Foreword

This standard is a pursuance of the AMTEC 04:1988 "Power Operated Corn Sheller– Methods of Test" initiated by the Agricultural Machinery Testing and Evaluation Center (AMTEC) under the project entitled "Standardization of Postharvest Machinery Testing and Evaluation" which was funded by the Bureau of Postharvest Research and Extension (BPRE) of the Department of Agriculture (DA).

This standard was reviewed by the Study Team for the Formulation of Standards for Corn Sheller and by the Technical Committee on Postharvest Machinery and was circulated to various private and government agencies/organizations concerned for their comments and reactions. This standard was presented to the Philippine Society of Agricultural Engineers (PSAE) and subjected to a public hearing organized by the National Agriculture and Fisheries Council (NAFC).

This standard has been technically pursued in accordance with PNS 01: Part 4:1998 – Rules for the Structure and Drafting of Philippine National Standards.

Revisions had been made to adopt various improvements in the design of the machine that may affect its performance. The main changes are listed below:

- scope was delineated thereby indicating the aspects covered and the limits of applicability;
- general conditions for test and inspection and test preparation was modified based on the actual test conducted by Agricultural Machinery testing and Evaluation Center (AMTEC);
- the following annexes were added: annex A concerning list of field and laboratory test equipment and materials, annex B regarding test materials, and annex F pertaining to laboratory work;
- annex E concerning field performance and grain analysis was revised;
- a separate annex was added for sampling and measurement for test materials; and
- items to be included in the test report were enumerated based on the actual test report submitted by the AMTEC.

CONTENTS **Page**

ANNEXES

PHILIPPINE AGRICULTURAL ENGINEERING STANDARD PAES 209:2000

Agricultural Machinery – Power-Operated Corn Sheller – Methods of Tests

1 Scope

This standard specifies the methods of test and inspection for power–operated corn sheller. Specifically, this shall be used to:

1.1 verify the mechanism, main dimensions, weight, materials, accessories of the corn sheller and the list of specifications submitted by the manufacturer;

1.2 determine the performance of the machine;

1.3 evaluate the ease of handling and safety features;

1.4 determine the effect on kernel quality through laboratory analysis of kernel samples taken during the test; and

1.5 report the results of the tests.

This standard is applicable also to the machines used as husker-sheller.

2 Reference

The following normative document contains provisions which through reference in this text constitute provisions of this National Standard.

PAES 208:2000 Agricultural Machinery: Power-Operated Corn Sheller - Specifications

3 Definition

For the purpose of this standard, the definitions given in PAES 208:2000 and the following shall apply:

3.1
clean shelled kernel
shelled kernel free from foreign matter

3.2
concave clearance
clearance between cylinder shelling elements and concave component

3.3
corrected capacity
actual capacity of the sheller corrected at 20% kernel moisture content (wet basis), and 100% purity

3.4
feed rate
weight of unshelled corn fed into the sheller per unit of time

3.5
foreign matter
all matters other than corn kernels such as sand, gravel, dirt, pebbles, stones, lumps of earth, clay and mud, weed seeds and other crop seeds

3.6
output capacity
weight of shelled kernel collected per unit of time

3.7
oscillating screen
wire mesh or perforated sheet metal used to separate large and/or small particles

3.8
primemover
electric motor, a gasoline or diesel fed engine used to run the sheller

3.9
total kernel input
sum of the weight of collected shelled kernels and all the shelling losses

3.10
total losses
sum of blower, separation, unshelled and scattering losses in a sheller, expressed in percent by weight

4 General Conditions for Test and Inspection

4.1 Role of manufacturer
The manufacturer shall submit to the official testing agency specifications and other relevant information on the corn sheller. He/She shall abide with the terms and conditions set forth by an official testing agency. The sampled corn sheller shall be submitted for testing.

4.2 Role of the representative of the manufacturer
An officially designated representative of the manufacturer shall operate, adjust, repair, and shall decide on matters related to the operation of the machine.

4.3 Test site conditions
The corn sheller shall be installed on a stable level ground on a site with sufficient working space, and shall be positioned in such a way that the wind will not blow the corn cobs and other impurities into the clean kernel.

4.4 Suspension of test
If during the test run, the machine stops due to major component breakdown or malfunctions so as to affect the performance of the machine, the test may be suspended with the concurrence of the official testing agency and the manufacturer’s representative.

5 Test Preparation

5.1 Running-in and preliminary adjustment

Before the start of the test, the sheller should have undergone a break-in period. The sheller shall be operated at the test site by the official representative of the manufacturer for sufficient duration with and without load. During the running-in period, the various adjustments of the sheller shall be made according to the recommendation of the manufacturer. (No other adjustments shall be permitted while the test is on—going).

5.2 Test instruments and other needs

The suggested list of minimum field and laboratory test equipment and materials needed to carry out the sheller test is shown in Annex A. These instruments should be calibrated regularly. Before and after each test, the instruments shall be physically checked for operation and shall be cleaned, respectively. A checklist of instruments and materials shall be prepared to be used before departure to and from the testing area.

5.3 Test materials

The ear corn to be used in the test shall be prepared in sufficient quantity, using the procedure given in Annex B. However, if the test materials is beyond the recommended characteristics, the manufacturer has the option to pursue the test.

6 Pre-test Observation

6.1 Verification of specifications

The specifications claimed by the manufacturer and the physical details given in Annex C shall be verified by the official testing agency. A stable and level surface shall be used as reference plane for verification of dimensional machine specifications.

6.2 Test Materials

Representative test samples shall be collected from the test lot to determine its dimensions and shall be manually shelled for the determination of kernel-ear corn ratio, moisture content and control for corn kernel quality.

7 Performance Test

7.1 Operation of the Sheller

The sheller shall be operated at the recommended speed and feed rate of the manufacturer. The same feeding rate recommended by the manufacturer shall be maintained during the test run. After the test run, the shelling area shall be cleaned and then prepared for the next trial. This procedure shall be repeated for second and third trials.

7.2 Test trial

A minimum of two (2) test trials, with a duration of at least 15 minutes per trial, shall be adopted.

7.3 Sampling

Samples shall be collected at the different outlets during each test trial. Sampling procedure is given in Annex D.

7.4 Data Collection

7.4.1 Duration of Test
The duration of each test trial shall start with the feeding of the first sample and ends after the feeding of the last sample. However, all discharge from the different outlets shall be included after the cut-off time.

7.4.2 Noise level
The noise emitted by the machine, with or without load, shall be measured using a noise level meter both at the location of the operators and baggers. The noise, expressed in db(A), shall be taken approximately 5 cm away from the ear level of the operators and baggers.

7.4.3 Speed of Components
The speed of the shelling cylinder, oscillating screen shaft, fan shaft, primemover and other rotating components shall be measured using a tachometer.

7.4.4 Air Velocity
The air velocity generated by the fan, with or without load, shall be taken using an air velocity meter measured in m/s.

7.4.5 Fuel Consumption
Before the start of each test trial, the fuel tank shall be filled to its capacity and after each test trial, the fuel consumed shall be measured by refilling the tank to the same level using a graduated cylinder measured in li/hr.

7.5 Data recording and observations
Record sheet for all data and information during the test is given in Annex E.

8 Laboratory Analysis
Laboratory analysis shall be made to determine the kernel moisture content and kernel-ear corn ratio, purity, cracked and broken kernel and losses (blower, separation, unshelled and scattering). The laboratory procedure to be followed in the analysis is given in Annex F while the data sheet is given in Annex G.

9 Data Analysis

9.1 Calculation
For uniform result of output due to variation in kernel moisture content and purity, the output capacity shall be corrected at 100% purity and 20% moisture content. The formula to be used in the calculation of different test parameters are given in Annex H.

9.2 Presentation of results
Machine specifications and the results of the test shall be presented in tabular form in which data shall be taken from Annex C and E. A schematic diagram of the power transmission system and arrangement of the shelling elements shall also be included. Observations made on the machine while in operation shall be supported with photographs.

10 Test Report

The test report shall include the following information in the order given:

10.1 Title

10.2 Summary of Result

10.3 Purpose and Scope of Test

10.4 Methods of Test

10.5 Conditions of the Machine

10.6 Description of the Machine

10.6.1 Fig. 1 – Material Flow Diagram

10.6.2 Fig. 2 – Power Transmission System

10.6.3 Fig. 3 – Arrangements of Shelling Elements on the Cylinder

10.6.4 Table 1 – Machine Specifications

10.7 Results of Test

10.7.1 Table 2 – Field Performance Test Data

10.8 Observations (include pictures)

10.9 Name and Signature of Test Engineers

Annex A
Minimum List of Field and Laboratory Test Equipment and Materials

A.1	**Equipment**	
A.1.1	**Field**	**Quantity**
A.1.1.1	Grain Moisture Meter (duly calibrated using the standard method) Range: 10% to 40% (for corn)	1
A.1.1.2	Air Velocity Meter Range: 0 – 30 m/s	1
A.1.1.3	Tachometer (contact or photoelectric type) Range: 0-5,000 rpm	1
A.1.1.4	Noise Level Meter Range: 30 to 130 db(A)	1
A.1.1.5	Timers Range: 60 minutes; Accuracy: 1/10 sec	2
A.1.1.6	Measuring Tape Capacity: 5m	1
A.1.1.7	Camera	1
A.1.1.8	Weighing Scale Capacity: 100 kg; Scale divisions: 0.5 kg	1
A.1.1.9	Graduated Cylinder Capacity: 500- mL	1
A.1.2	**Laboratory**	
A.1.2.1	Weighing Scale (Sensitivity: 0.1 g)	1
A.1.2.2	Magnifying Lens (minimum of 10 magnifications)	1
A.1.2.3	Grain Sample Cleaner	1
A.2	**Materials**	
A.2.1	Field	
A.2.1.1	Canvass sheet (4 m x 8 m)	1
A.2.1.2	Nylon-catch bag (1.5 m x 1.5 m x 0.5 m)	1
A.2.1.3	Nylon Net (1.5 m x 1.5 m)	1
A.2.1.4	Sample Bags	20
A.2.1.5	Labeling Tags which include	20
A.2.1.5.1	Date of Test	
A.2.1.5.2	Machine on Test	
A.2.1.5.3	Sample Source	
A.2.1.5.3	Variety	
A.2.1.5.4	Trial Number	

Annex B
Test Materials for Power-Operated Corn Sheller

B.1 Sample Characteristics

Test materials to be used shall have the following characteristics:

B.1.1 Variety : commonly or locally grown

B.1.2 Moisture Content : 18% - 24%, wet basis

B.1.3 Kernel-Ear Corn Ratio : 0.77 – 0.81

B.2 Quantity to be Supplied

The amount of test material to be supplied shall be sufficient for one hour of continuous shelling operation including samples to be used for running-in prior to the actual conduct of test trials.

Approximately: 1 hour x shelling capacity (kg/h)

B.3 Sample Preparation

Prepare the sample in such a way that test sample to be used for the running-in and in each test trial shall have identical characteristics in terms of moisture content, variety and date of harvest and cultural management practices such as water management, fertilizer input, etc. Care should be taken so as to prevent alterations of the conditions of the test samples.

Annex C
Specifications of Power-Operated Corn Sheller

Name of Applicant (or Distributor) : _____
Address : _____
Telephone No. : _____
Name of Factory/Distributor : _____
Address : _____

GENERAL INFORMATION

Make : _____ Brand/Model : _____
Serial No. : _____ Classification : _____
Production date of sheller to be tested: _____

Items to be inspected

ITEMS	Manufacturer's Specifications	Verification by the Testing Agency
C.1 Dimensions and weight of sheller		
C.1.1 Overall length (mm)		
C.1.2 Overall width (mm)		
C.1.3 Overall height (mm)		
C.1.4 Weight of the machine (kg), without engine		
C.2 Crop(s) for which machine is suitable		
C.3 Rated output capacity (kg/h)		
C.4 Recommended cylinder speed (rpm)		
C.5 Engine		
C.5.1 Brand		
C.5.2 Model		
C.5.3 Serial Number		
C.5.4 Make		
C.5.5 Rated power (kW)		
C.5.6 Rated speed (rpm)		
C.5.7 Type		
C.5.8 Weight		
C.5.9 Starting system		
C.5.10 Cooling system		
C.6 Type of power transmission system		
C.6.1 Engine to _____		
C.6.2 Cylinder shaft to _____		
C.6.3 Fan shaft to _____		
C.6.4 Oscillating sieve/screen to _____		
C.6.5 Others (specify)		

ITEMS	Manufacturer's Specifications	Verification by the Testing Agency
C.7 Shelling Cylinder		
C.7.1 Type		
C.7.2 Size (L x D), mm		
C.7.3 Cylinder teeth		
C.7.3.1 Type		
C.7.3.2 Size		
C.7.3.3 Number/row		
C.7.3.4 No. of rows		
C.7.3.5 Arrangement		
C.7.3.6 Means of attachment		
C.7.3.7 Material		
C.7.3.8 Others		
C.7.4 Material		
C.8 Fan		
C.8.1 Type		
C.8.2 No. of units		
C.8.3 Impeller		
C.8.3.1 Material		
C.8.3.2 Number of blades		
C.9 Oscillating screen		
C.9.1 Dimension (L x W), mm		
C.9.2 Size of perforations, mm		
C.9.3 Length of stroke, mm		
C.9.4 Material		
C.10 Concave component		
C.10.1 Overall diameter, mm		
C.10.2 Clearance		
C.10.2.1 Maximum, mm		
C.10.2.2 Minimum, mm		
C.10.3 Material		
C.11 Hopper (if available)		
C.11.1 Location		
C.11.2 Material		
C.11.3 Feature		
C.12 Feeding Table (if available)		
C.12.1 Dimensions (L x W), mm		
C.12.2 Height from the ground (mm)		
C.12.3 Orientation		
C.12.4 Mode of attachment		
C.12.5 Material		
C.13 Transport device		
C.13.1 Type		
C.13.2 Size		
C.14 Safety device(s), if any		
C.15 Discharge device		
C.16 Labor requirement		
C.17 Adjustment(s)		
C.18 Other special features		

.

C19 Illustration of transmission system

Annex D
Sampling and Measurement for Test Material

D.1 Sampling Procedures for Harvested Corn Ears

The conditions of crop such as ear corn dimensions, kernel-ear corn ratio, and moisture content of kernel to be used in each test trial shall be taken using "representative samples" which represent the different condition of the harvested ear corn on the pile. This is done by taking samples, each at the top, middle and bottom of the pile. Samples representing the materials for each test trial shall be placed in appropriate containers for laboratory analysis.

D.2 Sampling from Different Outlets

D.2.1 During each test trial, samples shall be collected from the different outlets to be analyzed in the laboratory for losses, purity and kernel quality. The minimum amount of samples to be taken shall be twice as much as what is needed for a particular analysis. The excess sample shall be used for reference purposes or for an eventual second check in case of review. The sampling procedures shall be undertaken at the following sheller outlets:

D.2.1.1 Main kernel outlet – Using a plastic bag or an appropriate container, collect three or more samples of approximately 0.5 kg each from the outlet.

D.2.1.2 Corn-Cob Outlet – In the collection of sample in this outlet, use a rectangular box-shaped nylon catch with a dimension of 1.5 m x 1.5 m x 0.5 m open at one end of the small side. Three samples shall be collected from this outlet for a minimum duration of five (5) seconds per collection. Separate the free corn kernel mixed with the cob and the kernels that are still attached to the cob. Put them in separate containers and label them as separation loss and unshelled loss, respectively.

D.2.1.3 Fan Outlet – During the test, three samples shall be taken from the fan outlet for a duration of at least 15 seconds per collection by using a nylon net with a dimension of 1.5 m x 1.0 m held by two persons at both ends. These samples shall be placed in appropriate containers and labeled as blower loss.

D.3 Collection of Scattered Corn Kernels

For testing purposes, scattered corn kernels shall be gathered since these corn kernels are part of the total corn kernel input. Spread canvas sheets to the shelling floor area to catch these corn kernels after each trial. Placed the collected corn kernels in appropriate containers and label them as scattered corn kernels.

Provisions shall be provided for the collection scattered corn kernels with maximum distance of 1.0 m away from the base of the machine.

D.4 Handling of Samples

All samples to be taken to the laboratory shall be placed in appropriate containers and properly labeled. If the samples are not to be immediately analyzed they should be air-dried and if necessary, treat samples with chemicals such as insecticide in order to prevent the samples from possible damage. If the sample is to be used for determining moisture content, it must be kept in dry and airtight containers.

D.5 Other Measurements Required During the Test Run

Data shall be taken for the following: speed of rotating components, air velocity, and noise level at the location of the operators and baggers. For each data, there shall be a minimum of five observations. These shall be taken without and with load. Before taking data, it should be ensured that the feed rate, speed and other functional characteristics have stabilized. The time of sampling shall be properly space during the whole duration of the test trials. For air velocity, measurement shall be taken in at least six measuring points. The test engineer shall decide on the location of the measuring points that will provide him with a good estimate of the fan's air velocity.

D.6 Measurement of Fuel Consumption

To get the amount of fuel consumed, the tank shall be filled to full capacity before the test. After the test, fill the tank with measured fuel to the same level before the test. When filling up the tank, careful attention shall be paid to keep the tank horizontal and not to leave empty space in the tank.

Annex E
Field performance Test Data Sheet

Test Trial No. : _____ Date : _____
Test Engineers : _____ Location : _____
Test Specimen : _____

Items to be inspected

ITEMS	Trial 1	2	3	Ave.
E.1 Crop Condition				
E.1.1 Kind/Variety				
E.1.2 Days after harvest				
E.1.3 Moisture content (%)				
E.1.4 Size of ear corn				
E.1.4.1 Length (mm)				
E.1.4.2 Diameter (mm)				
E.1.5 Kernel-ear corn ratio				
E.2 Performance test				
E.2.1 Speed of components (rpm)				
E.2.1.1 Primemover				
E.2.1.1.1 Without load				
E.2.1.1.2 With load				
E.2.1.2 Shelling cylinder shaft				
E.2.1.2.1 Without load				
E.2.1.2.2 With load				
E.2.1.3 Fan shaft				
E.2.1.3.1 Without load				
E.2.1.3.2 With load				
E.2.1.4 Oscillating screen shaft				
E.2.1.4.1 Without load				
E.2.1.4.2 With load				
E.2.2 Fan air velocity (m/sec)				
E.2.2.1 Without load				
E.2.2.2 With load				
E.2.3 Noise level [db(A)]				
E.2.3.1 Feeder				
E.2.3.1.1 Without load				
E.2.3.1.2 With load				
E.2.3.2 Bagger				
E.2.3.2.1 Without load				
E.2.3.2.2 With load				
E.2.4 Shelling time (min)				
E.2.5 Shelled kernel (kg)				
E.2.6 Shelling capacity (kg/h)				
E.2.7 Fuel time (min)				
E.2.8 Fuel consumed (L)				
E2.9 Fuel consumption (L/h)				

E.3.1 Observations:

E.3.1.1 Ease of transporting the machine

_____
_____
_____

E.3.1.2 Adjustments such as belt tensions, clearance, air velocity and others

_____
_____
_____

E.3.1.3 Safety features

_____
_____
_____

E.3.1.4 Ease of cleaning the concave and cylinder

_____
_____
_____

E.3.1.5 Ease of cleaning the fan component

_____
_____
_____

E.3.1.6 Labor requirement

_____
_____
_____

E.3.1.7 Failure or abnormalities that may be observed on the sheller or its component parts during and after the shelling operation.

_____
_____
_____

E.3.1.8 Others

_____
_____
_____

Annex F
Laboratory Work

F.1 Measurement of ear corn dimensions

This shall be taken using at least ten representative samples of ear corn and measure the length and diameter.

F.2 Measurement of kernel-ear corn ratio

In measuring the kernel-ear corn ratio, take at least ten representative samples of ear corn. Take the weight of each ear corn and manually shelled the kernels. Determine the weight of the kernel for each ear corn then compute for the kernel-ear corn ratio.

F.3 Purity Determination

Take three 500 grams samples from the main corn kernel outlet. Clean the corn kernels to remove the impurities and other foreign matters, the clean corn kernel shall be weighed and recorded. The percent purity is calculated using the formula in clause H4.

F.4 Determination of Losses

F.4.1 Blower loss
Three samples shall be taken from the fan outlet to collect the corn kernels mixed with impurities. Each sample shall be cleaned and weighed. The total weight of the clean corn kernels and the total time of collection shall be recorded for the computation of blower loss (see Clause H5.2).

F.4.2 Separation loss
Three samples shall be taken at the cob outlet to collect loose corn kernels mixed with the cob. The total time of collection of the three samples shall be taken and recorded for the computation of separation loss (see Clause H5.3).

F.4.3 Unshelled loss
Unshelled kernels collected at the cob outlet shall be hand shelled and weighed. The total weight and time of collection shall be taken and recorded for the computation of unshelled loss (see Clause H5.4).

F.4.4 Scattering loss
Kernels scattered around the sheller with a maximum distance of 1.0 m away from the base of the machine, shall be collected after each trial, cleaned and weighed for the determination of scattering loss. (see Clause H5.5)

F.5 Determination of Net Percent Cracked Kernels

Three samples each from manually shelled and machine shelled corn kernels shall be taken for analysis. Each sample consists of 100 corn kernels. These corn kernels shall be inspected for the presence of fissures. The net percent cracked kernels shall be taken as the difference between the values obtained from the manual and machine shelled kernel samples (see Clause H8).

F.6 Determination of Percent Mechanically Damaged Kernels

Three samples from machine shelled kernels shall be taken for analysis. Each sample shall consist of 100 grams. Separate those kernels that were broken or crushed and weigh. Compute for the percent broken kernels (see Clause H9).

Annex G
Laboratory Grain Analysis Data Sheet

Machine Tested: _____ Analyzed by: _____
Date of Test: _____ Date Analyzed:_____

G.1 Crop Conditions

G.1.1 Moisture Content, (% w.b)

Average			

G.1.2 Kernel-Ear Corn Ratio

Sample No.	Weight of Ear Corn (g)	Weight of Kernel (g)	Kernel-Ear Corn Ratio
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
Average			

G.2 Kernel Analysis

G.2.1 Purity Determination

Initial Weight of Samples (uncleaned) = 500 gms

ITEMS	Trial 1				Trial 2				Trial 3				Gen. Ave.
	1	2	3	Ave.	1	2	3	Ave.	1	2	3	Ave.	
Cleaned (g)													
Purity (%)													

G.2.2 Loss Determination

Trial No.	Blower Loss		Separation Loss		Unshelled Loss		Scattering Loss	
	Duration:		Duration:		Duration:		Duration:	
	Sample Wt. (g)	Total (kg)	Sample Wt. (g)	Total (kg)	Sample Wt. (g)	Total (kg)	Sample Wt. (g)	Total (kg)
1 a								
b								
c								
Ave.								
2 a								
b								
c								
Ave.								
3 a								
b								
c								
Ave.								
Gen. Ave.								

G.2.3 Shelling Efficiency/Recovery Determination

Trial No.	Blower Loss		Separation Loss		Unshelled Loss		Scattering Loss		Total	
	wt.	%	wt.	%	wt.	%	wt.	%	Output (kg)	Input (kg)
1										
2										
3										
Average										

Annex H
Formula Used During Calculations and Testing

H.1 Kernel-ear corn ratio (R_e)

$$R_e = \frac{W_k}{W_e}$$

where:

W_k is the weight of kernel, g
W_e is the weight of the ear corn, g

H.2 Fuel consumption (F_C), L/h

$$F_c = \frac{F_1}{T_o}$$

where:

F_1 is the amount of fuel consumed, L
T_O is the time of operation, h

H.3 Capacity

a) Actual capacity (C_a), kg/h

$$C_a = \frac{W_c}{T_o}$$

where:

W_C is the weight of shelled kernel, kg
T_O is the duration of operation, h

b) Corrected capacity (C_C), kg/h (at 100% purity, 20% moisture content)

$$C_c = \frac{100 - MC_o}{100 - MC_m} \text{ x } P \text{ x } C_o$$

where:

C_C is the corrected capacity, kg/h
C_O is the actual capacity, kg/h
MC_O is the observed moisture content, %
MC_m is the kernel moisture content, at 20%
P is the kernel purity, %

H.4 Purity (P), %

$$P = \frac{W_c}{W_u} \text{x} 100$$

where:

W_u is the weight of uncleaned kernel, g
W_C is the weight of cleaned kernel, g

H.5 Losses

H.5.1 Summation of all losses (L_t), kg

$$L_t = \text{Blower loss} + \text{Separation loss} + \text{Unshelled loss} + \text{Scattering loss}$$

H.5.2 Blower loss (B_1)

a) Amount

$$B_1, \text{kg} = \frac{\text{Weight of blown clean kernel, kg}}{\text{Duration of collection, h}} \text{ x duration of operation, h}$$

b) Percentage

$$B_{1,}\% = \frac{\text{Blower loss, kg}}{\text{Cleaned shelled kernel, kg} + \text{Summation of all losses, kg}} \text{ x } 100$$

H.5.3 Separation Loss (S_1)

a) Amount

$$S_1, \text{kg} = \frac{\text{Weight of separated clean kernel, kg}}{\text{Duration of collection, h}} \text{ x duration of operation, h}$$

b) Percentage

$$S_{1,}\% = \frac{\text{Separation loss, kg}}{\text{Cleaned shelled kernel, kg} + \text{Summation of all losses, kg}} \text{ x } 100$$

H.5.4 Unshelled Loss (U_1)

a) Amount

$$U_1, \text{kg} = \frac{\text{Weight of unshelled clean kernel, kg}}{\text{Duration of collection, h}} \text{ x duration of operation, h}$$

b) Percentage

$$U_{1,}\% = \frac{\text{Unshelled loss, kg}}{\text{Cleaned shelled kernel, kg} + \text{Summation of all losses, kg}} \text{ x } 100$$

H.5.5 Scattering loss (S_C l), %

$$S_c l,\% = \frac{\text{Weight of clean scattered kernels, kg}}{\text{Cleaned shelled kernel kg} + \text{Summation of all losses, kg}} \text{ x } 100$$

H.6 Shelling Efficiency (S_e) , %

$$S_c, \% = \frac{\text{Clean shelled kernel , kg} + \text{Blower loss kg} + \text{Separation loss, kg} + \text{Scattering loss, kg}}{\text{Clean shelled kernel, kg} + \text{Summation of all losses, kg}} \text{ x } 100$$

or

= 100% - Unshelled loss (%)

H.7 Shelling Recovery (S_r), %

$$S_r, \% = \frac{\text{Clean shelled kernels, kg}}{\text{Cleaned shelled kernel, kg} + \text{Summation of all losses, kg}} \text{ x } 100$$

H.8 Cracked kernel (C_g), %

$$C_g = \frac{\text{Number of cracked kernels}}{\text{100 kernel sample}} \text{ x } 100$$

H.9 Mechanically damaged kernel (D_g), %

$$D_g = \frac{\text{Weight of mechanically damaged kernels, g}}{\text{100 gram sample}} \text{ x } 100$$