Development of a Sampling Plan and Application of a Grading Scheme for Determining Apple Packout Losses

H.W. Hogmire¹, T.A. Baugher¹, and M. Ingle²
Division of Plant and Soil Sciences, West Virginia University Experiment Farm, Kearneysville, WV 25430

G.W. Lightner³
U.S. Department of Agriculture, Appalachian Fruit Research Station, Kearneysville, WV 25430

Additional index words. Malus domestica, culls, fruit, defects, packinghouse

Abstract. A sampling plan was developed and used along with a modified grading scheme as a tool to predict apple (Malus domestica, Borkh.) fruit quality, thus providing a means to evaluate the impact of orchard management practices on market potential. Apple extra fancy/fancy packout was predicted to within 10% by examining a 100-fruit sample from each of five bins at the submersion tank. Packout loss factors were predicted to within 5% by sampling 100 fruit from each of four bins. A modified Russo/Rajotte grading scheme in chart format proved to be a useful tool for assessing packout losses. An evaluation of downgraded fruit, comparing the grading scheme to grower practice, yielded coefficients of determination ranging from 0.83 to 0.94 for five of six fruit lots sampled. The grower’s marketing intentions and the tendency of packinghouse staff to give more attention to the most obvious defects during grading influenced the ability to predict packout and the severity of loss factors.

Increased production and market competition have focused attention on fruit quality as a key component affecting the profitability of commercial apple orchards. Growers must be able to identify the factors that reduce packout and know how they impact returns to make wise management and marketing decisions for each orchard block.

Both field and packinghouse studies have been conducted to determine the factors responsible for apple packout losses (Bahn and Morin, 1980; Bahn et al., 1981; Gerling, 1984; Weires, 1984). In the packinghouse studies, economic losses were calculated based on an examination of all downgraded or culled fruit. Data based only on downgraded or culled fruit, rather than fruit examined before grading, are subject to variability that is influenced by the number and efficiency of packinghouse staff and the marketing intention of the grower. In addition, where a combination grade is packed, losses due to the difference in return between extra fancy and fancy grades would not be accounted for by limiting evaluation to downgraded or culled fruit.

To facilitate better marketing decision-making, it would be advantageous if growers could predict fruit packout for a given orchard block before placement in storage, and without the expense involved of operating the grading line. Identifying loss factors would also enable one to evaluate and improve upon field operations. Using U.S. grade standards (USDA Agricultural Marketing Service, 1972), and inspection procedures (USDA Agricultural Marketing Service, 1978), Russo and Rajotte (1983) organized the factors affecting fruit quality into a chart format to determine packout and assess the impact of management decisions on the market grade of fruit.

Limited information is available to indicate the sample size required or the method of sampling to accurately predict fruit packout. In a North Carolina study (Proctor and Shaffer, 1983), the number of trees that should be sampled per block was 1.8 times the cube root of the total number of bearing trees in the block. A sample size of at least 1% (USDA Agricultural Marketing Service, 1978) and 6% (Johnson et al., 1967) of the containers of fruit has been recommended to estimate fruit quality. Johnson et al. (1967) reported on the sampling of bulk bins through a port installed in the side for obtaining a representative sample.

The primary objective of this study was to develop a plan for sampling fruit before packing to assess loss factors and determine the market potential of fruit. The secondary objective was to apply a theoretical grading scheme (Russo and Rajotte, 1983), which is based on USDA grade standards, as a tool to predict apple packout.

Two lots of ‘Delicious’ apples were sampled from each of three major packinghouses in West Virginia from Dec. 1986 to May 1987. The six lots ranged from 12,000 to 38,000 kg in weight. A lot of fruit came from a single orchard block and was packed during a single run. Samples of 100 fruit were randomly collected from the packinghouse line and placed in padded 20-kg crates. Bruised fruit were separated from unbruised fruit to eliminate the possibility of measuring damage that could occur from experimental handling. The samples were transported to the WVU Experiment Farm (3 to 30 km) immediately following collection and the apples were sized and evaluated for defects within 48 hr.

Individual apples were evaluated for external defects and color using a modified grading scheme (Russo and Rajotte, 1983). The Russo/Rajotte scheme uses current USDA grades and standards (USDA Agricultural Marketing Service, 1972), but is more quantitative. The grading scheme consists of a score chart with all possible defects listed vertically on the left and a 1 to 10 rating, corresponding to units of defects measured, arranged horizontally across the top. The interception of each defect and rating is marked by a box that is coded (by shading) to indicate the sample size required or the method of sampling to accurately predict fruit packout.

Table 1. Means and standard deviations of apple defects and grades determined in optimum sample size study.

<table>
<thead>
<tr>
<th>Characteristics considered for sample size formula (%)</th>
<th>Mean (%)</th>
<th>SD (σt)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Defects</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scald</td>
<td>16.7</td>
<td>4.8</td>
</tr>
<tr>
<td>Bruises/abrasions</td>
<td>5.9</td>
<td>4.2</td>
</tr>
<tr>
<td>Limb rubs</td>
<td>5.7</td>
<td>6.1</td>
</tr>
<tr>
<td>Tarnished plant bug scares</td>
<td>5.0</td>
<td>4.3</td>
</tr>
<tr>
<td>Grades</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Extra fancy/fancy</td>
<td>60.6</td>
<td>10.4</td>
</tr>
<tr>
<td>US #1</td>
<td>2.8</td>
<td>2.7</td>
</tr>
<tr>
<td>Utility</td>
<td>23.0</td>
<td>10.2</td>
</tr>
<tr>
<td>Cull</td>
<td>13.6</td>
<td>7.5</td>
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</tbody>
</table>

¹Associate Professor.
²Professor.
³Computer Specialist.

Received for publication 22 Feb. 1988. Approved for publication by the Director, West Virginia Agr. and For. Expt. Station as Scientific Article No. 2098. We thank Sandra Walter, Larry Crim, Dixie Gaynor, Mervyn D’Souza, Jim Kotecon, and the grower cooperators for their contributions to the study. The cost of publishing this paper was defrayed in part by the payment of page charges. Under postal regulations, this paper therefore must be hereby marked advertisement solely to indicate this fact.
Fig. 1. Defects sorted out by grower compared to defects determined with modified Russo/Rajotte theoretical grading scheme (X ± se of the mean). Coefficients of determination are significant at the 0.05 level in all but A-1. A, B, C = packinghouse; 1, 2 = fruit lot. Defects: 1 = form; 2 = color; 3 = scald; 4 = punctures; 5 = water core/sun scald; 6 = russetting; 7 = old cuts, stem pulls; 8 = abrasions, dents; 9 = bitter pit/lenticel spot; 10 = cork spot; 11 = bruising; 12 = limb rubs; 13 = tufted apple budmoth; 14 = tarnished plant bug; 15 = blister spot.

cate the appropriate USDA grade. The scheme was modified for this study to facilitate recording the cause in addition to the type of defect. Also, the chart was computerized, and information on each fruit was directly recorded on a DataMyte 1000 Data Collector (DataMyte Corporation, Minnetonka, Minn.) and later downloaded to a computer. If an apple had multiple defects, the two most obvious were scored.

These basic steps for collecting and evaluating samples were followed in the two experiments described below. The experimental design was completely randomized.

The first experiment was conducted at one of the three packinghouses to determine optimum sample size needed for accurate representation of a single lot of fruit. Based on USDA inspection recommendations (USDA Agricultural Marketing Service, 1978) and research by Johnson et al. (1967), we selected 100 apples per bin as a sampling unit and sampled 10 bins. Each 100-apple sample was randomly collected from the bin submersion tank (located at the beginning of the packing line) with a nylon net. As a bin was submerged in the tank, apples floated to the surface and randomly into the net. Four net scoops of 25 to 30 apples, representing fruit from throughout the tank, were gathered from randomly selected bins to obtain the 100-apple sample.

The selection of optimum sample size was based on 95% confidence limits on the means of important percentage defects and grades. An equation developed by Snedecor and Cochran (1968) for determining optimum sample size was used. Since the objective was to determine the sample size that would be most representative but with least associated research cost and grower inconvenience, values inserted in the equation were selected on this basis.

In a second experiment, the application of the modified Russo/Rajotte grading scheme was tested by sampling fruit at two different times from each of three packinghouses (A-1, A-2, B-1, B-2, C-1, C-2) with distinctly different management practices and market outlets. Data from C-1 served a dual purpose in this and the optimum sample size study.
Fruit was sampled at the submersion tank as in the first experiment, using a sample size of five. A second set of samples was collected from each of the same bins at the conveyor leading from the grading belt to the number 1 (downgraded) packing line. The modified Russo/Rajotte interpretations of the grade standards were regressed against those of the packinghouse staff.

Comparisons between the modified Russo/Rajotte scheme and grower packinghouse records were also made. Standard deviations were determined on the mean differences between percent extra fancy/fancy packouts. After the initial sampling, it was decided that basing percent packout on weight rather than fruit count might improve the grade correlations. Determining weights also has the advantage of developing correlations between defects and fruit size.

For the purpose of determining the optimum number of samples to collect from the bin submersion tank, means of extra fancy/fancy grade, and bruises/abrasions defects were calculated, and the following equation, modified from Snedecor and Cochran (1968), was used: 

\[ n = \left( \frac{\sigma^2}{L^2} \right) \]

where \( n \) = unknown sample number, \( L \) is for 95% confidence level on the mean of the 10 samples (2.228), \( \sigma \) is the standard deviation on the mean of the 10 samples, and \( L \) is the predetermined allowable error in the sample mean. (The Snedecor and Cochran formula uses \( \frac{1}{n} \) but we substituted \( \frac{1}{\text{sample}} \) since it was known.)

The mean for bruises/abrasions was 5.9% and the SD was 4.2 (Table 1). With an L of 5%, \( n \) was found to be four samples. The mean for extra fancy/fancy grade was 60.6% with a SD of 10.4. With an L of 10%, which was considered to be a reasonable error because of the flexibility in interpreting the grade standards, \( n \) was five samples. Based on these results, five samples of 100 fruit were selected as the optimum sample size per lot. The sample size equation was subsequently applied to the other lots of fruit sampled in the second experiment, and the results were similar.

A comparison of defects, as determined with the Russo/Rajotte grading scheme vs. grower practice, yielded significant \( r^2 \) values at the 0.05 level (0.83-0.94) in five of six fruit lots sampled (Fig. 1). The poor coefficient of determination in the first lot of fruit sampled (A-1) was primarily due to inexperience in working with the grading scheme. Variability between defects sorted out by the grower and defects determined experimentally was partially due to differences in grading of obvious vs. less obvious defects. For example, in B-2 (Fig. 1), the grower found a higher percentage of obvious defects such as bitter pit, bruising, and tufted apple bud-moth injury, but a lower percentage of the less obvious defects such as poor color, scald, and russetting. This is to be expected when considering the nature of the grading process. Fruit is exposed to view for a relatively short time while moving on a conveyor. Insect and mechanical damage, which usually result in a physical alteration of the fruit surface, are more likely to catch the attention of packinghouse staff than those subtle defects such as color and scald, where a quick judgment is more difficult to make.

Except for A-1 and C-2, the modified grading scheme was within 10% in predicting actual extra fancy/fancy packout (Fig. 2). The larger difference between actual and predicted packout in A-1 was due to inexperience with evaluation techniques and in C-2 was mainly due to variable grading of blister spot, a less obvious defect that was present on many fruit (Fig. 1). Whether or not grower packout was higher or lower than predicted packout was sometimes related to market intentions. Growers make adjustments in packing criteria to meet the requirements of specific markets. An example was the varying interpretation of USDA grades by grower A in lot 1 vs. 2 (Fig. 2). The first truckload of fruit was packed for a super-midsize chain with moderate quality standards, while the second load was packed for a chain known for high standards.

Percentage packout was not significantly affected by calculation on a weight vs. a count basis. Correlations were observed (0.05 level), however, between fruit weight (size) and two defects, Limb rub was correlated with large fruit, and scald was associated with small apples.

By using the modified Russo/Rajotte grading scheme to evaluate a 100-fruit sample from each of five bins, growers could predict fruit defects to within 5% and packout to within 10%. The ability to make these predictions before grading has some important advantages. The grower could determine whether or not it would be profitable to operate the grading line for a specific load of fruit. Information gained would be useful in protecting storage and marketing decisions. By identifying defects, growers could begin making adjustments in management strategies to reduce potential losses the next season, or might even be able to reduce similar losses in later-maturing cultivars yet to be harvested. The sampling plan and grading scheme would also serve as a useful tool for evaluating the impact of integrated orchard management practices on fruit quality. By providing a feedback mechanism that links field operations to market potential, this tool could increase the profitability of fruit production.

**Literature Cited**


