Measuring the physical quality of pellets

BY THOMAS WINOWISKI

REVIEWED AND EDITED BY CHARLES STARK, ADAM FAHRENHOLZ, AND CASSANDRA JONES

The physical quality of pelleted feed may contribute to the production efficiency and well being of the animal, or it may simply be a cosmetic aspect that is important to the buyer. Regardless of the reason, when quality is desired there must be a way to measure it. Furthermore, this measurement should be possible to make as the feed is being produced and be predictive of how the feed will appear when it reaches the animal.

Durability

Pellet durability indicates the ability of the pellet to resist attrition during storage and transport. In the real world, pellets are lifted, dropped down chutes into empty bins, augured, blown, stacked in bags and every combination of the previously-listed actions. Every time a pellet rubs against a surface or impacts against an object there is potential for abrasion to occur. Numerous pellet durability methods have been used to predict how well pellets will withstand such trauma.

Mechanical tumbling

Early work in durability testing was done at Kansas State University. Dr. Harry Pfost developed a system to simulate normal handling conditions. Approximately 25 kg of pellets were loaded into a surge hopper, emptied into a 15 cm screw, conveyed one meter to a bucket elevator, lifted 2.5 meters and discharged back into the surge hopper. After recycling for 10 minutes, the feed was removed and the percentage of fines was measured (Pfost, 1962). Using this system, researchers were able to observe the effect of temperature, binders and die thickness on pellet durability.

Butler Manufacturing Company simplified this system into a single rotating chamber called the "KSU Tumbler" or "Tumbling Can." In this method, 500 grams of cooled, screened pellets are placed in a metal box with dimensions of 30 cm by 30 cm by 12 cm and containing a baffle 23 cm long, 5 cm wide and centered diagonally inside the box. This box, or can, is rotated at 50 RPM for 10 minutes, after which the pellets are removed and screened. The pellet durability index (PDI) is defined as the percentage of pellets surviving the test and retained on the screen (Pfost, 1976).

The KSU Tumbler often shows good correlation to the actual quality of pellets delivered to the animal. For example, fines in three different formulations of turkey finisher pellets were measured as the pellets moved to the farm. The different formulations were expected to result in different pellet qualities. This was born out by both the KSU Tumbler and the actual delivered fines (**Table 20-1**).

The first formulation was the standard corn/soya mix; in the second, 1% lignin sulfonate binder was added; in the third, 10% wheat displaced an equal amount of corn. The KSU Tumbler predicted 23.0%, 14.0% and 18.6% delivered fines for the three treatments, respectively. Actual measured fines were 21.3%, 9.7% and 15.1% (Winowiski, 1988).

Deviating from the standard KSU Tumbler method will change the results. Changing the RPMs usually results in less abrasion (i.e., higher PDI). Using a larger sample reduces abrasion (higher PDI) while a small sample increases abrasion (lower PDI). Steel hex nuts or ball bearings are often added to the tumbling chamber to increase the level of destruction. Any kind of loose added metal can be used for this purpose, but large 20 mm hex nuts are recommended. Smaller nuts are difficult to remove from the mass of pellets, and ball bearings tend to roll away. It should be noted that new hex nuts are more destructive than old ones, probably due to the sharpness of their corners.

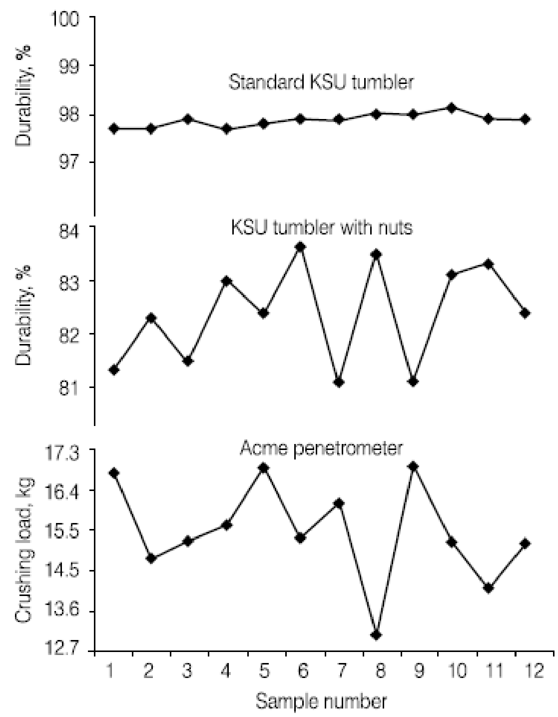
Table 20-1. Prediction of delivered fined in pelleted turkey diets according to the KSU Tumbler.

	Control	1% Lignin Sulfonate	10% Wheat
Pellet Durability Index	77.0 ± 1.3	86.0 ± 1.3	81.4 ± 1.3
Fines in Cooler, %	12.6 ± 2.9	7.8 ± 1.5	6.6 ± 1.0
Fines after Fat Application, %	18.7 ± 1.2	11.6 ± 1.2	16.0 ± 1.2
Fines after Trucking, %	22.2 ± 13.5	11.2 ± 1.9	17.2 ± 2.5
Fines from Farm Silo, %	21.3 ± 6.4	9.7 ± 1.3	15.1 ± 3.4

The standard KSU Tumbler method may work well for grain concentrate pellets that are expected to deliver with a fines content of 10% or more. However, when a grain concentrate is formulated for dairy cattle—where fines levels are expected to be below 5%—the KSU Tumbler may not be destructive enough to identify quality differences. It is still a useful tool to ensure quality product is shipped out to customers, but it often does not allow the level of discrimination that is needed for understanding the pelleting process.

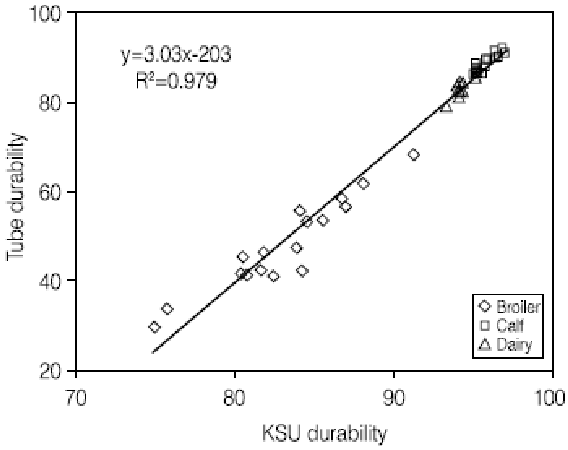
Figure 20-1 illustrates 12 samples that were tested first by the Standard KSU method and then returned to the tester for an additional 10 minutes of tumbling with four 20 mm hex nuts. What was a flat line for quality by the standard test shows differences between samples when nuts are added for extra abrasion. It is interesting that pellet hardness results measured on an Acme Penetrometer are a mirror imagine of the extended tumbling results. In this case, harder pellets tended to be less durable. The erratic response in this example is probably related to variation in the addition rate of molasses; high levels of molasses will cause a pellet to be soft, yet durable.

Figure 20-1. Comparison of three test methods for dairy pellets.



A variation of the KSU Tumbling Can is the "tube tester." Cylinders, either metal or PVC, are sealed on one end and fixed with a removable cap on the other. Sample size is usually 100 grams of screened pellets. Metal objects such as hex nuts are almost always added with the pellets. The tubes are rotated end-over-end at a speed appropriate to give maximum impact of the pellets at the bottom of the tube. Tube lengths range from 45 to 100 cm. Rotation times range from 10-20 minutes. One strong advantage of the tube tester is that it is simple and inexpensive to build. Also, multiple tests can be performed simultaneously, depending on the number of tubes employed.

Figure 20-2. Correlation between a Tube Tester and the standard KSU Tumbler.



This tube method has never been standardized by the industry, but it is an effective method and correlates well to the KSU Tumbler. For example, direct comparison between the standard KSU Tumbler and Tube Tester was made on 41 samples selected from either broiler, calf or dairy rations (**Figure 20-2**). In this case, the tube was 90 cm long, rotated at 20 RPM for twenty minutes and contained 100 grams of pellets with two 20 mm hex nuts. Even though a smaller sample size, extended tumbling time and inclusion of hex nuts made this tube tester more aggressive than the standard KSU Tumbler, correlation between the two methods was good (Winowiski, 1982).

Pneumatic tumbling

Pneumatic testers have also been used to measure pellet durability. In most cases, 100 grams of sieved pellets are tested. Thus, the weight of the pellets recovered at the conclusion of the test is the actual percent durability. Pneumatic testers generally offer the following advantages over mechanical tumblers:

- Automatic removal of fines requires less work;
- 100 gram sample eliminates percentage calculation;
- Shorter run time—usually 30 seconds or one minute;
- No exposed moving parts; and
- Quieter.

Possible short-comings of the pneumatic testers are that velocity or pressure of the airflow can affect the result, and this is sometimes not controlled. Also, pneumatic testers cannot be used for large pellets; 8 mm might be the practical maximum pellet diameter that could be used.

One of the earliest commercial pneumatic pellet testers was developed in England by John Payne of Holmen Bruk (Major, 1982). While the KSU Tumbler was spreading throughout the Americas, the Holmen Tester became the most popular durability tester in Europe, with very little overlap. Borregaard recently developed an improved pneumatic machine that is replacing both the Holmen Tester and, to some extent, the KSU Tumbler.

Table 20-2. Pellet durability index of various feeds according to analytical method.

Diet	KSU Box	KSU Modified Tumbling Box with Nuts	Holmen	Borregaard
Rabbit	98.4	96.5	96.5	97.7
Dairy, 18% CP	97.9	95.3	94.6	97.2
Dairy, 38% CP	96.7	91.0	90.2	9..6
Beef, 16% CP	96.1	91.6	89.0	94.0
Turkey Grower	94.7	82.0	84.6	87.2
Swine Starter	95.5	83.8	80.5	82.4
Broiler, 2% fat	89.1	68.2	68.5	64.9

Various testers were used to evaluate durability of of commercial feed (**Table 20-2**). All four methods identified rabbit pellets as the most durable and broiler pellets as the least. However, the Holmen, Borregaard and modified KSU were more effective at discriminating intermediate differences in quality versus the KSU without nuts. Correlation between all methods was high (Payne, 1997).

Hardness

Pellet hardness is sometimes measured, whether as an indication of physical integrity or to ensure the pellets are not too hard for the particular target animal. Pellet hardness is measured one pellet at a time, versus the tumblers which test hundreds of pellets at once. In order to get a reasonable average, it is necessary to test at least 10 pellets per sample. One problem that is difficult to overcome with hardness testing is the selection of the 10 pellets to be sampled. The very act of selecting these pellets biases the result.

Pellet strength will vary depending on what part of the die it is produced on. The center of the die often has a higher extrusion rate, less dwell time and more wear; pellets from this portion will be softer and less durable. On the average, more pellets come from the center rows of the die, but the longer and harder pellets that are produced on the outside of the die are more likely to be selected for testing.

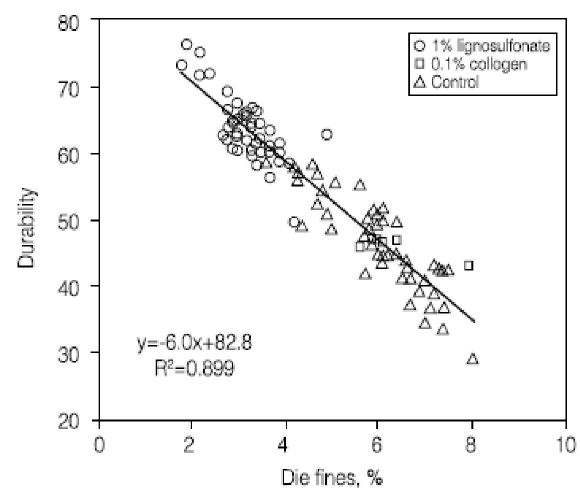
It is generally accepted that harder pellets will also be more durable. This may not always be true. Pellets that contain molasses tend to be soft but remain durable. Consider the difference between breaking a molasses versus a short bread cookie. The molasses cookie is softer, but when it breaks it produces almost no crumbs. High molasses pellets can be softer but have good durability because they generate few fines.

The first hardness testers were produced by Stokes and Pfizer. Currently the Kahl Hardness Tester is the most commonly used, but other devices such as the Acme Penetrometer can also be of service.

Fines

The amount of fines coming directly off the pellet mill can be a good indicator of pellet quality. Even the best pellets will have about 1% fines at this point. As quality declines, the amount of fines will increase. To test this, 100 samples of turkey grower and finisher pellets were collected directly off the die, cooled, weighed and fines removed over a US No. 6 Sieve (Winowiski, 1987). The fines were weighed and their percentage calculated. The screened pellets were then tested in a KSU Tumbler with two 20 mm hex nuts in each chamber. During the sampling period, temperature, fat and binder varied, producing a wide range of pellet durabilities. Correlation between fines and durability was good (**Figure 20-3**).

Figure 20-3. Correlation between fines in samples collected off the pellet mill die and pellet durability.



Size

Size does matter in pellet durability. Pellets tend to achieve a stable length that is about two to four times their diameter. Pellets that are shorter either lack physical strength or have been mechanically abused. One method of estimating quality is to weigh 10 grams of pellets, count the number of pieces and then calculate the average weight per piece. If a piece does not have a full diameter, do not count it.

Grain concentrate pellets of varying durability were tested by this method (Winowiski, 1995). Pellet weight was directly proportional to durability (see **Table 20-3**). Pellet length should not be used as a quality assurance method, but it does provide a first indication of quality when samples have similar handling histories.

Measuring length as pellets travel through the mill can also be useful in identifying problem areas where pellets are broken. A large difference between two sampling points may indicate that the pellets are being subjected to unusual mechanical stress in that segment.

Table 20-3. Pellet durability index vs. pellet size.

KSU durability	Holmen durability	Size (mg/pellet)
89.7	51.0	87
92.1	59.5	97
94.2	71.0	108
95.3	78.0	115

Water stability

Pellets for feeding shrimp require stability in water for extended times of one to three hours. High durability is required for good water stability, but durability alone is no indication of the longevity of a pellet once it is submerged in water. Two of the most important mechanisms that contribute to durability are hydrogen bonds and salt bridges. Both of these binding mechanisms release rapidly in water, allowing the feed particles to disperse. The fact that water stability can only be tested in water and that shrimp pellets are generally small makes quantitative testing difficult.

A quick subjective method is simply to put pellets in a beaker, add water and observe. Pouring this mixture through an appropriate sieve, drying, collecting and weighing the portion retained on the sieve would be one way to quantify submerged survivability. One problem with this method is that some feed ingredients expand when they absorb water and might be retained on the sieve even though they should be included in the disintegrated portion of the pellet. Sieve openings for collecting the surviving pellets should be slightly larger than the original pellet diameter.

Mistakes to avoid

Short pellets and fines don't travel far; they tend to sift toward the bottom of the pile and fill holes rather than rolling along the surface of a pile. This causes pellets to naturally segregate. Thus, pellets collected at the outside of a pile will generally have better durability than those in the center. This phenomena can be observed in coolers, trucks, bins and even sieves in the laboratory.

For example, if 1,000 grams of pellets are collected and sieved to remove fines before testing, pellets collected on the top surface will have a higher durability than those on the bottom. Longer, more durable pellets tend to "float" to the top. Pellets collected from the outside holes of a die will have higher durability than those from the middle due to less-aggressive extrusion conditions. Pellets collected from the sides of a cooler are likely to be more durable than those collected from the center because the long pellets tend to roll to the sides, while the short pellets remain in the center. Likewise, pellets collected from the sidewalls of a bin or truck will be longer and more durable than those collected in the center.

There are many good ways to test pellet durability. The primary consideration must be that the test correlates to the real world—i.e., a KSU Tumbler should not be used to predict submerged survivability of shrimp pellets. The second consideration should be simplicity; the test should be easy to conduct so that people will actually use it. Another factor to consider is that the method should be difficult for the user to bias. The testing equipment needs to be stable and provide consistent results. Finally, regular testing must be done to develop a data base for comparison.

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Mr. Thomas Winowiski is the Technical Applications Manager at Borregaard LignoTech USA, Inc.

This content was edited and reviewed by Dr. Charles Stark, Jim and Carol Brown Associate Professor of Feed Technology at Kansas State University, Dr. Adam Fahrenholz, Assistant Professor of Feed Milling at North Carolina State University, and Dr. Cassandra Jones, Assistant Professor of Feed Technology at Kansas State University.