A MODEL FOR X-RAY INSPECTION ECONOMICS IN VIDALIA ONION PACKING HOUSES

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Inadequate segregation of diseased onions prior to controlled atmosphere (CA) storage spells huge economic losses to the Vidalia onion grower-handlers. Suppliers, for example, lost from as much as 10-20% (Purvis et al., 2002) to 50-70% of their CA-stored onions due to Botrytis neck rot (Boyhan & Torrance, 2002). There are about 125 million pounds of onions that can be put into CA storage annually (University of Georgia College of Agricultural and Environmental Sciences, 2001). While there are no economic estimates found in literature for disease-related losses at the retail level, Sumner et al. (2001) has indicated that bacterial soft rot and various mold rots, indicative of poor handling practices, could also manifest at the terminal or retail markets.

The virtually undetectable progression of these pathogenic diseases and the premium placed by customers on quality highlight the importance of adopting a more stringent inspection method in packinghouses. The use of X-ray imaging inspection technology, while well-studied in its potential to offer better product quality control, has remained nonexistent in the Vidalia onion industry.

A project, then, has been proposed to develop a model that would simulate the incidence, detection and removal of internally damaged onions as the commodity moves from the field to the packinghouse. The results of the simulation model would enable suppliers to assess the costs and benefits of this technology under varying agronomic, operational and market environment realities. While this proposed project may be limited only to assessing packinghouse level impacts, it is recognized that the adoption of the technology will have economic implications beyond the packinghouse. The development of an integrated model incorporating the distribution and sales systems would be necessary to provide a more accurate assessment of the technology's full impact on the Vidalia onion industry.

Objective
The overall objective of this project is to assess the likely impact of adding an X-ray imaging technology on the profitability of an onion packinghouse. To achieve this end, 2 models will be developed. The first model will simulate the movement of onions from the field to the packinghouse, focusing primarily on internal damage incidence, detection and removal. The second model will utilize the results of the previous one to give an economic assessment of the inspection technology.

1 Graduate Student and Professor
Materials and Methods

Freshly harvested onions from 4 cultivars covering early, mid- and late season maturity categories were obtained from the Vidalia Onion and Vegetable Research Center in Lyons, Georgia. Polar and equatorial diameters and the weight of each onion were measured and resulting data were fitted to theoretical probability distributions. Statistical tests, such as the Chi-Square and Kolmogorov-Smirnov tests, were conducted to determine goodness of fit.

These onions were passed through an X-ray linescan inspection unit. All onions were placed on the belt conveyor with a consistent orientation (x-ray beam will be collinear with the root-shoot axes of the produce). Visual evaluation of X-ray images for the presence of distinct features indicative of defects, as described in the literature, will be done to assess the internal quality of the onions. Defective onions were removed from the system and were quartered to verify if a defect is indeed present. Quartering involved cutting the onion across its equatorial diameter and then halving along its neck-root axis. This method, according to Tollner (2004), provides a more stringent evaluation of disease or damage incidence. The performance of the X-ray inspection unit was measured in terms of hit, miss, false alarm and correction rejection rates.

The results of these preliminary steps, which include the fitted statistical distributions of bulb size and mass for the 4 onion cultivars (Sugar Belle, Sweet Vidalia, Savannah Sweet and Pegasus) measured, as well as the X-ray inspection unit performance measures, are presented in the succeeding page.

Actual packinghouse studies will also be conducted. Other parameters necessary in the development of the model will be measured or estimated using published or field sources. Among those that will be measured include (a) number of onions entering a packinghouse per unit time, (b) size and weight distribution of these onions, (c) probability of external damage rejection, (d) probability of internal damage incidence, and (e) false alarm and error rates of the X-ray machine. Those that will be estimated include: (a) probability of bruise damage in packinghouses, (b) field production cost, (c) packinghouse cost, and (d) market price.

The results of the simulation model will be used to assess the costs and benefits of adding an X-ray machine under varying field, packinghouse and market conditions. Results will be reported on a per cultivar basis. The simulation model will be developed using the ARENA, a discrete-event simulation modeling and analysis software.
Preliminary Results

A. Statistical Distributions

1. Mass (All 4 Cultivars)

Distribution Summary

<table>
<thead>
<tr>
<th>Distribution</th>
<th>Expression</th>
<th>Square Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beta</td>
<td>57 + 684 * BETA(1.89, 3.43)</td>
<td>0.000904</td>
</tr>
</tbody>
</table>

Chi Square Test

- Test Statistic = 16.2
- Corresponding p-value = 0.642

Kolmogorov-Smirnov Test

- Test Statistic = 0.0312
- Corresponding p-value > 0.15

2. Minimum (Equatorial) Diameter (All Cultivars)

Distribution Summary

<table>
<thead>
<tr>
<th>Distribution</th>
<th>Expression</th>
<th>Square Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Triangular</td>
<td>TRIA(45, 95.6, 131)</td>
<td>0.001948</td>
</tr>
</tbody>
</table>

Chi Square Test

- Test Statistic = 35.6
- Corresponding p-value = 0.0352

Kolmogorov-Smirnov Test

- Test Statistic = 0.022
- Corresponding p-value > 0.15

B. Internal Damage Detection

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>X-ray Inspection Performance Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Hit Rate, %</td>
</tr>
<tr>
<td>Sugar Belle</td>
<td>87.50</td>
</tr>
<tr>
<td>Savannah Sweet</td>
<td>100.00</td>
</tr>
<tr>
<td>Sweet Vidalia</td>
<td>96.43</td>
</tr>
<tr>
<td>Pegasus</td>
<td>97.39</td>
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</tbody>
</table>

Citations


