

PHILIPPINE NATIONAL STANDARD

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**Agricultural machinery – Fruit Dryer –
Methods of Test**



BUREAU OF PRODUCT STANDARDS

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National Foreword

This Philippine Agricultural Engineering Standards PAES 249:2010, Agricultural machinery – Fruit Dryer – Methods of Test was approved for adoption as Philippine National Standard by the Bureau of Product Standards upon the recommendation of the Agricultural Machinery Testing and Evaluation Center (AMTEC) and the Philippine Council for Agriculture, Forestry and Natural Resources Research and Development of the Department of Science and Technology (PCARRD-DOST).

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PHILIPPINE AGRICULTURAL ENGINEERING STANDARD PAES 249: 2010
Agricultural Machinery – Fruit Dryer – Methods of Test

1 Scope

This standard specifies the methods of test and inspection for fruit dryer. Specifically, it shall be used to:

- 1.1** verify the mechanism, dimensions, materials and accessories of the fruit dryer 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; and
- 1.4** report the results of the tests.

2 References

The following normative documents contain provisions, which through reference in this text constitute provisions of this National Standard:

- PAES 103:2000** Agricultural Machinery – Method of Sampling
PAES 248:2010 Agricultural Machinery – Fruit Dryer – Specifications

3 Definitions

For the purpose of this standard, the definitions given in PAES 248 and the following shall apply:

3.1

airflow rate

volume of air in cubic meters delivered to the mass of fruits per minute

3.2

drying air temperature

mean temperature of the air to be used for drying the fruit, measured at a number of points as close as practicable to its entry to the drying bed

3.3

drying capacity

maximum capacity that the fruit dryer can removed moisture content per unit time

3.4

drying efficiency

heat utilization efficiency

ratio of the total heat utilized to vaporize moisture in the material, to the amount of heat added to the drying air, expressed in percent

3.5

drying rate

amount of water removed per unit of time, expressed in kilogram per hour

3.6

drying system efficiency

ratio of the total heat utilized for drying, to the heat available in the fuel expressed in percent

3.7

fuel consumption

total amount of fuel consumed divided by the total drying time

3.8

heat utilization

total amount of heat utilized to vaporize moisture in the material, expressed in kJ/kg of water

3.9

holding capacity

load capacity

weight of fruits required to fill the dryer at the initial moisture content

3.10

moisture reduction rate

ratio of the average percent moisture content removed from the fruits, to drying time, expressed in percent per hour

3.11

static pressure

pressure build-up in the plenum chamber to maintain uniform distribution of air flow through the sliced fruits, expressed in mmH₂O

4 General Conditions for Test and Inspection

4.1 Machine on test

The machine on test shall be commercially produced or prototype unit or slightly used machine depending upon the test objective. In case of testing commercially manufactured dryers, the dryer sampled for acceptance, lot, routine, and type of tests in accordance with PAES 103 shall be submitted for test.

4.2 Role of manufacturer/distributor

The manufacturer/distributor shall submit specifications and other relevant information about the fruit dryer and shall abide with the terms and conditions set forth by an official testing agency.

4.3 Role of the operator

An officially designated operator shall be skilled and shall demonstrate, operate, adjust, and repair as the case may be, related to the operation of the dryer.

4.4 Test site conditions

The site should have ample provisions for material handling and workspace and suitable for normal working condition.

4.5 Test instruments

The instrument to be used shall have been calibrated and checked by the testing agency prior to the measurements. The suggested list of minimum test instruments and materials needed to carry out the fruit dryer test is shown in Annex A.

4.6 Termination of Test

If during testing, the dryer has a major component breakdown or malfunction, the test engineer from the official testing agency shall terminate the test.

5 Test Preparation

5.1 Materials and equipment

5.1.1 Fuel

The fuel to be used shall conform to the specification supplied by the manufacturer.

5.1.2 Material to be dried

The fruit to be used shall be single variety and the minimum moisture content shall be 75%. The fruits shall be peeled and sliced before drying.

5.1.3 Measuring instruments

The measuring instruments for performance testing shall be calibrated by the testing agency prior to the tests.

5.2 Preparation of the dryer for testing

A check that the dryer has been assembled and installed in accordance with the instruction of the manufacturer based on installation manual shall be made by the manufacturer and testing agency.

5.3 Test set-up

Thermometer shall be mounted on or inside the dryer for temperature sensing. These shall be mounted at the following locations: (1) near the dryer to sense ambient temperature; (2) at the plenum interface; (3) after the plenum; and (4) immediately outside the dryer to sense exhaust air temperature. Temperature sensors shall be partially shielded to minimize errors from heat radiation effects.

For the measurement of airflow and static pressure, pitot tube and manometer or any other suitable apparatus shall be installed.

The control of drying air condition shall be made by adjustment of the setting of automatic control forming part of the dryer, or by manual adjustment of the furnace by the representative of the manufacturer if automatic temperature control mechanism is not fitted. Adjustments for the purpose of maintaining a steady temperature of the drying air may be made in any time but any adjustment of automatic control shall have been sanctioned by the testing center.

6 Test and Inspection

6.1 Verification of the technical data and information of the manufacturer

6.1.1 This inspection is carried out to verify the mechanism, main dimensions, materials and accessories of the dryer in comparison with the list of technical data and information of the manufacturer.

6.1.2 The following observations shall also be made:

6.1.2.1 Quality of manufacture

6.1.2.2 Adequacy of protection of components (e.g. bearings, shaftings, belts, etc.)

6.1.2.3 Presence of safety devices

6.1.2.4 Operation and maintenance manual, spare parts catalogue, special tools required for adjustments and repair kit shall be available and supplied to end-users.

6.1.3 The items to be measured, inspected and observed shall be recorded in Annex B.

6.2 Performance test

6.2.1 This is carried out to obtain and validate data on overall fruit dryer performance.

6.2.2 Data on fruits to be dried shall be recorded in Annex C.

6.2.3 Operation of the fruit dryer

The dryer shall be operated at the drying air temperature of the fruit as specified by the manufacturer.

6.2.3.1 The following shall be measured at 30-minutes intervals or as necessary.

6.2.3.1.1 Air velocity

Measurement of air velocity shall be made at the air duct.

6.2.3.1.2 Temperature

Fruits temperature, drying air temperature, ambient and exhaust air wet bulb and dry bulb temperature shall be recorded.

6.2.3.1.3 Static pressure

This shall be taken at the plenum/transition duct (between blower and the dryer).

6.2.3.1.4 Sound level

This shall be measured with the dryer full of fruits, operating at recommended settings of different components, with burner on. (The station of the operator will be considered to be within one meter of the controls).

6.2.3.1.5 Moisture content

Samples for moisture content determination shall be taken at the bottom, middle and top drying racks (for vertically arranged trays) or beginning, center and last drying trays (for horizontally arranged trays) of the fruit dryer.

6.2.3.1.6 Power, fuel and speed

Measurement shall be made of the power and fuel consumption during each test run. Speed of the prime mover and fan shall be obtained and recorded.

6.2.3.2 Sampling for determination of fruit quality

This shall be done to inspect the physical quality of the fruits after drying operation. Samples from the input and final output shall be taken during each test run. All samples to be taken to the laboratory shall be placed in appropriate containers and properly labeled.

6.2.4 Data collection

6.2.4.1 Duration of test

The duration of each drying cycle shall be such that one full capacity of fruits has been dried from the initial to the final moisture content

6.2.4.2 Data recording and observations

6.2.4.2.1 All the data obtained and any observations of breakdown or failure on the dryer shall be recorded in Annex C.

6.2.4.2.2 Visual inspection test shall be made on welded parts of the fruit dryer and shall be recorded in Annex C.4.

7 Laboratory Analysis

This is carried out to have physical analysis on the samples before and after drying operation. The following shall be determined.

7.1 Variety of the fruit

7.2 Moisture content

7.2.1 This shall be taken using oven-dry method.

7.2.2 Weigh 100g of sliced fruit samples, place in the moisture can and record the weight. Ensure that no moisture lost or gained by the sample between the time it was collected and when it is weighed in moisture can. Record the initial weight.

7.2.3 Dry the sample in the oven with temperature of $103\text{ }^{\circ}\text{C} \pm 1\text{ }^{\circ}\text{C}$ for 24 hours.

7.2.4 After removing samples from the oven, the moisture can with the samples should be placed in desiccators and allowed to cool to ambient temperature.

7.2.5 Weigh the moisture can plus the dried sample. Record the final weight. Calculate the moisture content using Formula in Annex E.

7.3 Water activity, a_w (done using water activity meter)

7.4 Hardness (done by using hardness tester)

7.5 Sensory test

In this test, the samples before and after drying shall be observed in terms of the flavor, discoloration and odor using Standard Sensory Evaluation.

7.6 Presence of foreign matters (any matter which has not been derived from fruits, does not pose a threat to human health and is readily recognized without magnification or is present at a level determined by magnification method or any equivalent method that indicates non-compliance with good manufacturing and sanitation practices).

7.7 Data collected, obtained and calculated shall be recorded in Annex D.

8 Formula

The formula to be used during calculation and testing are given in Annex E.

9 Test Report

The test reports shall include the following information:

9.1 Title

9.2 Summary

9.3 Purpose and Scope of Test

9.4 Methods of Test

9.5 Condition of Machine

9.6 Description of the Machine

Table 1 – Machine Specifications

9.7 Results and Discussions

9.8 Observations (include pictures)

Table 2 – Performance test data

9.9 Names, signatures and designation of test engineer

Annex A

Suggested List of
Test Instruments and Materials

A.1	Instruments	Quantity
A.1.1	Field	
A.1.1.1	Thermometer (range: 0°C to 100°C)	4
A.1.1.2	Digital timers (range: 24 hours) Accuracy: 0.1 sec	
A.1.1.3	Tape measure (with maximum length of 5m)	1
A.1.1.4	Weighing scale (capacity: 50 kg) 0.1 kg accuracy	
A.1.1.5	Vernier Caliper Accuracy: 0.1 mm	1
A.1.1.6	Pitot tube	1
A.1.1.7	Manometer	1
A.1.1.8	Tachometer (contact type or photo electric type) Range: 0 rpm to 5,000 rpm	1
A.1.1.9	Air velocity meter	1
A.1.1.10	Power meter (60 Hz, 220V)	1
A.1.1.11	Scientific Calculator	1
A.1.1.12	Marking pen and pencil	1
A.1.1.13	Digital Camera	1
A.1.2	Laboratory	
A.1.2.1	Weighing scale (capacity: 1000 g) 0.01 g accuracy	1
A.1.2.2	Air oven	1
A.1.2.3	Water activity meter	1
A.1.2.4	Fruit hardness tester Accuracy: 0.1g	1
A.1.2.5	Aluminum moisture can	3
A.1.2.6	Dessicator	1
A.1.2.7	Magnifying glass	1
A.2	Materials	
A.2.1	Sliced fruits	
A.2.2	Sample bags	
A.2.3	Labeling tags which include	
A.2.3.1	Date of test	

Annex B

Specifications of Fruit Dryer

Name of Applicant/ Distributor: _____

Address: _____

Tel No: _____

Name of Manufacturer: _____

Address: _____

Tel No: _____

GENERAL INFORMATION

Make: _____ Type: _____

Serial No: _____ Brand/Model: _____

Production date of Fruit Dryer: _____

Testing Agency: _____ Test Engineer: _____

Date of Test: _____ Location of Test: _____

Items to be inspected

ITEMS	Specification of the Manufacturer	Verification by the Testing Agency
B.1. Capacity, kg/h		
B.2 Drying chamber		
B.2.1 Material(s) of construction		
B.2.2 Dimensions, mm		
B.2.2.1 length		
B.2.2.2 width		
B.2.2.3 thickness		
B.2.3 Drying racks		
B.2.3.1 Material(s) of construction		
B.2.3.2 Dimensions, mm		
B.2.3.2.1 length		
B.2.3.2.2 width		
B.2.3.2.3 thickness		
B.3 Air distribution system		
B.3.1 Plenum		
B.3.1.1 Material(s)		
B.3.1.1.1 Intake manifold		
B.3.1.1.2 Exhaust manifold		
B.3.2 Ducting		
B.3.2.1 Material		
B.3.2.2 Dimensions, mm		
B.3.2.2.1 length		
B.3.2.2.2 diameter (if cylindrical)		
B.3.2.2.3 width (if rectangular)		
B.3.2.2.4 height (rectangular)		

B.3.3 Fans		
B.3.3.1 Type		
B.3.3.2 Brand/Model		
B.3.3.3 Airflow rate, m³/min		
B.3.3.4 Static pressure, Pa		
B.3.3.5 Material(s) of construction		
B.3.3.6 Prime mover		
B.3.3.6.1 For electric motors		
B.3.3.6.1.1 Type		
B.3.3.6.1.2 Brand		
B.3.3.6.1.3 Make or manufacturer		
B.3.3.6.1.4 Serial number		
B.3.3.6.1.5 Rated power, kW		
B.3.3.6.1.6 Rated speed, rpm		
B.3.3.6.1.7 Frequency, Hz		
B.3.3.6.1.8 Voltage		
B.3.3.6.2 For engine		
B.3.3.6.2.1 Type		
B.3.3.6.2.2 Brand		
B.3.3.6.2.3 Make or manufacturer		
B.3.3.6.2.4 Serial number		
B.3.3.6.2.5 Displacement, cc		
B.3.3.6.2.6 Cylinder arrangement		
B.3.3.6.2.7 Rated power, kW		
B.3.3.6.2.8 Rated speed, rpm		
B.3.3.7 Other (specify)		
B.4 Heating system		
B.4.1 Main		
B.4.1.1 Type		
B.4.1.2 Type of fuel		
B.4.1.3 Presence of temperature control		
B.4.1.4 Fuel consumption, L/h		
B.4.1.5 Other feature(s)		
B.4.2 Supplementary		
B.4.2.1 Type (direct or indirect)		
B.4.2.2 Type of fuel		
B.4.2.3 Presence of temperature control		
B.4.2.4 Other feature(s)		
B.5 Instruments and controls		
B.5.1 Temperature		

B.5.1.1 Air temperature		
B.5.1.1.1 Type (s)		
B.5.1.1.2 Location (s)		
B.5.1.2 Fruit temperature		
B.5.1.2.1 Type(s)		
B.5.1.2.2 Location(s)		
B.5.2 Pressure/airflow indicator(s)		
B.5.2.1 Type(s)		
B.5.2.2 Location(s)		
B.5.3 Other feature(s)		
B.6 Safety feature(s)		
B.6.1 Product safety		
B.6.2 Machine safety		
B.6.3 Operation and maintenance safety		

Annex C

Performance Test Data Sheet

Test Trial No. _____ Date: _____
 Test Engineer: _____ Location: _____
 Assistants: _____ Test Specimen: _____
 Test Requested by: _____ Manufacturer: _____

C.1 Fruit Condition	
C.1.1 Kind/Variety	
C.1.2 Initial moisture content, %	
C.1.3 Total weight of sliced fruits, kg	
C.1.4 Damaged parts, %	
C.2 Holding capacity, kg/batch	
C.3 Initial weight of test material, kg	
C.4 Initial moisture content, %	
C.5 Final moisture content, %	
C.6 Actual drying time, h	
C.7 Drying capacity, kg/h	
C.8 Moisture reduction rate, %/h	
C.9 Average drying air temperature, °C	
C.10 Ambient air temperature, °C	
C.10.1 Dry bulb	
C.10.2 Wet bulb	
C.11 Ambient air relative humidity, %	
C.12 Dryer exhaust air temperature, °C	
C.12.1 Dry bulb	
C.12.2 Wet bulb	
C.13 Exhaust air relative humidity, %	
C.14 Fan air velocity, m/s	
C.15 Air flow rate, m ³ /min	
C.16 Plenum static pressure, mmH ₂ O	
C.17 Fuel consumption rate, kg/h	
C.18 Average power consumption during drying process	
C.18.1 Input power, kW	
C.18.2 Line voltage, V	
C.18.3 Load current, A	
C.19 Heating system efficiency, %	
C.20 Drying system efficiency, %	
C.21 Welding Acceptance Test	
C.21.1 Crack prohibition	
C.21.2 Weld/base-metal fusion	
C.21.3 Crater cross section	
C.21.4 Weld profile	
C.21.5 Time of inspection	
C.21.6 Undersize welds (if any)	

C.21.7 Undercut	
C.21.8 Porosity (presence of air holes on the welded parts)	

C.22 Evaluate the following observations

Items	Remarks
C.22.1 Ease of operation	
C.22.2 Ease of repairing of parts	
C.22.3 Ease of cleaning	
C.22.5 Availability of the switches needed	
C.22.6 Quality of manufacture	
C.22.7 Adequacy of protection of components (e.g. bearings, shafting, belts, etc.)	
C.22.8 Safety controls/devices	
C.22.9 Availability of manuals, brochure and standard and special tools for adjustments and repair	
C.22.10 Instrumentation	
C.22.11 Ease of loading and unloading	
C.22.12 Availability of settings and adjustments	

C.23 Other Observations (e.g. temperature stability, noise in dB(A), breakdown on any parts during operation):

Annex D

Laboratory Analysis of the Samples

Machine tested: _____
Variety of corn used: _____
Date of test: _____
Laboratory Analyst: _____

D.1 Physical analysis on fruit samples

Before drying	
Discoloration, %	
Moisture content, %	
Odor*	
Flavor*	
Discoloration*	
Damaged parts*	
Presence of foreign matters*	
After drying	
Discoloration, %	
Moisture content, %	
Odor*	
Flavor*	
Discoloration*	
Damaged parts*	
Presence of foreign matters*	

*Evaluation/Comments/Observations

D.2 Other observations:

Annex E

Formula

E.1 Drying Capacity

$$D_c = \frac{W_i}{T_d}$$

where:

$$\begin{aligned} D_c &= \text{drying capacity, kg/h} \\ W_i &= \text{initial weight of test material, kg} \\ T_d &= \text{actual drying time, h} \end{aligned}$$

E.2 Moisture Reduction Rate

$$MC_r = \frac{MC_i - MC_f}{T_d}$$

where:

$$\begin{aligned} MC_r &= \text{moisture reduction rate, kg/h} \\ MC_i &= \text{initial moisture content of test material, \%} \\ MC_f &= \text{final moisture content of test material, \%} \\ T_d &= \text{actual drying time, h} \end{aligned}$$

E.3 Heating system efficiency

$$HSE = \frac{Q_d}{Q_f} \times 100$$

$$Q_d = \frac{(h_2 - h_1) \times V_a}{V_{sp}} \times 60 \frac{\text{min}}{\text{h}}$$

$$Q_f = F_{FR} \times HV_F$$

where:

HSE	=	heating system efficiency, %
Q_d	=	heat supplied to the dryer, kJ/h
Q_f	=	heat available in the fuel, kJ/h
h_2	=	final enthalphy of drying air (see psychrometric chart)
h_1	=	initial enthalphy of ambient air (see psychrometric chart)
V_a	=	airflow rate of drying air, m ³ /min
V_{sp}	=	specific volume of drying air, m ³ /kg dry air
F _{FR}	=	Fuel feed rate, kg/h
HV _F	=	Heating value of fuel, kJ/kg

E.4 Heat Utilization

$$Q_u = \frac{Q_d \times T_d}{m_r}$$

where:

Q_u	=	heat utilization, kJ/kg
Q_d	=	heat supplied to the dryer, kJ/h
T_d	=	drying time, h
m_r	=	moisture remove, kg

E.5 Drying Efficiency

$$Eff_d = \frac{Q_r}{Q_d} \times 100$$

$$Q_r = \frac{Q_v \times m_r}{T_d}$$

where:

Eff_d	=	drying efficiency,%
Q_r	=	heat required to vaporize moisture inside fruit, kJ/h
Q_d	=	heat supplied to the dryer, kJ/h
Q_v	=	heat of vaporization of water, kJ/kg

E.6 Drying System Efficiency

$$Eff_{ds} = \frac{Q_u}{F_{FR} \times HV_f} \times 100$$

where:

Eff_{ds}	=	drying system efficiency, %
Q_u	=	heat utilization, kJ/kg
F_{FR}	=	fuel feed rate, kg/h
HV_f	=	heating value of fuel, kJ/kg

E.7 Performance factor of carnot cycle

$$PF_c = \frac{T_2}{T_2 - T_1}$$

where:

PF_c	=	performance factor of carnot cycle
T_2	=	temperature of condenser, °K
T_1	=	temperature of evaporator, °K

E.8 Performance Factor

$$PF = \frac{M_A C_{PA} (T_H - T_L)}{w}$$

where:

PF	=	performance factor
M_A	=	mass flow, kg/s
C_{PA}	=	specific heat of air, kJ/kg-°K
T_H	=	plenum temperature, °K
T_L	=	ambient temperature, °K
w	=	work of compressor, kJ/s

Philippine Agricultural Engineering Standards

AMTEC-UPLB – PCARRD Project: “Development of Standards for Agricultural Production and Postharvest Machinery”

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