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# Standard Specification for Developing and Validating Prediction Equation(s) or Model(s) Used in Connection with Livestock, Meat, and Poultry Evaluation Device(s) or System(s) to Determine Value[1]



## 1. Scope

1.1 This specification covers methods to collect and analyze data, document the results, and make predictions by any objective method for any characteristic used to determine value in any species using livestock, meat, and poultry evaluation devices or systems.

1.2 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory requirements prior to use.*

## 2. Referenced Documents

2.1 *ASTM Standards:*[2]

F2463 Terminology for Livestock, Meat, and Poultry Evaluation Systems

## 3. Terminology

3.1 For definitions of terms used in this specification, refer to Terminology F2463.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *accuracy, n*—statement of the exactness with which a measurement approaches the true measure for that characteristic; accuracy is contrasted with precision, which is concerned with the repeatability of the measurements. Therefore, with a large bias, a measurement may be of high precision, but of low accuracy.

3.2.2 *calibration data set, n*—data set used to develop the initial prediction equations; same as developmental or prediction data set.

3.2.3 *coefficient of determination, n*—percentage of variability in the response (dependent) variable that can be explained by the prediction equation.

$$R^2 = 1 - \frac{\sum(y - \hat{y})^2}{\sum(y - \bar{y})^2}$$

3.2.4 *root mean square error for calibration, n*—square root of the sum of squared residuals divided by $n_c - (k + 1)$, where $n_c$ is the sample size for the calibration data set, and $k$ is the number of explanatory variables in the prediction equation.

$$\sqrt{\frac{\sum(y - \hat{y})^2}{n_c - (k+1)}}$$

3.2.5 *root mean square error for validation, n*—square root of the sum of squared residuals divided by $n_y$, where $n_y$ is the sample size for the validation data set.

$$\sqrt{\frac{\sum(y - \hat{y})^2}{n_v}}$$

3.2.6 *validation data set, n*—the data set used to test the predictive accuracy of the equations developed from the calibration data set.

3.2.7 *value, commerce, n*—measure of economic worth in commerce.

## 4. Significance and Use

4.1 The procedures in this specification are to be used by all parties interested in predicting composition or quality, or both, for the purpose of establishing value based upon device or system measurements. Whenever new prediction equations are established, or when a change is experienced that could affect the performance of existing equations, these procedures shall be used.

## 5. Procedure

5.1 *Experimental Design:*

5.1.1 *Define the Population for Development of a Prediction Equation:*

5.1.1.1 To establish the predictive ability and validity of an equation(s) using measures (independent variables) from an

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

evaluation device or system, it is necessary to define the population on which the prediction model is intended to be used.

*(1)* The species on which measurements will be made must be defined.

*(2)* The population for scope of use must be clearly defined. This may include, but is not limited to, factors such as geographical location, gender, age, breed type, or any other factor that may affect the equation accuracy.

*(3)* The characteristic to be predicted must be clearly defined.

5.1.2 *Select a Sample Population for Development of a Prediction Equation:*

5.1.2.1 The sample size for the calibration data set must be at a minimum 10*k*, where *k* is the number of variables in the prediction equation, or 100 observations, whichever is greater. The sample size for the validation data set must be at least 20 % of the size of the calibration validation data set. For example, if the prediction equation has five explanatory variables, the calibration data set will require a minimum of 100 observations and the validation set must have at least 20 observations. These are minimal requirements; larger sample sizes are encouraged, keeping in mind that the calibration data set must be larger than the validation data set.

5.1.2.2 The sample size must be large enough to be representative of the population; otherwise the resultant equation will not be suitable for use in the population to which the equation will be applied. This may require a larger sample size than the minimal requirement in 5.1.2.1. When possible, it may be useful to refer to existing data sets that describe a particular population to ensure that the sample includes most of the variation in the population. For example, if one were developing an equation to predict yield grade in U.S. fed beef packing plants, one would want to make sure that the samples used to develop and validate the regression model encompassed most of the normal variation in yield grade, yield grade factors, and factors that might affect the accuracy of the model. In this example, the simple statistics of these characteristics in the calibration data sets should be compared to the simple statistics of these characteristics in references such as the National Beef Quality Audits. Users are encouraged to work with a statistician.

5.1.3 *Develop an Experimental Process*—A clearly defined process must be established and documented. That process, which includes consistent, repeatable methods, should be used to obtain the measurements under the same conditions in which the device or system would be expected to operate. In particular, the validity of the approach and the repeatability of the procedure must be documented and demonstrated. For many of the common characteristics to be predicted (such as percent lean), there are a number of reference methods commonly accepted within the discipline. Where accepted methods exist, they should be used and cited. Where accepted methods do not exist, a sound, science-based process of method development should be followed. Consideration should be given to sources of variation for the measurements and strategies to minimize any bias that may exist.

5.1.4 *Independent Third-Party Consultation*—After the experimental process has been established (but before initiation of the sampling), it is recommended that the users obtain an independent third-party consultation to review the procedures for compliance with the guidelines established in the previous sections. The consultation should focus on areas such as the number of samples, the sample selection protocol, and the project procedures to ensure that the process will allow the users to determine effectively the predictive ability and validity of the equation or model.

5.1.5 *Develop the Model or Equation:*

5.1.5.1 Collect data for the calibration (developmental) data set and develop the model or equation. Report the value of the coefficient of determination, $R^2$, for the calibration data set.

5.1.5.2 Describe the sample used to develop the model or equation. Calculate the simple statistics (standard deviation, mean, minimum, and maximum values) of the data set that was used to develop the prediction model (calibration data set—for example, see Table 1).

5.1.6 *Validation of Prediction Models or Equation(s):*

5.1.6.1 *Objective*—To demonstrate the validity of the initial prediction model or equation with a different sample.

5.1.6.2 Select a sample for validation of a prediction equation. A general recommendation is for the size of the validation data set to be 20 % of the size of the calibration data set. However, the sample must be large and variable enough to be representative of the population to which the equation or model will be applied (refer to the calibration data set statistics for guidance).

5.1.6.3 Collect data for the validation data set. In validation trials, data used to determine predicted values must be collected under conditions where the devices or systems will be used or as close to on-line as possible. Prediction equations must not be applied to populations whose range of relevant characteristics (independent and dependent variables or factors

**TABLE 1 Simple Statistics of Beef Carcass Characteristics for Calibration Data Set (*n* = 400)**

| Data Set | Characteristic | Mean | SD | Minimum | Maximum |
|---|---|---|---|---|---|
| Calibration | Hot carcass weight, kg | 351 | 41 | 227 | 460 |
| Calibration | Marbling score[A] | 505 | 106 | 250 | 1090 |
| Calibration | Preliminary yield grade | 3.07 | 0.58 | 2.1 | 5.5 |
| Calibration | Adjusted preliminary yield grade | 3.29 | 0.62 | 2.0 | 5.6 |
| Calibration | Adjustment of preliminary yield grade | 0.22 | 0.22 | -0.3 | 1.1 |
| Calibration | Kidney, pelvic, and heart fat, % | 2.08 | 0.69 | 0.0 | 4.5 |
| Calibration | Longissimus area, $cm^2$ | 90.2 | 11.3 | 53.5 | 135.5 |
| Calibration | Yield grade | 2.65 | 1.06 | -0.5 | 6.3 |

[A] 200 = Practically Devoid$^{0}$; 300 = Traces$^{0}$; 400 = Slight$^{0}$; 500 = Small$^{0}$; 600 = Modest$^{0}$; 700 = Moderate$^{0}$; 800 = Slightly Abundant$^{0}$; 900 = Moderately Abundant$^{0}$; 1000 = Abundant$^{0}$.

that affect the relationship between independent and dependent variables) is practically different from the range of those characteristics in the calibration data set.

5.1.6.4 Apply the model or equation from the calibration data set to the validation data set and evaluate the difference between the predicted and actual values. Report the coefficient of determination, $R^2$, for the validation data set.

5.1.6.5 The model or equation would be deemed valid if the root mean square error for validation is within 20 % of the root mean square error for calibration. The model or equation would be deemed invalid if the root mean square error from validation is greater than the root mean square error from calibration by more than 20 % of the root mean square error from calibration.

5.1.6.6 Describe the sample used to validate the model or equation. Calculate the simple statistics (standard deviation, mean, minimum, and maximum values) of the data set. These statistics define the bounds of the population to which the model or equation can be applied.

5.2 *Revalidation of Prediction Model(s) or Equation(s):*

5.2.1 *Potential Factors Influencing the Decision to Revalidate:*

5.2.1.1 One factor is the range of the independent variables or the prediction of the dependent variable used in the validation sample is practically different than the range in the current population ("practically different" can be defined as ten or more percent of the population measured fall outside the range of independent variables for the validation data set; users carry the burden of proof to demonstrate no practical change during the cumulative preceding 12 month period). This evaluation should be conducted at least annually and should encompass all relevant observations (observations in which the predicted value influenced seller payment) in the previous 12 month period.

5.2.1.2 A second factor is a device or system modification/change that practically affects at least one independent variable that causes a change that is greater than the established tolerance.

5.2.1.3 A third factor is a process modification/change that practically affects at least one independent variable that causes a change that is greater than the established tolerance.

5.2.2 *Determination of Appropriate Corrective Action:*

5.2.2.1 Compare differences in independent variable ranges or the predicted values to determine if a practical reason to revalidate exists.

5.2.2.2 Upon identification of a practical reason to revalidate, operators must initiate revalidation promptly and notify any appropriate government entity, if required.

5.3 *Documentation of Results:*

5.3.1 *Records:*

5.3.1.1 Users must maintain written records of the data, procedures, and test results used to validate or revalidate a prediction equation; these records must be maintained so long as they are the basis for the validation of a prediction equation or model in use.

5.3.1.2 Parties using prediction equations or models to determine value of livestock, meat, or poultry have a right to protect trade secrets, subject to applicable laws.

5.3.2 *Representations*—All representations or claims about the performance of a prediction equation or model must use terminology that is consistent with this standard, supported by available data, and based upon the procedures outlined above.

## 6. Keywords

6.1 coefficient of determination; model; prediction equation; revalidation; root mean square error; standard deviation; validation