



A Vortex Forage and Biomass Sample Dryer

Dennis R. Buckmaster
 Associate Professor of Agricultural Engineering

Introduction

Moisture measurement of forages is important during both harvest and feeding. Inaccurate moisture measurement during hay harvest can lead to mold, excessive dry matter and quality loss, heat generation, and even fire. Inaccurate moisture measurement of silage at harvest can lead to excessive moisture transport, poor packing, excessive dry matter and quality loss, and poor fermentation. Moisture measurement of forage and other high moisture feeds is critical at feeding time to properly balance nutrient concentrations. Forage moisture can vary significantly over time and with location in a storage structure; therefore rapid, accurate, and inexpensive methods of evaluating moisture are needed.

Methods for on-farm analysis include electronic meters, microwave drying, Koster™ testers, and drying ovens. Researchers evaluating alterna-

tive methods consistently use a drying oven as the standard. Most agree that use of a microwave oven is an accurate method (typical error -2 to +1%), but it requires more time and operator skill than most alternatives. As evidenced by the multitude of extension fact publications and internet informational pages, microwave drying of small samples appears to be the on-farm method of choice; however, this method requires constant supervision and can lead to inaccurate results due to burning of a sample. A Koster tester does not require constant supervision, but it requires a significant amount of drying time and is less accurate (typical error ±3%) than a microwave oven. Electronic meters can be consistent, but require frequent calibration.

The vortex dryer can be built for approximately \$40 and is as accurate as a drying oven. Most hay samples can be dried in 15 to 20 minutes; most silage samples will dry in 40 to 60 minutes, depending on crop characteristics.



Figure 1. Assembled vortex dryer with lid removed

Accuracy of a Vortex Dryer

Accuracy of the vortex dryer was determined by comparing results from 200 gram (7.06 ounce) sub-samples of 12 different forages dried in a vortex dryer and a drying oven. Four replicates of each sub-sample were dried using each method. The vortex dryer average error was -0.1%. Moisture estimates were within 1% of the actual value 95% of the time. There was no statistical difference between the vortex estimates and the drying oven estimates. Just because the method is accurate, however, does not mean the estimate from a sample is accurate. Proper sampling is critical – particularly when there is variability within a field, from field to field, from load to load, across a bunker face, etc. The vortex device and the associated method allows for replicate sample drying in a relatively short period of time. With approximately the same time, effort, and cost, a person could dry three 200 gram forage samples in three vortex dryers rather than three 100 gram samples in a microwave oven; there would be no risk of burning the samples and the larger vortex dryer samples reduce sampling error.



Figure 2. Assembled vortex dryer

Building a Vortex Dryer

A completed vortex dryer is shown in Figures 1 and 2. The components required are listed in Table 1 (page 6); it takes approximately three hours to build the dryer once supplies are available. It is important to use CPVC rather than PVC for the coupling and air entrance tube; blow dryers can heat the tube to a temperature which softens PVC. With enough air flow resistance, the temperatures might also get high enough for PVC to release toxic fumes (above 140°F). CPVC is rated for higher temperatures.

One critical aspect of the vortex dryer involves the placement of the air entrance tube so that air swirling occurs. The air should enter the drying chamber tangent to the vertical chamber (figure 2; entrance tube is offset and is flush with the drying chamber base on the inside). To properly place the air entrance tube hole approximately ¼” from the bottom, either use a hole saw or a large drill bit to drill a hole nearly large enough for the air entrance tube (figure 3). Use a rotary tool with a sander or a file to shape the hole so the entrance tube fits into the hole snugly. The end of the entrance tube should be shaped to the contour of the inside of the drying chamber. This can be done with a scroll, jig, or band saw and a little filing or sanding. Glue the air entrance tube to the drying chamber base using CPVC glue since operating temperature may approach 140°F.

The floor of the chamber should be inserted into the vertical chamber so the top of the floor will be flush with the bottom of the air entrance tube when it is installed (figure 3). This eliminates a dead zone at the bottom of the drying chamber. The dryer illustrated in figure 3 has a plastic sheet floor glued in place. Plywood could be used with screws installed from the outside to fasten the wood floor in place.

The base of the drying chamber can be made of PVC (less expensive) or CPVC. The metal duct fittings can be attached to each other and the CPVC or PVC base with either pop rivets or small bolts (put heads inside, nuts outside).

The vortex sample dryer lid is a sandwich of window screen, two layers of furnace filter, and window screen (figures 4 and 5). The lid frame illustrated in figure 4 was made of plywood and clamped together with small screws; the lid should be cut to fit snugly into the top of the chamber (figure 5). The lid

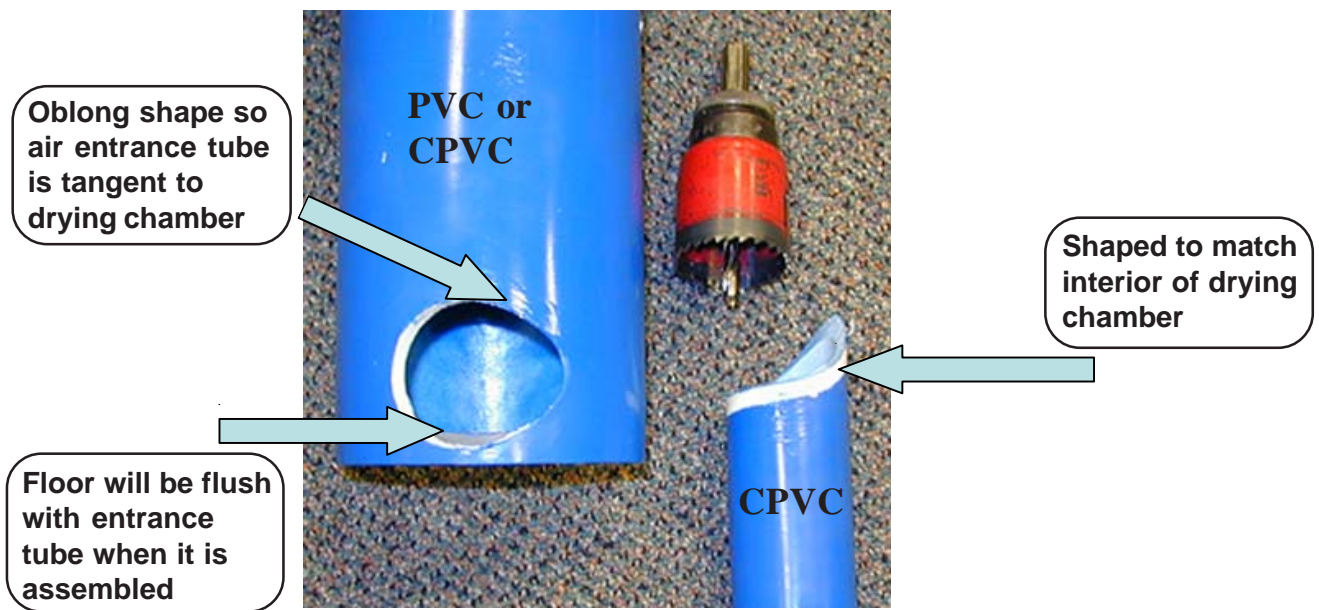


Figure 3. Bottom of drying chamber and entrance tube ready for installation.

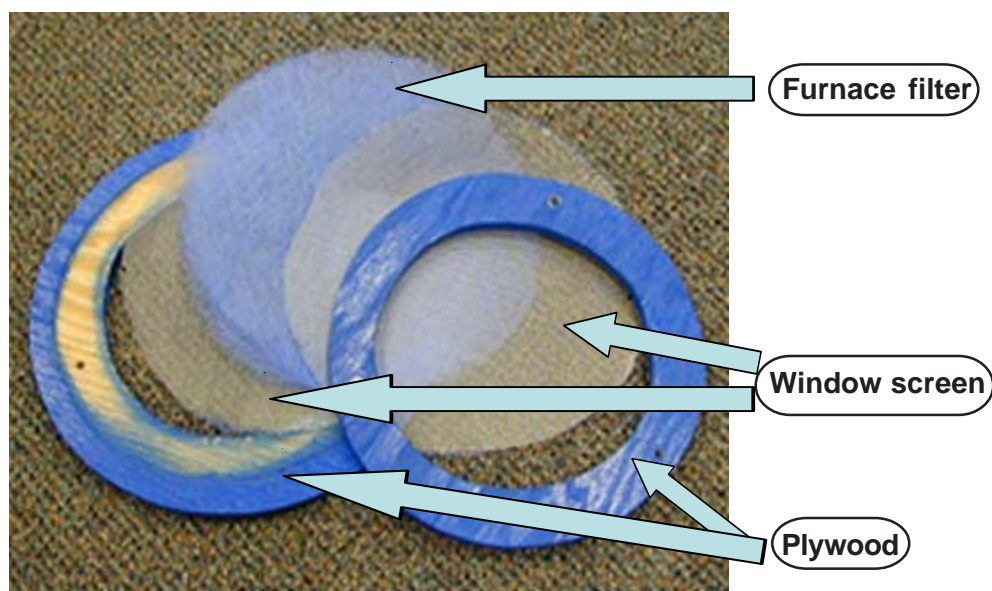


Figure 4. Disassembled vortex dryer lid "sandwich" of window screen, furnace filter, and window screen between two wooden rings.

eliminates sample loss during drying; it is important because as samples dry, particles will be flying around in the drying chamber.

Depending on the blow dryer used, the connection to the entrance tube may need to be changed. A CPVC coupler will work in most cases with some sanding or filing to fit the blow dryer outside diameter. It is recommended to glue the blow dryer to the coupler with glue for plastic which can tolerate the

high temperatures (CPVC glue may work, depending on the plastic used to make the blowdryer); leave the coupler un-glued from the air entrance tube (figure 6). This will allow easy removal of the blow dryer from the vortex dryer, yet provide a rigid connection during operation.



Figure 5. Vortex dryer lid snugly fitting into the drying chamber.



Figure 6. Blow dryer glued to the coupler which would slide onto the air entrance tube (unglued).

For a complete listing of Agricultural and Biological Engineering fact sheets, visit <http://www.age.psu.edu/extension/informationindex.html>

First Edition 03/05

The Pennsylvania State University is committed to the policy that all persons shall have equal access to programs, facilities, admission, and employment without regard to personal characteristics not related to ability, performance, or qualifications as determined by University policy or by state or federal authorities. It is the policy of the University to maintain an academic and work environment free of discrimination, including harassment. The Pennsylvania State University prohibits discrimination and harassment against any person because of age, ancestry, color, disability or handicap, national origin, race, religious creed, sex, sexual orientation, or veteran status. Discrimination or harassment against faculty, staff, or students will not be tolerated at The Pennsylvania State University. Direct all inquiries regarding the nondiscrimination policy to the Affirmative Action Director, The Pennsylvania State University, 328 Boucke Building, University Park, PA 16802-5901, Tel 814-865-4700/V, 814-863-1150/TTY.

Drying a Sample with a Vortex Dryer

Scales accurate within 1 gram or better should be used.

Step 1. Weigh and record the empty (tare) weight of the dryer. (Suggestion: with lid, without blow dryer.)

Step 2. Add 200 grams of sample.

Note the total weight at this point is wet gross weight. (Sample weights below 200 grams could be used, but a 200 gram sample makes the math easier. Samples larger than 200 grams have not been tested.)

Step 3. Connect the blow dryer to the air entrance tube and turn it on. Be sure the air inlet(s) to the blow dryer are not obstructed or the blow dryer may overheat and cause a fire. Operate the blow dryer on the “high” setting for rapid sample drying.

Note: If you wish to dry a sample for subsequent quality analysis at a laboratory, use the “low” setting of the blow dryer to keep air and sample temperature below 140°F. The drying time requirement may be longer, but the sample quality will not be altered.

Step 4. Operate the dryer for an extended period of time, depending on the sample. Experience during the development of this method suggests that these times should yield samples which are dried to within 1% of their final dry weight:

Hay samples: 15 to 20 minutes

Haycrop silage samples: at least 40 minutes

Corn silage samples: at least 60 minutes

Note: You may refine these time requirements (step 4) after getting experience with a particular blow dryer and a particular sample type (e.g., grass silage). The goal is to dry to a constant weight as documented in step 7, below.

Step 5. Weigh the dryer (components included as in step 1; for example, with lid, without dryer) and record the dry gross weight.

Step 6. Compute moisture content, wet basis (MC%) as:

$$\text{MC\%} = \frac{\text{wet gross} - \text{dry gross}}{\text{wet gross} - \text{tare}} \times 100$$

(Note: If you used a 200 gram sample, the denominator is 200, so moisture content could be determined by: [wet gross – dry gross] divided by 2.)

Step 7. Dry the sample for another 5 to 10 minutes to be sure it is dry. Repeat steps 5 and 6 as long as weight is changing.

Buying a Vortex Dryer

Three Penn State student clubs are working together to build and sell vortex sample dryers as a fund raiser. As an alternative to building one from the directions provided, you may order a vortex dryer at a very reasonable price by visiting: www.abe.psu.edu/vortex

Alternatively, you may call 814-865-3392 to request vortex dryer ordering information.

Table 1. Vortex sample dryer bill of materials.

Description	Specifications	A source (part number) ^a
Blow dryer ^b	1200 to 1600 W	Department store
CPVC or PVC base	4" diameter x 7" length, schedule 40,	Plumbing or hardware store
CPVC tube	1.5" diameter x 6" length, schedule 40	Plumbing or hardware store
CPVC coupling	1.5" diameter	Plumbing or hardware store
Round duct reducer	6" to 4" galvanized steel	McMaster Carr (2013K58)
Round duct reducer	9" to 6" galvanized steel	McMaster Carr (2013K23)
Filter	furnace filter	Department or hardware store
Window screen	two pieces 10" in diameter	Department or hardware store
Wood for lid	½" plywood, 9" diameter	Building supply store
Wood for lid	½" plywood 11" diameter	Building supply store
Wood or sheet PVC for floor	½" thick, 4" diameter	Building supply store
Fastening hardware	Pop rivets, screws, and CPVC glue	Building supply or hardware store

^a Many good retail sources are available. Only one is specified for specific components only for simplicity and clarity.

^b Blow dryer outside diameter should be compatible with the CPVC coupling used as a connector.

Suggested related reading:

Garthe, J.W. and S. Zummo. 1990. Sampling forages for testing. ABE Extension Fact Sheet I-104. Available: <http://www.age.psu.edu/extension/factsheets/i/I104.pdf>

Garthe, J.W. and S. Zummo. 1990. Determining forage moisture content with a microwave oven. ABE Extension Fact Sheet I-106. Available: <http://www.age.psu.edu/extension/factsheets/i/I106.pdf>

Gay, S.W., R. Grisso, and R. Smith. 2003. Determining forage moisture concentration. VA Cooperative Extension Publ. 442-106. Available: <http://www.ext.vt.edu/pubs/bse/442-106/442-106.pdf>.

Peters, J. 2000. On-farm moisture testing of corn silage. Focus on Forage 2(6):1-3. University of Wisconsin. Available: <http://www.uwex.edu/ces/crops/uwforage/CSMoistTest.htm>.

Pitt, R.E. ed. 1993. Forage moisture determination. Publication 59. NRAES. Ithaca, NY. Visit: www.nraes.org.

Staples, C.R. 1988. Microwave drying for measurement of forage moisture. Univ. of FL Cooperative Extension publ. DS23. Available: <http://edis.ifas.ufl.edu/pdf/DS/DS15800.pdf>.

Steevens, B.J. R. Belyea, and R. Crawford. 1993. Using a microwave oven to determine moisture in forages. Agricultural Publ. G3151. Available: <http://www.muextension.missouri.edu/explore/agguides/dairy/g03151.htm>.