An integrated protocol for the quantification of rice post-harvest losses in sub-Sahara Africa

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Abstract

This protocol developed by the Africa-wide rice Processing and Value Addition Taskforce is composed of six sections; introduction, methods for the quantification of physical grain loss and grain quality loss at eight different points along the rice value chain, data collection on paddy and milled rice production volumes in different sub-Sahara Africa countries, data analysis, conclusion and acknowledgement. This protocol has already been validated in six African countries.

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1. Introduction

Paddy rice production in sub-Sahara Africa (SSA) in 2014 was estimated at 22.2 million tones (IRRI, 2015) but this quantity does not reach the table of consumers due to physical grain loss (PGL) during inappropriate post-harvest processing. Furthermore, poor post-harvest processing causes grain quality loss (GQL) and ruins market values of the final products for consumers. Knowledge on the magnitude of losses at each point along the value-chain and how these losses affect productivity is imperative in combating post-harvest losses in any crop. To this effect, a protocol was developed by the Africa-wide Rice Processing and Value-Addition Taskforce and is being used to measure PGL and GQL at different points along the rice value-chain in different countries. The identification of points of losses and quantification of losses along the rice value-chain will not be a one-time activity but a continuous process to identify areas were progress is being made and those needing more attention.

1.1. Rice variety

1. Use sample from the same field for all analysis.
2. Use the most widely cultivated variety in the hub.

1.2. Materials

2. Ten representative farmers per hub with each willing to provide 0.5 ha of paddy field for the study
3. The field (0.5 hectare with yield of at least 2 t/ha) for each farmer must be in the same location. This plot will be divided into two and randomly designated as Farmer's harvesting time or Optimum harvesting time plots.
4. Scale with a capacity of at least 10 kg and accuracy of ±1 gram
5. Scale with a capacity of at least 2 kg and accuracy of ±0.01 gram
6. Four 35 m^2 tarpaulins for threshing and drying
7. Grain moisture meter or drying oven with temperatures > 200^oC
8. Mechanical thresher (motorized or pedal)
9. Cemented raised and fenced surfaces for improved drying
10. Laboratory dehusker and polisher (Satake is preferable)
11. Good commercial rubber roll mill identified in the hub (Satake is preferable)
12. Colorimeter (Minolta colorimeter is preferable)
13. Rice storage bags
14. Pallets for storing rice
15. Improved parboiling technology (GEM parboiler is preferable)
16. Non-chemical insecticide chambers or other technologies that kills insects
17. Storage space at farmers, millers or trader's warehouse
18. Weighing container for 10kg and above (should be used to weigh all samples > 2 kg)
19. Weighing container for 2kg and below (should be used to weigh all samples < 2 kg)
20. IRRI rice quality reference manual (http://www.knowledgebank.irri.org/postproductioncourse/images/modules/References/Module 6/Rice Quality Reference Manual.doc)
21. IRRI grain quality kit with quality kit manual (http://knowledgebank.irri.org/images/docs/postharvest-irri-qualitykit-manual.pdf)

2. Quantification of percent physical grain loss

2.1. Field mapping

Six 10 x 20 and six 1.5 x 1.5 meters plots are mapped in each farmer's field. These fields are randomly assigned into two groups with 3 replications; those that will be

harvested at the optimum harvesting time (35 days after heading with Moisture content of paddy = 20—24%) and those that will be harvested at farmer's harvesting time. The 10 x 20 plots are used for the determination of losses due to transportation to threshing area, threshing, cleaning and drying. The 1.5 x 1.5 plots are used for the quantification of shattering, incomplete cutting of panicle and infield stacking losses.

2.2. Harvesting

2.2.1. Harvesting Losses during optimum harvesting time (OHT)

At 35 days after (50%) heading (DAH) and when 85% of the paddy grains look mature, measure the MC of the grain in all plots using a moisture meter and record but ensure that it is between 20—24% before harvesting. Harvest 1.5 x 1.5 m plots (D1, D2 and D3) designated as optimum harvesting time (OHT) using knife or sickle from the three locations in one farmer's field. The panicles from the three plots are collected and placed separately on a tarpaulin. The grains that drop on the ground before or during harvesting in the three plots are separately collected, dried to 14% MC and recorded as *shattering loss during OHT*. The harvested panicles are hand threshed separately, dried to 14% MC and recorded as *harvested paddy at OHT*. This harvested paddy should be stored to prevent insect attack and taken to the laboratory for physical grain quality analysis. The grains that drop on the tarpaulin before hand threshing are separately collected, dried to 14% MC and recorded as *infield stacking loss at OHT*.

2.2.2. Harvesting Losses during farmer's harvesting time (FHT)

On the day the farmer is harvesting his field, measure the MC of the grain in all plots using a moisture meter and record. Harvest the 1.5 x 1.5 m plots (E1, E2 and E3) designated as farmer's harvesting time (FHT) using knife or sickle from the three locations in one farmer's field. The panicles from the three plots are collected and placed separately on a tarpaulin. The grains that drop on the ground before or during harvesting in the three plots are separately collected, dried to 14 % MC if MC >14% and recorded as *shattering loss during FHT*. The harvested panicles are hand threshed separately, dried to 14% MC if MC>14% and recorded as *harvested paddy at FHT*. This harvested paddy should be stored to prevent insect attack and taken to the laboratory for physical grain quality analysis. The grains that drop on the tarpaulin

before hand threshing are separately collected, dried to 14% MC if MC>14% and recorded as *infield stacking loss at FHT*.

2.2.3. In field transportation loss at OHT

On the day the farmer is harvesting his field, measure the MC of the grain in all plots using a moisture meter and record. Harvest the 0.25 ha plot designated as optimum harvesting time (OHT) plot using knife or sickle from the three locations in one farmer's field. The panicles from the three plots are collected and placed separately on a tarpaulin. Weigh and record the weight of panicles from the three plots separately. Divide the panicles from each plot into four equal parts (A1, A2, A3 A4, B1, B2, B3, B4, C1, C2, C3 and C4) by weighing accurately where A, B, and C are the three plots. Ask the farmer to transport A2, A3 A4, B2, B3, B4, C2, C3, and C4 panicles separately to the threshing area. Thresh A1, B1 and C1 separately on the tarpaulin at the point of harvest making sure that no grains are lost (left on panicle or dropped) weigh and record the weight and MC separately for the three plots. At the threshing area, place panicles on another tarpaulin. Thresh the A2, B2 and C2 on the tarpaulin at the threshing area making sure that no grains are lost (left on panicle or dropped), weigh and record the weight and MC separately for the three plots. If there is a loss due to transportation, the weight recorded at the threshing area should be less than the weight recorded at the harvest point. The difference between these two weights is the *in field transportation loss at OHT*. *Dry samples A1, B1, C1, A2, B2, and C2 to 14% MC and preserve for loss assessment during milling.*

2.2.4. In field transportation loss at FHT

At 35 days after (50%) heading (DAH) and when 85% of the paddy grains look mature, measure the MC of the grain in all plots using a moisture meter and record but ensure that it is between 20—22% before harvesting. Harvest the 0.25 ha plot designated as farmer's harvesting time (FHT) plot using knife or sickle from the three locations in one farmer's field. The panicles from the three plots are collected and placed separately on a tarpaulin. Weigh and record the weight of panicles from the three plots separately. Divide the panicles from each plot into four equal parts (A11, A12, A13 A14, B11, B12, B13, B14, C11, C12, C13 and C14) by weighing accurately where A1, B1, and C1 are the three plots. Ask the farmer to transport A2, A3 A4, B2, B3, B4, C2, C3, and C4 panicles separately to the threshing area. Thresh

A11, B11 and C11 on the tarpaulin at the point of harvest making sure that no grains are lost (left on panicle or dropped), weigh and record the weight and MC separately for the three plots. At the threshing area, place panicles on another tarpaulin. Thresh the A12, B12 and C12 on the tarpaulin at the threshing area making sure that no grains are lost (left on panicle or dropped), weigh and record the weight and MC separately for the three plots. If there is a loss due to transportation, the weight recorded at the threshing area should be less than the weight recorded at the harvest point. The difference between these two weights is the *in field transportation loss at FHT*. *Dry samples A11, B11, C11, A12, B12, and C12 to 14% MC and preserve for loss assessment during milling*.

Note: These samples should be stored separately from henceforth.

2.3. Threshing

2.3.1. Loss due to improved threshing method (ITM) at OHT

This threshing is done during the optimum harvesting time. Thresh A3, B3, and C3 using an improved threshing method. The panicles should be hand-threshed if there is no improved mechanized threshing method. Weigh and record the weight and MC separately for the three plots. Collect 300 g from each of the samples, dry to 14% MC and store for grain quality analysis. (*Note: if the panicles are hand-threshed, then physical grain loss is expected zero and care should be taken to ensure that no grain is loss by leaving on panicle or dropping. However, if an improved mechanical thresher is used, then grains that spill or those that are left on the panicle must be collected and their weight and MC recorded*)

2.3.2. Loss due to farmer's threshing method (FTM) at OHT

This threshing is done during the optimum harvesting time. Ask farmers to thresh A4, B4, and C4 using farmer's method. Weigh and record the weight and MC separately for the three plots. Collect 300 g from each of the samples, dry to 14% MC and store for grain quality analysis.

2.3.3. Loss due to improved threshing method (ITM) at FHT

This threshing is done during the farmer's harvesting time. Thresh A13, B13, and C13 using an improved threshing method. The panicles should be hand-threshed if there is no improved mechanized threshing method. Weigh and record the weight and MC

separately for the three plots. Collect 300 g from each of the samples, dry to 14% MC and store for grain quality analysis. (*Note: if the panicles are hand-threshed, then physical grain loss is expected zero and care should be taken to ensure that no grain is loss by leaving on panicle or dropping. However, if an improved mechanical thresher is used, then grains that spill or those that are left on the panicle must be collected and their weight and MC recorded*).

2.3.4. Loss due to farmer's threshing method (FTM) at FHT

This threshing is done during the farmer's harvesting time. Ask farmers to thresh A14, B14, and C14 using farmer's method. Weigh and record the weight and MC separately for the three plots. Collect 300 g from each of the samples, dry to 14% MC and store for grain quality analysis.

2.4. Cleaning

2.4.1. Loss due to farmer's cleaning method (FCM) at OHT

At the optimum harvesting time, after collecting all data relating to threshing, ask farmer to cleaning A4, B4 and C4 using farmer's cleaning method. Once farmer finishes to clean the samples, weigh and record weight and MC. Collect all grains that must have spilled and abandoned, weigh, record weight and MC.

2.4.2. Loss due to farmer's cleaning method (FCM) at FHT

At the farmer's harvesting time, after collecting all data relating to threshing, ask farmer to cleaning A14, B14 and C14 using farmer's cleaning method. Once farmer finishes to clean the samples, weigh and record weight and MC. Collect all grains that must have spilled and abandoned, weigh, record weight and MC.

2.5. Drying non parboiled paddy

Drying of normal paddy (At least 200 kg of threshed paddy is needed to evaluated each method and type of drying loss)

2.5.1. Loss due to improved drying method (IDM) at OHT

At the optimum harvesting date and after collecting all data on threshing, Record the weight and MC of the samples before drying starts. Technician should dry A3, B3 and C3 to 14% MC making sure that no grains are lost due to spillage. Record weight and

MC after drying and store samples separately and safely. *Preserve the rest of the samples for loss assessment during milling.*

2.5.2. Loss due to farmer's drying method (FDM) at OHT

At the optimum harvesting date and after collecting all data on threshing, Record the weight and MC of the samples before drying starts. Ask farmer to dry A4, B4 and C4 using farmer's drying method. If farmer think the grains are dry enough, ask the farmer to collect grains and put in storage bags separately. Record weight and MC for these samples and collect 300 g for grain quality analysis. Check for any grains that have spilled and have been abandoned. Collect these grains weigh and record weight and MC. *Preserve the rest of the samples for loss assessment during milling*.

2.5.3. Loss due to improved drying method (IDM) at FHT

At the farmer's harvesting date and after collecting all data on threshing, Record the weight and MC of the samples before drying starts. If MC> 14% then Dry A13, B13 and C13 to 14% MC making sure that no grains are lost due to spillage. Record weight and MC after drying and store samples separately and safely. *Preserve the rest of the samples for loss assessment during milling.*

2.5.4. Loss due to farmer's drying method (FDM) at FHT

At the farmer's harvesting date and after collecting all data on threshing, Record the weight and MC of the samples before drying starts. Ask farmer to dry A14, B14 and C14 using farmer's drying method. If farmer think the grains are dry enough, ask the farmer to collect grains and put in storage bags separately. Record weight and MC for these samples and collect 300 g for grain quality analysis. Check for any grains that have spilled and have been abandoned. Collect these grains weigh and record weight and MC. *Preserve the rest of the samples for loss assessment during milling.*

2.6. Parboiling

2.6.1. Parboiling (soaking and steaming)

Get a list of all parboiling groups and individuals in the hub. Randomly select 6 groups or 6 individuals per hub to use for this study. . It is important that each group or individual is capable of parboiling at least 100 kg of paddy per session and showed parboil two times (2 replications). All parboilers in the same hub should use the same popular variety in the hub. A parboiling session is the period from cleaning to drying

inclusive and this normally takes 2 days. The 1st day is used for cleaning and soaking while the 2nd day is used for steaming and drying. Quantitative losses during parboiling can arise during cleaning (winnowing, washing), soaking, steaming and drying. Although drying loss of non-parboiled rice was evaluated for farmers, it is important to evaluate drying loss of parboiled rice by parboilers. The improved parboiling method (reference) should be replicated thrice and the variety should be as that used by parboilers in the hub.

2.6.2. Loss due to Improved parboiling method (IPM)

Researcher should parboil rice using improved parboiling method and drying method on-station. Weigh the total amount of paddy to be parboiled and record weight and MC before parboiling start. Winnow the paddy on a tarpaulin so that all substances (good grains, poorly filled grains and other substances) can be collected. All good grains must be included into the sample before proceeding. Wash and collect all substances (good grains, poorly filled grains and other substances). Good grains should be added to the sample before proceeding. Dry poorly filled grains to 14% MC. Weigh and record weight and MC separately of poorly filled grains and other substances after drying. During soaking and steaming, make sure that no grain is lost. Technician should parboil both sample paddy from farmers and improved paddy from station or paddy of high quality.

2.6.3. Loss due to improved drying method (IDM) of IPP

Once steaming is completed, the improved parboiled paddy (IPP) should be spread on tarpaulin placed on a raised surface (cemented surface) and sun-dried to dry to 18% MC. At this stage, if the sun intensity is high, the paddy should be transferred and drying continued on the same type of surface under a shade to 14% MC. Otherwise, the paddy can be gathered and covered inside the tarpaulin until the sun intensity is low, after which drying can continue to 14% MC. During drying ensure that no grain is lost. Weigh and record weight and MC of the sample. Collect 300g of this sample and preserve for grain quality analysis.

2.6.4. Loss due to traditional parboiling method (TPM)

Parboilers should parboil rice using parboiler's (traditional) method. Weigh the total amount of paddy to be parboiled and record weight and MC before farmer start

parboiling. If winnowing is done, this should be on a tarpaulin so that all substances discarded by farmer (good grains, poorly filled grains and other substances) are collected. Weigh and record poorly filled grains, good grains and other substances separately. If washing is done, collect all substances (good grains, poorly filled grains and other substances) discarded by farmer, dry to 14% MC, weigh and record weight and MC separately after drying. During soaking and steaming, collect all grains that may have drop or abandoned in soaking and steaming vessels by parboiler.

2.6.5. Loss due to improved drying method (IDM) of TPP

Once steaming is completed, 2 kg of steamed traditional parboiled paddy (TPP) should be spread on tarpaulin placed on a raised surface (cemented surface) and sun-dried to dry to 18% MC. At this stage, if the sun intensity is high, the paddy should be transferred and drying continued on the same type of surface under a shade to 14% MC. Otherwise, the paddy can be gathered and covered inside the tarpaulin until the sun intensity is low, after which drying can continue to 14% MC. During drying ensure that no grain is lost. Weigh and record weight and MC of the sample. Collect 300g of the sample and preserve for grain quality analysis.

2.6.6. Loss due to farmer's drying method (FDM) of TPP

Once steaming is completed, record the weight and MC of the parboiled samples before drying starts. Ask farmer to dry sample with farmer's drying method (FDM). If farmer think the grains are dry enough, ask the farmer to collect grains. Weigh and record weight and MC of sample. Collect 300 g of this sample for grain quality analysis Check for any grains that may have spilled and have been abandoned. Collect these grains weigh and record weight and MC and label grains. *Preserve the rest of the samples for loss assessment during milling.*

2.7. Transportation

2.7.1. Transportation of paddy rice from farm to mill or storage location.

Select the different types of transportation methods (animal-driven carts, two-wheel trucks, motorcycles or bicycle and vehicle). For each transportation type, ask three different transporters to perform the transportation operation thrice. Weigh the sample to be transported and let the transporter to transport the paddy from the farm to the

mill or storage location. Weigh the sample when it arrives the mill or storage location and record weight, MC and distance between the farms and mill or storage location.

2.7.2. Transportation of milled rice from mill to market or storage location

Select the different types of transportation methods (animal-driven carts, two-wheel trucks, motorcycles or bicycle and vehicle). For each transportation type, ask three different transporters to perform the transportation operation thrice. Weigh the sample to be transported and let the transporter transport the milled rice from the mill to the nearest market or storage location. Weigh the sample when it arrives the market or storage location and record weight, MC and distance between the mills and market or storage location.

2.8. Milling

Performances of local mills are compared with a laboratory mill. Make a list of mill types in the hub. Each sample should be milled with each mill type twice. (For example, if they are 4 Engerberg and 5 rubber roll mills in the hub, each sample (A1, B1, C1) should be divided into 4 and milled with 2 Engelberg and 2 rubber roll mills randomly selected in the hub). The following 8 samples **(A1, B1, C1 pooled),** (**A2, B2, C2 pooled**), (**A11, B11, C11 pooled**), (**A12, B12, C12 pooled**), (**A3, B3, C3 pooled**), (**A4, B4, C4 pooled**), (**A13, B13, C13 pooled**) and (**A14, B14, C14 pooled**) that were preserved for this stage (see above) right from the beginning are used for this work. The following should be done at each mill:

- Record the profile (name, gender and age) of each miller.
- Collect information on mills used in each hub—type (e.g. Engelberg), locally produced or imported and whether it is single or double pass mill.
- Select 3 mills per mill type present in the hub to perform study.
- Visit the selected mill with all the paddy groups, a balance and a grain moisture meter.
- For each mill, provide 10 kg of paddy at 14% MC from each of the 8 groups to the miller.
- Before the milling of each sample begins, clean the surrounding of the mill so that any paddy and mill rice grains that drops during milling can be collected, weighed and recorded as loss.

- During milling, collect husk and bran from each sample and check for paddy or milled rice in it.
- Separate paddy and milled grains, weigh and record weight separately.
- Weigh milled rice from each paddy sample after milling
- Weigh the husk and the bran separately and record.
- Collect 300g of milled samples and send to the laboratory for grain quality analysis.

2.9. Storage

- In each hub, select the most popular storage facility for the evaluation of losses and properly describe it.
- Select three storage locations in each hub.
- Three types of samples will be stored; paddy, parboiled milled and white milled samples.
- Take note of the rice variety being stored.
- Collect 50 kg of each sample for storage loss evaluation.
- Collect 3 kg of each sample and send for laboratory storage.
- Collect 300g of each sample and send for grain quality analysis
- Compensate farmer for space occupied in storage facility.
- Samples should be put in the same storage container as farmer's stock.
- Label accordingly for proper distinction even after long period of storage or if farmer mixes samples.
- Record weight of samples in storage containers and MC.
- Stores under farmer's conditions.
- Record room temperature and humidity

First Visit (After 3 months of storage)

- Record weight of samples in storage containers and moisture content.
- Mix well and collect 300g of each sample and send to laboratory for grain quality analysis

3. Quantification of percent grain quality loss

3.1. Grain quality analysis

All paddy samples in Sample should be milled with the same laboratory huller and polisher. The following grain quality parameters should be evaluated using methods described in the rice quality reference manual (IRRI, 2002). For paddy samples, the following parameters should be evaluated:

- Percent off-types
- Percent poorly filled grains
- Percent brown spots
- Percent impurities

For milled samples, the following parameters should be evaluated:

- Percent head rice
- Percent broken fractions
- Percent chalky grains
- Percent impurities
- Color

3.2. Effect of some milled rice quality parameters on price at the mill

Select 10 to 15 mills per hub in 2 hubs per country. If there are different types of mills (engelberg, rubber roll, large commercial mills) try to have a representative sample of each type of mill. For each sample that come to the mill, record the price per kg of paddy (collect 100 g of the paddy for paddy quality analysis) and the price per kg of the milled rice (also collect 100 g for milled rice quality analysis). Record and analyze 30 samples per mill. The following information should be collected for each sample:

For mills

- Type of mill
- Miller’s name
- Miller’s age
- Miller’s sex
- Distance of mill from main market
- Miller in association or not

For paddy

- Price per kg
- Percent off-types
- Percent poorly filled grains
- Percent brown spots

- Percent impurities

For milled rice

- Price per kg
- Percent head rice
- Percent broken fractions
- Percent chalky grains
- Percent impurities
- Color

4. Data on paddy and milled rice production

Data on the most current paddy and milled rice production volumes in each country are acquired from http://ricestat.irri.org:8080/wrsv3/entrypoint.htm (IRRI, 2016). This data is used to determine the average milling recovery recorded for the country. The average milling recovery can also be determined from data collected at the levels of mills in each study country.

5. Statistical Analysis

All data should be entered into the 'Data entry template for physical grain loss assessment.xlsx' (http://www.ricehub.org/RT/post-harvest/post-harvest-loss-/phl-assessment-protocol/) for PGL calculations and 'Data entry template for grain quality loss assessment.xlsx' (http://www.ricehub.org/RT/post-harvest/post-harvest-loss-/phl-assessment-protocol/) for GQL calculations. ***(****The shaded columns should not be altered otherwise the calculations will be faulty. Users can increase the number of rows by pulling the in-build equations down the columns.).* The $PGL_{traditional}$ at each point along the value chain is determined from the average PGL recorded at that point using traditional methods. The $PGL_{residual}$ at each point is determined from the average PGL recorded at that point using improved methods. The PGL_{actual} is the difference between $PGL_{traditional}$ and $PGL_{residual}$. The $GQL_{traditional}$ for paddy and milled samples at each point along the value chain is determined from the average GQL recorded at that point using traditional methods. The $GQL_{residual}$ at each point is determined from the average GQL recorded at that point using improved methods. The GQL_{actual} is the difference between $GQL_{traditional}$ and $GQL_{residual}$. The average price of paddy and milled rice at the mill for each country can be calculated. Different factors studied can be used to determine effect of PGL and GQL at each point along the value-chain and price at the

level of the mill using regression analysis. The PHL using the 'Rice post harvest loss calculation sheet.xlsx'
(http://www.ricehub.org/RT/post-harvest/post-harvest-loss-/phl-assessment-protocol/) by entering the following data predetermined above for each country and for a given year: paddy production, PGL, milled rice production, GQL and price of imported rice.

6. Conclusion

Field validation of this protocol has been completed in six African countries while assessment is still on going another six countries. The results are expected to provide for the first time rice post-harvest loss situation in different sub-Sahara African countries. It is expected that fund will be sought to do a continuous assessment of the post-harvest loss situation in each country to measure progress in reducing losses and areas where more work is needed.

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