harvest losses: All crops are naturally subject to biological deterioration, but the rate of deterioration can be highly influenced by a range of factors; starting from individual farming practices and continuing through the chain of interdependent activities between harvest and delivery of food to consumers. In 2011, the World Bank, in association with FAO and Netherland Research Institution (NRI), released an important industry study in which they described this continuum as a value chain, where a variety of functions are performed, including harvesting, assembling, drying, threshing, storage, transportation and marketing. Inefficient management practices which allow crops to be unnecessarily exposed to contamination by microorganisms, chemicals, excessive moisture, fluctuating temperature extremes, mechanical damage and ineffective storage practices contribute greatly to food losses (PHLIS, 2013). Adding to the losses caused by biological deterioration are the serious health risks which arise when damage caused to the external pods of legumes or husks/kernels of grains during pre and post-harvest stages, contribute to aflatoxin contamination and mould growth. For these reasons, a critical step in World Food Programme (WFP's) Action Research Trial was to educate farmers in understanding the influence of biological and environmental factors (as well as handling practices) on product deterioration and how new technologies and farming practices can improve the quality and safety of their crops.

Food Safety: Contamination of food is a major problem in SSA. Improving post-harvest management competencies amongst low-income farmers will not only lead to increased crop preservation and food volumes for consumption and trade, it has the potential to directly impact on the health and well-being of all people living in the region. The most serious of food related health risks is the constant threat of food poisoning caused by toxic aflatoxin contamination. Aflatoxins are highly carcinogenic toxins produced by the fungus Aspergillusflavus (Rembold, 2011). They are naturally occurring toxic substances, particularly prominent in maize, and a major issue when produce comes into contact with soil during harvesting, threshing and drying. Contamination of crops can also occur after grain has been placed into storage, due to pest infestation and poor storage conditions that lead to accelerated growth rates of Aspergillus fungi. Aflatoxins are difficult to see; they have no smell, feel, or taste and laboratory testing is required to discover its presence (Haile, 2009). The World Health Organization explains aflatoxins are directly associated to liver cancer, impaired immune function, stunted growth in children and are the third leading cause of cancer deaths globally (SAVE FOOD, 2013). The problem has become so widespread throughout Africa, particularly in the East African region, the poisoning has become an epidemic (Schwab, 2010).

Aflatoxins Control through Good Post-Harvest Management Practices: There is no procedure for eliminating an aflatoxin after it is produced, however limiting or avoiding concentrations can be achieved under proper management. Farmers involved in the trial were shown ways to limit the presence of poisonous aflatoxins on their crops and how contamination can be controlled with careful pre and post harvesting management. Pre-harvest instructions on land preparation and the correct timing of planting and harvesting to reduce a plants susceptibility to aflatoxins, as well as guidance on controlling moisture content and avoiding direct crop contact with exposed soil was provided. Farmers learned the importance of properly drying crops to reduce the chance of fungal growth and ways of creating low humidity storage conditions. The traditional practice of stockpiling dried crops either directly on the floor, in baskets, or in polypropylene sacks on the floor of their houses (due to fear of theft) was strongly advised against, regardless of the duration of storage.

However, before any meaningful post-harvest food loss reduction can be embarked upon, there is a clear need for accurate assessment of these losses to establish firm justification for the development and introduction of measures designed to reduce them and to establish that the cost/benefit ratios of corrective measures will be favourable. It is remarkable that an interdepartmental Sub-committee which reviewed past and current post-harvest loss assessment have submitted comprehensive findings (PHLIS, 2013). Moreover, loss data are generally unrelated to the cost of loss reduction. This was hardly unexpected since losses vary with crop, variety, year, pest and pest combination, length of storage, methods of threshing, drying, handling, storage, processing, transportation and distribution rate of consumption and according to both the climate and the culture in which the food is produced and consumed. Considering such enormous variability, one would expect the absence or non-availability of reliable statistics regarding type, location, cause and magnitude of post-harvest food losses. Yet reliable and objective methods of generating these statistics are needed if priorities are to be given to the reduction of these losses.

Although losses and savings are not the only elements which should be considered in loss reduction efforts, reliable figures on them can go a long way in gearing national policy makers to action and certainly, may motivate organizations which may wish to fund postharvest loss reduction programmes. For completeness, other elements worthy of consideration in loss reduction efforts (ARS 2008; FAO, 2004; FAO, 2011; Mvumi*et al*., 1995; Regmi*et al*., 2001) include:- type and nature of intervention, whether to intervene at all, the value of the crop in economic lines, fact that there will be social changes effected by intervention programmes and competition or conflict or both with other national priorities.

Methodology in Loss Assessment

An estimation of food losses is necessarily a complex process and because of its location-specificity, figures for one region will not apply to another region with a different climate. This limited general applicability of food loss figures, has often led to the use of extrapolated average figures for loss estimates under described conditions. Such a practice however, cannot underscore the important phases of the post-harvest system for individual crops under known sets of conditions.

The post-harvest period defines the time from the moment of separation of food item from the medium of immediate growth or production to the moment when the food enters the process of preparation for final consumption. It must be pointed out that it is prohibitively expensive and unjustifiable to mount countrywide assessment of losses in the whole post-harvest system. Expert judgement is highly desirable to identify the most serious food loss points in the post–harvest food supply system in order to mount in-depth assessment efforts at those high loss points. This is because the changes which may have to be introduced as a result of the loss assessment efforts are not likely to be widely accepted unless they are of practical values and are clearly beneficial to the individual who is to make the change.

Loss denotes the non-availability or disappearance of food and should be directly measurable in economic, a qualitative, quantitative as well as nutritional (PHLIS, 2013) terms as follows:

a. Economic loss, which denotes reduction in monetary value of a food as a result of physical loss.
b. Quantitative loss which implies reduction in weight.
c. Qualitative loss usually based on subjective judgements (e.g. damage) and is usually described by comparison with locally acceptable quality standards.
d. Nutritional and Germinative losses which are usually a combination of quality and quantity, since there can be a disproportionate loss of nutrients due to biodeteriogens which will not be apparent when weight loss alone is considered.

It is appreciated that there are limitations inherent in the identification of food losses but properly selected estimation methods can provide the information essential for reducing these losses. The components of loss have been identified as (Waart*et al*., 2011; Tyler and Dendy, 1978);- broken and damaged grains, mould damage, loss of viability/germinability, insect infestation, loss of weight, rodent damage, bird damage and nutritional quality loss.

Some of the loss components can be measured with far greater ease than others and, on this basis, those have been considered to have greater potential value for use in loss assessments than those which require techniques that are highly sensitive and also require careful interpretation of the results (Tyler and Dendy, 1978; Haile 2008).

The first important step to take in a post-harvest food loss assessment exercise is to search for and identify the points where the most acute food loss occurs. This is usually referred to as OVERALL ASSESSMENT and it implies the study of the whole physical and social system in which the food moves from producer to consumer. Such a study will identify how the commodities are handled and the number of participating middlemen with a view of permitting judgements to be made about the possibilities of loss reduction interactions. In developing such "commodity loss profile", locality – specific and commodity – specific information will be required and must be obtained. Such information are referred to as GUESS ESTIMATES and usually made by knowledgeable and experienced people. Such estimates are usually made without factual basis. They have however been especially useful when timely opinions are needed as to where the more serious losses occur. In using such guess estimates to reshape established practices, it is important to recognize the possible bias of the estimator. Thus in assessing a guess estimate, one needs to satisfy himself on questions (PHLIS, 2013) such as:

a. Was the estimate put in perspective by a thorough gleaning of available information?
b. Was the judgement based on an in-depth and long standing knowledge of local or even country-wide conditions?
c. Was it made to reveal some situations and cover others?

Although guess estimates have served a useful purpose and have hitherto been accepted by those seeking national resources and changes, they are limited in their overall reliability. However, in the face of increased sophistication and increasingly limited resources requiring benefit-related priorities, they can hardly be considered worth-while substitutes for scientifically derived figures.

In studying the overall assessment of loss of any food items, it is important to recognise what is generally called the "food pipeline" which traces the movement of the food from the producer to the consumer and which identifies along the route, the physical and biological ways in which food losses occur. An example of such a food pipeline is given in Table 1. It is important to note that this is only on ideal food movement and, in actual practice; the process may much simpler and may also be a lot more complicated. Despite the complexities of systems of commodity movements, experienced professionals can make useful estimates of losses and identify possibilities for loss reduction. Simple observation such as visual indexes of insects, moulds or leaking roofs may be all that is needed for a decision to be made (NAS, 1978; Basovarajaet *al*., 2007). Further, such factors as the use of pesticides or the type of storage facility can provide a knowledgeable person with a basis for judging where losses occur and in what magnitude.

The use to which a commodity is finally put has a bearing on loss estimation. As example, it is common knowledge that when food is harvested it may be divided into several lots for different end uses. Each lot, depending on its end use, usually receives different treatment. Some may be dried and stored for long periods to be used as seed while others are held only for short-term storage and consumption or movement off the farm. The two different lots have thus *ab initio* been exposed to different loss risks.

Table 1: The food pipeline

THE FOOD PIPELINE		
	Producer	
(Physical Faction)	Pre-processing	**Biological Process** 1. Broken grain 2. Excessive dehulling 3. Trimming
1. Heat 2. Front 3. Rain	Transportation	1. Spillage 2. Brushing 3. Breakage 4. Leakage 5. Pilferage
1. Rain	Storage	1. Insects 2. Moulds 3. Bacteria 4. Rodents 5. Birds 6. Pilferage 7. Sprouting 8. Rancidity 9. Overripening 10. Nutrient loss
1. Contamination	Processing &packing	1. Inefficiency 2. Excessive peeling & trimming 3. Polishing
1. Contamination	Marketing	1. Unsafe foods 2. Quality losses
	Consumer	

Source: Hodges *et al.* (2011)

Thus, it is usually the practice for farmers to consume their low-quality grain first since this is known to be subject to the most rapid loss. Such observations and information enable the expert to develop a commodity loss profile for a particular commodity. Such a profile would indicate: - final use of the commodity, channels through which it travels to final use, points at which losses occur and rough estimates of the relative magnitude of the losses at these points.

It is only this kind of complete information that will enable the expert to judge with confidence what should be investigated and where priorities are to be assigned.

The next important assignment is to analyze the critical point of potential or actual loss in the commodity loss profile. This exercise necessarily takes the investigator to the field and is therefore appropriately referred to as FIELD INVESTIGATION OF LOSSES. Such investigations must have clearly defined objectives and must have a pattern that is replicable so that loss comparisons can be made. Comparisons must be statistically valid and must be undertaken within a logical framework of field investigation and scientific measurement.

Two aspects of field investigation are very important viz: the SURVEY and the SAMPLING procedures. When the survey is made it should cover farm, villages or areas to determine the location at which the loss assessment will take place, the phase of the post-harvest system to be investigated and the farm, villages, etc. from which samples will be taken. A recognised statistical procedure should be employed for selecting farms: villages etc. and in this connection the "Stratified Random Sampling" technique has been a recommended statistical procedure (Adams and Harman, 1977; PHLIS, 2013).

The sampling procedure is the way the sample of a commodity is removed from the location under investigation, e.g. farm or village store. This needs to be carefully and expertly done and at the background of certain defectives. The size of a sample is limited by practical considerations such as whether the sample being removed for analysis will be returned to the store. A reasonable quantity for analysis such as 10 9 cobs of maize or 1 kg of it has been suggested as adequate for analysis (Adams and Harman 1977). Sampling of stored grain must also take into consideration the removal of commodity from the store for normal consumption or sale. This is necessary because rather too frequently the large losses reported only represent heavy damage to a small amount of residual stored commodity at the end of a season, while in fact the total food loss of the entire country may be much smaller.

The field investigations allow losses in commodity samples to be carried out but an investigator must relate losses to the pattern of consumption. If for example, food is left untouched throughout a post-harvest phase (e.g storage) period and at the time of removal the estimated loss is 10%, then this represents the total loss of over that period. However in most cases, food is removed at intervals during the storage period, and each quantity removed will have suffered a different degree of loss since it will have been exposed to deterioration for a different length of time. *The total loss over the season can be obtained by accurately weighing all the grain in and out of the store and comparing the totals.*

Specific food loss assessment consideration: rapid laboratory-based procedures

There are some well-known short cut tests such as presence of numbers of adult insects, amount of frass, or insect emergence usually employed in the laboratory. None of these has been considered sufficiently accurate when used alone for anything more than loose approximation. Although these and various other similar procedures have been given field trials in developing countries and the positive correlation between some of them with some loss quantifications suggest their use in making rapid assessments, some doubt exists concerning the application of these procedures in quantifying actual losses (Harris and Lindbia, 1978; ARS 2008). Their used in actual test situations and positive correlations to weight losses have been taken by some to indicate a practical degree of precision to routinely determine weight loss. Such is not the case. They cannot be so used unless the biological and physical characteristics of each assessment situation are completely understood. For example if lots of grain have the same histories, then their frass-to-loss relations will be similar and may be used to survey them on a comparative basis. However, if some have been removed (and frass is lost in the process) or some have lesser grain borers (thereby producing much frass), or some have weevils that make exit holes and some have moths that hold their frass in webbing, or the surface insects have been removed from some lots and not in others, then any standardization between lots, regions and grains become a new scientific investigation not subject to rapid comparison.

In spite of these limitations, the procedures are of value in a rapid visual and discussion appraisal of a situation when coming to a personal judgement. Their precision as indicators of actual losses depends on the expertise of the user in the preliminary examination of specific problem points and in making on-site rapid appraisals.

It is relevant to mention in passing that in loss assessment methodology, there are some laboratory-based procedures which were generated by the United States of America's Food and Drug Administration Unit. Expert opinion and results from first hand field and laboratory trials have concluded that these are too time-consuming. They require a tedious laboratory setting and difficult-to-standardize judgements. The techniques also require too small sample size or have too variable a relation to grain weight loss to warrant their use in determining food losses (Harris and Lindblad, 1978; FAO, 2004).

These procedures include: exit hole test, acid fuschin egg-plug test, berberinesulphate fluorescent stain egg test, gelatinization with sodium hydroxide, examination for internal insects and radiographic (X-ray) examinations

In any postharvest food loss assessment, the following two considerations are highly critical:

(a) the need not to attempt more than is feasible and

(b) the need to rapidly seek and identify for investigation, major loss situations that seem both amenable to study and practical interventions.

During this critical appraisal period, overall appraisal based on an expert evaluation of loss-inducing and loss-reducing factors may be all that is required. Such factors to be considered (PHLIS, 2013; Remboldet *et al.,* 2001) include:

1. Moisture
2. Temperature
3. Insects, rodents, and birds (kinds, numbers and association with grain).
4. Length of holding
5. Local quality and quantity controls.
6. Types of containers and other holding vessels
7. Sanitation/Insanitation
8. Trading quality factors
9. Use and non-use of pesticides
10. Evidence and non-evidence of grain damage (kind and amount)-Frass and webbing, Exit holes, Darkened (rottened) kernels and)Degermed kernels
11. Mechanical factors
12. Location of phase being investigated in the post-harvest system

It is in this regard that the short cut laboratory based methodology become very important and useful.

Rapid judgement – based procedures guesstimates

These are estimates based on little facts by knowledgeable persons. They have usually served many purposes such as providing immediate and urgent information that could not have been available in any other way. However because they are simple guesses or preconceived opinions from experience, there is a limitation to their validity as determiners of losses. They, however, have a valid role in making rapid judgements that may suffice for some purposes or which only precede more accurate evaluations.

Traditional local estimates

It is appreciated that there are times when local people can make accurate comparisons between conditions found in grains as it goes into and is taken out of storage (for example) and on actual wastages due to insects, birds and rodents. Such locally available information is useful in getting one's bearings on local situations. In this connection, interviews play vital roles which should not be passed over lightly. Interviews should be conducted with great care to assess the point of view and biases of the giver of information. Whenever it is possible to make on-site observations or measurements, these coupled with local information can provide estimates which will be especially useful in obtaining a good picture of the local conditions and which may be extrapolated to larger areas with reasonable accuracy.

On-site expert judgements

This is a form of rapid appraisal which should be used only by experts to assess percentage or weight losses. In making such judgements, the investigator should consider how local conditions affect the physical and biological potential for losses. For example, transportation in damaged bags or make-shift and broken-down vehicles with visible spillages indicate obvious loss situations. Short term storage, good sound bagging, well-constructed transport vehicles, strict weigh-in/weigh-out controls with accompanying records, the use of insect, rodent, bird and fungal control procedures and low temperatures are all indications of minimal losses. While high moisture, active insects, rodents and bird degradations as well as visible mould infection or high temperatures clearly indicate trouble and potentially heavy losses.

Visloss Count Method

In the Visloss count method, individuals were assigned to score the cob samples independently into different damage classes depending upon the photographs provided to them. The study calculates the mean bias of visual estimates and the standard error for the estimates of weight loss using visual scale equation. The bias was estimated for each sample within a batch as the difference between predicted value using visual scales (Visloss) and the measured loss using count and weigh method (Wghtloss). Only in one out of the five batches, that this bias was significant.

For the estimation of the damage class coefficients in equation (1) to be used in this method, samples were obtained from each of these six damage classes. The mean weight loss for each damage class was used as a preliminary estimate of coefficient. Later they were further adjusted after obtaining fit between visible percentage of grain loss (Visloss) and cob weight loss (Wgtloss). Visloss was estimated using visual scale and weigh method and Wgtloss by modified weight and count method, mentioned above. These coefficients were repeatedly adjusted within reasonable ranges to give best visual fit between Visloss and Wgtloss. Then, total loss based on the visual code method was estimated by the equation below:

$$Visloss = \frac{0\%N_1 + 2\%N_2 + 15\%N_3 + 30\%N_4 + 40\%N_5 + 80\%N_6}{N_T} \quad ....(1)$$

Where:*N1,…,N6 are the number of cobs in classes 1 to 6 in the sample, NT =total number of cobs in the sample, and Visloss is estimated weight loss* (Gangwar*et al*., 2007).

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Loss measurement techniques

(a) Losses due to Insects and Mites

Insects and mites are by all means, a major cause of post-harvest food losses. By boring into the foods and feeding on their surfaces, they remove food, selectively consume nutrient components through their metabolic activities, encourage higher moisture in the commodity and consequently promote the development of microorganisms. Methods of determination of losses due to these biodeteriogens (PHLIS 2013) are notably of three types:

1. In this, a comparison is made between the actual weight of a sample and the weight it would have had in the absence or damage. It involves the determination of a measured volume of the commodity and usually reflects the losses caused by a combination of the biodeteriogens as well as other factors.
2. Separation of damaged and sound kernels and the determination their comparative weights calculated in terms of the whole sample. This is also a gravimetric technique.
3. Determination of the percentage insect-damage grain and its conversion into a weight loss using a multiplication factor. This method gives approximate figures which are useful in preliminary surveys.

The gravimetric methods are very useful in weight loss estimates and are more complicated than simply weighing appropriate samples at successive intervals on a balance of appropriate analysis. This is because of the moisture content changes in the commodity throughout the year, and the procedure has to compensate for these changes.

Losses due to fungi and other microorganisms

When moulds occur, a considerable proportion of the grain is often discarded or used to feed animals. The impact of fungal infection on loss is consequently usually estimated by including the separation of mould damage from other types of damage during analysis.

The calculation of "weight loss" when the loss is due to fungal damage must therefore depend on local practices in the use of the damage material.

Although the methodology for fungal damage is treated separately from that of insects, it should be borne in mind that both are frequently interrelated and interacting, so that the degree of separation needed is currently unclear and will likely be situation-specific. In the methodology, allowances must be made for differences in moisture content of infected and uninfected commodity.

Losses caused by fungal contamination can arise through:

(i) The rejection of the food because of visible fungal contamination or fungal damage.

(ii) The rejection of food (which may not necessarily be visibly contaminated by mould) because of its mycotoxin content which can arise from:

(a) the direct fungal contamination of the food,

(b) the consumption of mycotoxin-contaminated feed by animals which leads to contaminated animal products (e.g meat and milk).

(iii) A decrease in the yield of food. In this wise, the ingestion of contaminated feed can reduce the fertility and productivity of animals (e.g a decrease in milk yield). High doses of mycotoxin have been known to result in death.

(iv) Acute and chronic illness caused in humans by the ingestion of mycotoxin.

There is no doubt that there is an increasing awareness of the mycotoxin problem (especially aflatoxin) with a corresponding likelihood of increased food rejection in the future. Currently there is a rapid method for observing aflatoxin in maize (utilizing the BGY fluorescence) while groundnuts are routinely sorted out using electronic colour sorters. Established assay procedures exist for the analysis of a wide range of foods and feeds for aflatoxin and other mycotoxins.

Methods for determining losses due microorganisms include

i. Loss measurement by Standard Table Based on Time, Temperature and Moisture (ARS 2008). Microorganisms reduce the organic material of food simpler organic compounds or even to the inorganic form. They will thus cause dealy to the commodity and with time completely destroy it. However, long before th commodity is completely destroyed, it is useless for food because of its musty odour, discolouration and possible formation of toxic substances. It has been suggested that this will occur by the time 1 to 2% of the dry weight of the commodity has been destroyed (Saul and Harris, 1978; Gangwa*et al*., 2007). Commodities in equilibrium with a particular relative humidity usually have fixed moisture contents which depend on the temperature of the environment. Consequently, by keeping commodities at fixed but differing moisture contents (in equilibrium with appropriate relative humidities) over chosen temperature one could determine when the weight loss per day of the **commodity will be for given moisture content and temperature.** Table 2 culled out Harris and Lindbland (1978), illustrates what is being described.

Table 2: Rate of dry matter loss in undamaged grain as related to grain moisture content and temperature (% Loss per Day)

Temp. (ºC)	15% M.C.*	20% M.C.	25% M.C.	30% M.C.
4.5	0.0003	0.0033	0.0098	0.0173
15.5	0.0010	0.0106	0.0312	0.0553
26.5	0.0034	0.0338	0.994	0.176--
38.0	0.0101	0.1074	0.3165	0.5623

***M.C.** = Moisture Content
Source: Tyler and Dendy (1978)

From this table, a commodity at 25% M.C. and 15.5^0 will lose 0.0312% of the dry matter per day. Thus, 60 days, the loss will be 0.0312 x 60 = 1.87%. By the time the grain will obviously be out of good condition.

ii. Loss measurement by weighing damaged and Undamaged Kernels and Calculating Loss. In this technique, the sound and mouldy kernels as counted, weighed and the average weight determined and percentage weight loss calculated thus;

$$\%\ weight\ loss = \frac{(UND - Dnu}{U(Nd + Nu)}\ x\,100$$

Where: U = Weight of undamaged grain; Nu = No. of undamaged grain; D = Weight of damaged grain; Nd = No. of damaged grain

iii. Loss Measurements by Comparison of Weigh-In and Weigh-Out. In this technique, losses are measured from start of storage until the commodity is removed from storage. The method to use should be based on changes in uni—weight because, as moulds destroy dry matter, they will reduce the unit weight of the grain. Use of identification sex, age, and size of local individuals throughout the survey.

Losses caused by rodents

Losses caused by rodents are generally difficult to assess, since they result in the removal of food from the environment. The usual method is to blame rodents for all losses that cannot be accounted for in any other way. Although techniques for the estimation of rodent population, development by specialists in the fields of rodent control are well established (Greaves, 1978), it is generally accepted that the resources for the valuation of losses due to them are inadequate and that GASGA and several FAO projects are now devoting efforts to this concern (Jackson and Temme, 1978; FAO 2004; FAO 2011). The direct assessment of losses to rodents is complex and can rarely be contemplated except as an aspect of a multidisciplinary research study.

Trapping to Extinction: In principle, a complete census of the population is made by trapping all the rodents that have access to the grain. The feeding capacity of the rodent population and hence the current daily grain loss to rodents can be estimated by multiplying the number of rodents by their daily food requirements. The assumption is made that rodents with access to stored grain will use it as their primary food source.

Losses caused by birds

There are times when commodities are held in the field for extended periods before harvesting for storage or direct to the table. Some of the most serious food losses occur at this stage and they have been attributed to birds such as the *Quelea spp*., parakeets and blackbirds (Waar*et al.*, 2011). However, the losses are rarely quantified.

The measurement of losses due to birds is beset with a number of inherent difficulties. Firstly, it is difficult to relate specific birds to designated damage or losses; feeding patterns may be irregular or overlap and insect outbreaks, drought or flood may alter expected patterns. Fungi may also enter as a secondary factor related to bird damage.

Although losses due to birds are real, satisfactory methods of determining them have seldom been available or used. However, among the available methods are;

Row-centimeter measurements (used on maize): In this technique, the number of damaged and undamaged ears in a row (15 – 100ft) are counted. On damaged ears, the average of damaged and undamaged kernel rols are measured to the nearest 2 or 3mm. These lengths are concerted to losses per area, e.g. tons/hectare. Less exacting are simple measurements of the portion of ear damaged, which may require some arbitrary averaging if the damage pattern is not symmetrical.

Visual loss estimates: This technique is unable to many different crops but the investigator must be trained and the procedure calibrated for each crop. It is much more rapid technique since counting is not specifically required. Damaged levels are established between these levels of damage or loss.

In general, post-harvest food losses to birds are unlikely to be or major importance compared to pre-harvest losses to birds and post-harvest losses to other factors. They will be important only in situations where the commodity is left in the field after harvest or spread in the open to dry for long periods or where stores allow birds access.

Losses due to Handling and Primary Processing

These losses may occur at the following stages of the post-harvest system:-threshing,, drying, bagging, or placing threshed grains in other containers, transportation to mill, milling, transportation from mill to storage or market (World Food Logistic Organization, 2010).

The losses would normally be determined by weighings before and after the particular step and by weighing the amount of commodity in food or unfood categories. It is generally agreed that there is little data on post-harvest food losses during transportation. Yet any transfer of food from one stage to another is attended by the possibility of loss. Three ways by which transportation loss may occur have been identified (ARS, 2008; NRC, 1996).

(1) During handling of crops between harvest, threshing, and milling
(2) In transportation allied to storage e.g. spoilage of bagged commodity exposed to rain during transportation and spoilage due to container damage.
(3) Result of the absence or inefficiency of transportation facilities and also of limited access to alternative market possibilities.

Although little attention has hitherto been given to this aspect of food loss, it is obvious that it requires greater attention in the interest of the overall efficiency of the post-harvest system.

Losses in nutrients and nutritive values: Commodities while passing through the post-harvest pipeline can undergo modifications in their chemical composition which will alter that flavour and nutritive value. These may be caused by chemical processes involving oxidation and maillard reactions, which take place even at normal temperatures. These changes can also be brought about by biodeteriogens notable insects and moulds (UN/FAO, 2011). The collection of these effects brings about a reduction in nutritive value be changing or destroying essential nutritive elements. Bacterial contamination may, at the same time or separately, also come from insects. It is well-known that destruction and alteration of proteins occur even at temperatures of around 300ºC. The processes of degradation tend to accelerate with rise in temperature when lowering in protein efficiency ratio (PER) of a food can thus be quite significant. The nutrients that are mostly affected in a commodity are:- carbohydrates, lipids, proteins and vitamins (ARS, 2008).

Changes in carbohydrates: Standard analytical techniques exist for quantifying the individual sugars in any food and the changes in these will usually give quite information on the extent of deterioration. In situations of biodeterioration, increases have been observed in non-reducing sugars (Sowunmi, 1981; Basovarajа*et al*., 2007) as well as considerable degradation in sucrose content (Sowunmi, 1982; Alexandratos and Bruinsma, 2012).

Changes in lipids: The changes in the lipid contents of foods, usually referred to as rancidity, are often good indications of deterioration. Three types of rancidity are now currently recognised:

Hydrolytic rancidity: Is usually the hydrolysis of lipids. It involves the cleavage of triglycerides to yield free fatty acids (f.f.a) and is usually of enzymatic origin. The quantification of f.f.a is thus a useful measure of the extent of loss and biodeterioration (Compton and Sherington, 1999).

Ketonic rancidity: This is essentially oxidative except that it is occasioned by bacterial and moulds which usually attack the short chain fatty acids (C4 to C14).

Oxidative rancidity: This is the commonest form of rancidity and the most important from nutritional and biological viewpoint. It leads to the formation of peroxides, alcohols and ethylenic ketones and finally free radicals. In the course of these transformations, there are changes in taste and smell, destruction of essential polyunsaturated fatty acids, accompanied by changes in certain amino acids, methionine in particular, and in several vitamins, notably vitamins A and D. Certain vitamins of the B-complex are also affected and there is a direct acceleration of the consumption of Vitamin E following the formation of free radicals. There is also an increased required for selenium which is an activator of glutathione peroxidise (Compton *et al.,* 1998).

The measurement of peroxide value (PV); Anisidine value (AV) and the total oxidation value (Totox value) will therefore give indications of the extent of food loss.

Changes in proteins: Protein degradation is often associated with the Maillard – type of browning (Hodge, 1983;Haile *et al*., 2009). One of the important factors in this reaction is pH and the presence of carbohydrates increases the effects of degradation. Thus, the proteins in cereals, which are rich in carbohydrates, seem to be more sensitive to damage by heat or to prolonged storage under poor conditions, particularly in hot climates (Ferrando, 1981; Hodges *et al.,* 2009).

During poor situations in the post-harvest system, the protein content of foods get denatured and this is manifested by decreased solubility of the protein moieties in some solutions (Kader 2005). There is also a decrease in the physiological availability of the amino acids, which among others will provide useful information on the extent of nutritional loss in food in the post-harvest pipeline.

Change in Vitamins: The rise in temperature caused by insects increases the rate of physic-chemical degradation process of nutrients, particularly, vitamins. The fat-soluble vitamin A,D and E are among the least stable. Thiamine (Vitamin B1) is the least stable of all water-soluble vitamins while riboflavin (vitamin B2) being highly sensitive to heat, is also very unstable (FAO 2004). Kader (2005); Haile (2009), Kader and Rolle (2009) have all shown decreases vitamins during biodeterioration.

Aside from causing the loss of nutritive elements, moulds develop substances that have anti-vitamin effects (ARS 2008). Thus, the quantification of the vitamin content of a food at any particular stage in the post-harvest system can provide useful indications of the extent of nutritional loss in the commodity.

Loss in Nutritive Value

In addition to providing energy to meet the basic requirements food must meet the protein requirements, of animals and provide materials for their maintenance and growth. Although, in vitro analysis for the gross content of individual nutrients are essential and will provide reasonable information in the extent of nutritional loss in a food, it is generally agreed that they are not sufficient in themselves (ARS 2008; Pellet, 1978) and that there is need to use in vivo tests (based on the reactions of the organism itself) which will assess the useful and available nutrient content of the food.

Biological assays have proved very useful and nutritional bio-indexes such as protein efficiency ratio (PER) biological value (BV), net protein utilization (NPU), "apparent" and "true" digestibility quotients (AD and TD) have always provided good indications of the nutritive value of a food. In addition, since food has to provide the energy requirements of animals its content of useful energy is obviously of vital importance. Consequently, digestible and metabolizable energy values (DE and ME) of a food, quantified in bioassays, have been recognised as sensitive yardsticks when measuring the overall nutritive value of food. They are known to equalize energy in foods with respect to the energy contributions by individual nutrients. In practice, the efficiency of utilization of the available energy can also be computed from the DE and ME data to give a good picture of the extent of nutritional loss in the food (Trostle, 2010).

Compared with all other methodology for assessing food loss, there is no doubt that nutritional evaluation is most precise but at the same time, the most costly and time consuming. It will generally be unsuitable in situations where decisions are needed quickly or where there is inadequate expertise to execute the programme. The importance of nutritional evaluation lies in the fact that the ultimate goal of food is to provide basic energy and protein requirements of an animal as well as meet its maintenance and growth needs: information that are directly obtainable from these studies alone.

Conclusion

Food loss assessment in the developing countries is plagued with some basic problems. There are only a handful of trained technocrats who have the time, experience and the trust to do the work. There is also the cooperation of the farmers they have to battle with. Not infrequently, these farmers misunderstand the honest investigations of research to having things to do with tax assessments and other social problems. The result is that they provide false information at the best or are downright hostile. Further there is the problem of poorly instructed or untrained field officers who are likely to provide representative information of low accuracy and little value. There is no doubt in my mind that at present, available information is so limited that it cannot substantiate the use of "average" or representative values for losses of food commodities on a national basis. The much more detailed research into food loss assessments on a national scale currently being undertaken by the Nigerian Stored Products Research Institute on a planned systematic basis using well-conceived standard methodologies will most probably provide the much needed aggregate estimates of loss that can be statistically substantiated. In addition, such well-conceived training workshops as this will increase the critical shortage of the much needed trained personnel in identifying and estimating food losses in the post-harvest system.

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