IDENTIFICATION OF FEASIBLE GRADING SYSTEM IMPROVEMENTS USING SYSTEMS ENGINEERING

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ABSTRACT. *Systems engineering was used to identify peanut grading system needs, establish requirements, and compare proposed solutions that meet consensus specifications established by all industry segments. Previous attempts to change the grading system were hindered by difficulty in getting all segments to agree on proposed changes. The systems engineering approach overcame this obstacle. Four proposed systems that will improve the current system while meeting all industry requirements are at various stages of the technology transfer process. The improvements included in these proposed solutions are: (1) high moisture foreign material identification, (2) measuring moisture during sampling, (3) measuring single kernel moisture, and (4) grading larger samples with an automated sample cleaning, shelling, sizing, and data collection system. Each of these improvements help ensure that consumer demands for quality are met without unfairly burdening any one segment of the peanut industry. Technology exists to implement other solutions such as objective damage detection, improved sampling, or aflatoxin measurement. However, resource or performance limitations presently prevent their implementation.* ***Keywords.*** *Peanuts, Grading, Systems science, Inspection.*

Domestic and foreign consumer demands for food quality intensify as consumers focus on potential quality problems, and as they expect an increasingly wholesome and consistent food supply. Peanuts are no exception. Particularly, potential quality problems such as aflatoxin, foreign material, and off-flavor, threaten both export and domestic markets. Thus, quality measurement procedures must accurately reflect true quality of the lot marketed so subsequent processing and handling results in only high quality peanuts reaching consumers. Besides determining value, quality measurements give the seller information on the growing, harvesting, handling, and storage practices that lead to a specific quality level. The seller may use this information to adjust any of these practices to improve peanut quality for marketing subsequent lots. Quality measurements give the buyer information so subsequent handling and processing results in peanut products that meet or exceed consumers' quality expectations.

The current grading system for farmer-marketed or farmers' stock peanuts has remained essentially unchanged since the 1960s. Requests to improve the system have come from such peanut industry associations as: the National Peanut Council, which includes farmer, sheller, manufacturer, and regulatory representatives; the Federal-State Inspection Service (FSIS), which oversees peanut grading; the Peanut Grading Working Group, which includes representatives of all segments of the peanut industry and provides direction and critique of grading research; the Peanut Administrative Committee, which administers the marketing agreement for peanuts; and the Southeastern Peanut Association, which includes shellers in the southeastern United States. Requested improvements include: eliminate inspector subjectivity; reduce labor required; reduce inspection costs; provide foreign material piece count and identification by type; ensure the sample accurately represents the load; provide a system of premiums or penalties based on grade factors to encourage proper practices such as growing, harvesting, storage, etc.; and measure levels of naturally occurring or applied chemicals. All these changes are requested by the peanut industry as part of their plan to address short and potential long-term consumer concerns, while returning a fair profit to all segments of the peanut industry. The objectives of this article are to identify specific problems with the farmers stock grading system as identified by the peanut industry, prioritize the grading system figures of merit, report industry requirements that proposed solutions must meet, and report specific solutions to these problems.

THE CURRENT SYSTEM

Farmers' stock and shelled stock peanuts are inspected under both federal and state supervision (USDA, 1990). Approximately 600,000 lots of peanuts are inspected each year at about 500 locations throughout the peanut belt which stretches from Arizona to Florida to Virginia. The FSIS employs about 2,000 temporary inspectors to grade these lots during the harvest season from August to November. Equipment used in the inspection process, and inspectors' salaries are provided by the person buying the peanuts. The grade quality factors are percentages of: foreign material (FM), debris such as sticks and rocks; loose shelled kernels (LSK), kernels shelled by harvesting and handling before marketing; moisture content (MC);

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sound mature kernels (SMK), undamaged edible kernels: sound splits (SS), edible kernels split in half during shelling; damaged kernels (DK), kernels discolored by freezing, insects, or molds like *Aspergillus flavus*; other kernels (OK), small inedible kernels; hulls; extra large kernels (ELK), found only in Virginia-type peanuts; and fancy pods, large pods from Virginia peanuts only.

The farmers' stock grading process begins with sampling 5 to 20 random locations within a 4540 kg (5 ton) to 18 160 kg (20 ton) lot using a pneumatic sampler, producing two 1.8-Kg (4-lb) samples (fig. 1). One sample is graded and the other held as a check. Both FM and LSK are removed from the grade sample and a percentage of each is determined by hand calculation. Penalties are applied for FM more than 4%, and lots with more than 10.49% must be cleaned and resampled before marketing. Penalties are about $1/% FM and cleaning costs are about $15/ton. The LSK receive oil stock price which is about 1/6th of edible stock price. Whole pods from the cleaned sample are reduced to a 500 g subsample which is pre-sized to improve shelling efficiency. After shelling, the kernels are sized on a screen shaker and sampled for moisture content. Moisture above 10.49% requires the lot to be further dried and subsequently regraded.

In the sizer, the kernels are separated into three fractions: kernels which ride a 6.4 mm (0.25 in.) × 19 mm (0.75 in.) slotted screen (+16s), kernels which fall through the screen (−16s), and split kernels. The proportion of each category is hand calculated.

The −16s are not edible and receive the oil stock price. The +16s and the splits are visually inspected to determine the percent of discolored, or damaged, kernels. All kernels, including LSK, are examined for visible *A. flavus* (VAF) which is an indirect indication of aflatoxin (AT), a suspected carcinogen. Detection of *A. flavus* on any kernel in the sample rejects the entire lot. The farmer has the option of accepting oil stock price for this lot or withholding it from market and using the peanuts for seed or other nonfood purposes. Once grade, or percentage of edible and inedible material, is determined and the peanuts are purchased, the lot is placed in aerated storage and subsequently shelled and processed into edible products or crushed for oil, depending on grade. Lot value is calculated from the grade percentages using a price chart. All SMK, SS, LSK, and OK add value to the lot; whereas excessive MC, SS, FM, and DK result in penalties.

Problems with the Current System

Research and industry experience show errors associated with the current peanut quality measurement system, as with any commodity grading system, are due to sampling, equipment, and human inaccuracies. Inaccuracies can cause over- or underpayment to the seller, improper segregation of the peanut lot, or inaccurate grade information supplied to the buyer. Dowell (1992), Dickens et al. (1984), Davidson et al. (1990), and Whitaker (1991) reported coefficient of variation (CV) values for all grade factors. Some sampling error is caused by the abrasive action of the pneumatic sampler shelling pods during the sampling process (Dickens, 1964; Davidson et al., 1990). The kernels from the shelled pods are then classified as LSK and the hulls from the shelled pods are classified as FM. Post sampling errors are from

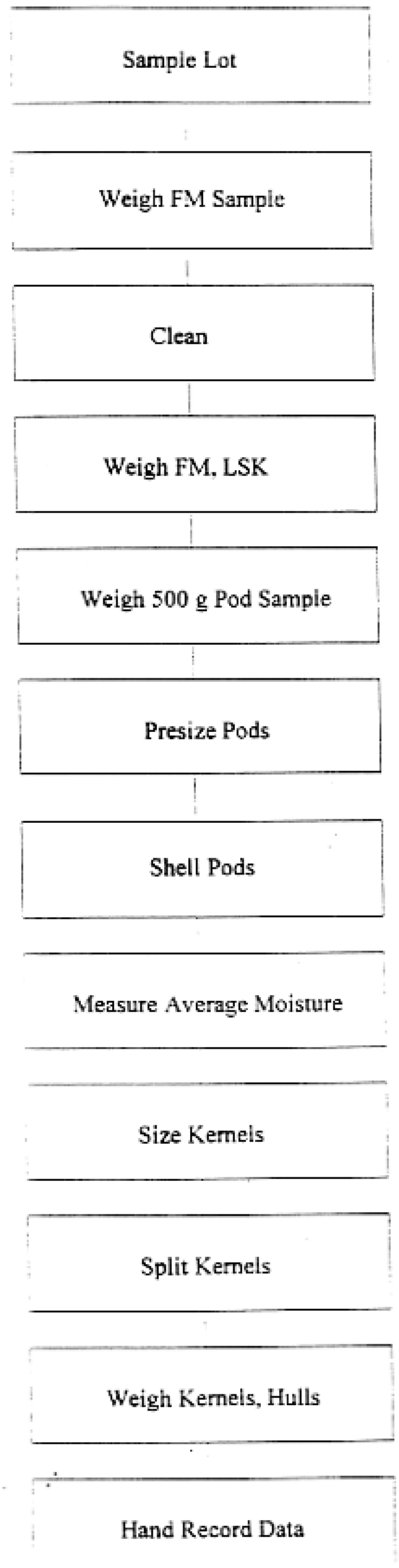

Figure 1–Current farmers stock grading system.

human and equipment inaccuracies which include sizing kernels, measuring moisture (Dowell and Lamb, 1991), determining damaged kernels (Dowell, 1990), measuring split kernel out-turns (Davidson et al., 1990), and determining aflatoxin.

The current farmers' stock grading equipment requires considerable additional hand cleaning and shelling from the inspector. The feeding mechanism of the sample cleaner loses some dirt during the cleaning process, biasing the sample. Small pods fall through the sheller grate, requiring hand shelling of these small pods. Consequently some inspectors, especially when under time pressure, may select only large pods to be shelled. This reduces hand shelling and sample processing time but biases the sample. Screens for the kernel sizer can be out of tolerance and shakers improperly set, causing inaccurate large and small kernel counts. The current system requires inspectors hand record and calculate grade factors. The allowable tolerance, or amount of sample that can be lost, for sample accountability is 5 g (0.01 lb), based on a 500 g (1.1 lb) sample size. If this tolerance is not satisfied when adding all fractions of the graded sample, regrading is required. Due to time constraints, some inspectors may use a slightly larger sample size to ensure the tolerance is met if some of the sample is lost, however, this results in an overestimation of some grade factors.

Inability of the current grading system to accurately detect aflatoxin has been targeted by several industry segments and documented by several researchers (Dowell et al., 1992; Tsai et al., 1989; Davidson et al., 1984; Dickens and Welty, 1969; Dickens and Satterwhite, 1971; National Peanut Council, 1989). These researchers showed that the current VAF method is subjective and less accurate than chemical testing. They showed 2 to 30% of tested lots were incorrectly accepted while containing aflatoxin, and 1 to 30% of tested lots were incorrectly rejected. A more accurate test for aflatoxin than the VAF method is needed.

Although the technology exists to improve the grading system, any proposed changes must meet specific industry requirements including: cost, time, labor, and accuracy. Perhaps the biggest obstacle to implementing any proposed change is the need for approval from all segments of the industry, from farmers to manufacturers. Any segment can veto a change if it might adversely affect that segment. For this reason, a systems engineering approach (Wymore, 1993) was used to determine exactly what each industry segment expected from the grading system and what each segment was willing to pay or sacrifice for grading system changes. Systems engineering is defined by Wymore (1993) as the intellectual, academic, and professional discipline, the principal concern of which is the responsibility to ensure that all requirements for a bioware/hardware/software system are satisfied throughout the life cycle of the system. Many past efforts to change the grading system have failed primarily because at least one industry segment did not have adequate input into the proposed change and felt it would shoulder a disproportionate cost for benefits received. This article reports solutions which adhere to the requirements established by all industry segments.

Grading System Requirements

Determining exactly what each industry segment expects from the peanut grading system has been more difficult than developing solutions. In general, industry members agree that grading must accurately measure quality with minimal cost and within the time constraints dictated by marketing conditions. Considerable time was spent interviewing representatives of all industry segments to precisely define terms like "accurately" and "minimal", and reduce needs to specific measurable and mutually agreeable requirements. The performance (PERF), utilization of resource (U/R), and tradeoff (T/O) requirements developed to precisely quantify these terms are presented below.

Performance Requirements

- The proposed system should not be less accurate than the existing system. The CV (Steele and Torrie, 1980) will be used to compare accuracy. The CV is the sample standard deviation divided by its mean. More variation between samples from the same lot produces a higher CV; smaller sampling, human, and equipment errors produce a smaller CV. For a proposed solution to be acceptable, the CV should not increase for any single grade factor or price/ton. Dowell (1992), Dickens et al. (1984), Davidson et al. (1990), and Whitaker (1991) all reported CVs of about 20, 20, 2, 2, 25, 13, 43 and 2% for FM, LSK, SMK+SS, SMK, SS, OK, DK, and $/ton, respectively.
- The complete sample processing time of the proposed system should not be slower than the present system. From cleaning to final certificate generation, the present system processes a sample in about 20 min. However, when samples are staged throughout the grading system, a sample is completed about every 6 min (National Peanut Council, 1990). The improved system must complete a sample every 6 min or less to prevent slowing down the harvesting and marketing process.
- The system must not decrease inspector safety. Levels of 0.5 micron (0.2×10^{-6} in.) dust particles in grading rooms cannot exceed 90,000 particles per minute (Dowell, 1989). About 41 grading related injuries occur per year with the present system, with an average claim of about $1,114. An acceptable new system must have dust levels and injury costs below these levels.

Utilization of Resources Requirements (U/R)

- Resources required, such as money and personnel, should not increase. The current equipment costs are: pneumatic sampler, $30,000; sample divider, $2,000; sample cleaner, $1,500; pod presizer, $1,250; sample sheller, $1,900; kernel sizer, $700; kernel splitter, $2,250; moisture meter, $3,150; scale, $1,200; and microscope, $525. Equipment for a new system should not cost more than the equipment it replaces.
- The proposed system should not require more maintenance than the present system. Main-

tenance of the present equipment costs about $1,000/year and requires about 20 h of service per year.

- Depending on the state, the labor cost for inspection is $4 to 5/sample. The improved system should not require more skill, higher labor cost, or more labor than the present system. Currently there are about 500 buying points employing about 2,000 inspectors. Any proposed system improvement should reduce the total number of inspectors.
- The proposed system should reduce the number of procedures prone to inspector error. Presently, inspectors hand record 24 numbers and hand calculate 14 percentages per sample. Previous research (National Peanut Council, 1988) showed that 10 to 25% of all grade certificates (FV-95s) have illegible data, calculation errors, or missing data, and 2 to 17% of these cause a change in dollar value of the load.
- The proposed system should not reduce the supply of edible peanuts through factors like segregating too many lots, which removes peanuts from the edible market. The percentage of each year's crop determined unfit for edible products (SEG III) varied from 0.5% in 1982 to 9.12% in 1990 due to environmental conditions.

Table 1. Weights for performance (PERF) and utilization of resources (U/R) figures of merit (FOM)*

PERF FOM	Weights
1. Provide Accurate Grade Information	
1.1 Measure sound mature kernels accurately	0.08
1.2 Measure aflatoxin accurately	0.06
1.3 Measure damaged kernels (DK) accurately	
1.3.1 DK weight by type	
1.3.1.1 freeze: fungal-	0.0018 ea†
1.3.1.2 insect, curing, concealed, other	0.0006 ea
1.3.2 Detect presence of DK	
1.3.2.1 freeze; fungal	0.0054 ea
1.3.2.2 insect, curing, concealed, other	0.0018 ea
1.3.3 Total DK weight	0.036
1.4 Measure foreign material (FM) accurately	
1.4.1 FM piece count	
1.4.1.1 nut grass; johnson grass	0.0064 ea
1.4.1.2 sticks; rocks; gherkins; glass; corn	0.00064 ea
1.4.2 FM weight by type	
1.4.2.1 dirt	0.0032
1.4.2.2 sticks; rocks; gherkins; glass; corn;	0.00016 ea
1.4.3 FM total weight	0.008
1.4.4 Detect presence of FM	
1.4.4.1 high moisture FM (4 types); metal; glass; lg. rocks	0.0012 ea
1.4.4.2 nutgrass; johnson grass; corn; wood	0.0006 ea
1.4.4.3 sticks; small rocks; dirt; hay; leaves	0.00024 ea
1.5 Measure Loose Shelled Kernel Accurately	0.04
1.6 Measure Moisture Content (MC) Accurately	
1.6.1 MC average	0.024
1.6.2 MC range	0.012
1.6.3 MC zone	0.004
1.7 Measure Sound Splits (SS) Accurately	0.02
1.8 Measure Pesticide Residue Accurately	
1.8.1 Lasso	0.007
1.8.2 Temik	0.005
1.8.3 Kylar; total use by type	0.003 ea
1.8.4 Other	0.002
1.9 Measure Other Kernels (OK); Hulls; Extra Large Kernels; Fancy Pods; Peanut Type Accurately	0.008 ea

Tradeoff Requirements

Tradeoff requirements objectively define how PERF requirements of competing concepts will be traded off against U/R requirements, if one system scores better in PERF and the other scores better in U/R. In the peanut grading system some of the PERF requirements are mandatory; however, all of the U/R requirements can be traded off against each other. For example, a proposed system which decreases inspector safety will not be accepted, regardless of the benefits. However, equipment costs, or other costs or resources, can increase provided this increase is offset by something else like a decrease in maintenance cost or an increase in value added to the peanuts. The following tradeoff formula was used:

$$\text{Tradeoff score} = [\,(\text{PERF score} + \text{U/R score}) + 2\,(\text{PERF score} \times \text{U/R score})\,]\,/\,4 \qquad (1)$$

This formula penalizes proposed solutions scoring exceptionally well in one area but scoring poorly in others. A score of 1 reflects an ideal system. Any real system will score between 0 and 1.

Figures of Merit and Scoring Functions

The figures of merit (FOM) for each PERF or U/R requirement were prioritized by the peanut industry resulting in the weights shown in table 1. The magnitude of the weight for a FOM reflects the significance of that FOM to the peanut industry. A score for an FOM is a measure of how well each proposed solution performs for that FOM and is calculated from a scoring function. A score of

Table 1 (continued). Weights for performance (PERF) and utilization of resources (U/R) figures of merit (FOM)*

PERF FOM	Weights
2. Determine Farmers' Stock Price Accurately	0.20
3. Return Trailers Quickly	0.15
4. Safety	
4.1 Dust Levels, no. injuries	0.06 ea
4.2 No. Missed Days, No. Dr. Appointments	0.015 ea
5. Insure Equipment is Reliable and Dependable	
5.1 How often is Equipment Available	0.04
5.2 How Reliable is Equipment	
5.2.1 Avg. Time Down	0.012
5.2.2 No. Times System Down; Main. Time	0.009 ea
5.3 Maintainability	0.03
U/R FOM	
1. Increase Profits	
1.1 Farmer's Profits; System Profits	0.30 ea
2. Maintain or Reduce Costs	
2.1 Inspection Eq. Costs	0.04
2.2 Equipment Maint. Costs; Op. Costs	0.03 ea
3. User Friendliness	
3.1 Train Time; No. Regrades; Corr. Time; Entry; No. Personnel	0.02 ea
4. Maintain Peanut Supply	0.10
5. Labor Pool	
5.1 Average Time Positions Vacant	0.04
5.2 No. of Vacancies; Man-hours spent filling vacancies	0.03 ea

* The magnitude of the weight of each FOM reflects the importance of that FOM as determined by the peanut industry. The weights for either the PERF or U/R FOM sum to 1.0.

† The weights are for each figure of merit listed.

0 means a proposed solution contributed nothing to that FOM, whereas a score of 1 means the proposed solution did everything expected for that FOM. The scoring function describes how the score changes for a given change in the FOM. This method of evaluation allows quantitative comparison of different proposed solutions and an overall score to be computed. For example, the current grading system SMK CV is 1.82% and, since the current system is the benchmark, it receives a score of 0.5. If a proposed system doubles sample size, research (Dowell, 1992) shows the CV reduces to 1.48%. Assuming a linear relationship and a score of 1 when CV is 0, the proposed system CV yields a score of 0.59. This score is multiplied times the weight of 0.08, shown under item 1.1 in table 1, and combined with other FOM scores within the PERF FOM to yield a total PERF score. A total U/R score is calculated similarly. Other scoring functions, such as sine functions or normal distributions, can be used, but a straight line relationship was assumed in most of this work. The total PERF and U/R score is inserted in equation 1 to give an overall score for the system. The following example illustrates how equation 1 and the weights in table 1 are used to compare two conceptual designs. Assume one conceptual design is average in every respect, and thus scores a 0.5 in every category, thus the PERF and U/R score will be 0.5.

Equation 1 gives:

$$\text{Tradeoff score} = [(0.5 + 0.5) + 2\,(0.5 \times 0.5)] / 4$$

$$= 0.375 \tag{2}$$

Now assume a conceptual design is proposed that reduces the SMK CV from 1.82 to 1.48%, thus increasing the CV score from 0.5 to 0.59. Assume, for this example, everything else stays the same. The PERF score now becomes:

$$\text{PERF score} = (0.08 \times 0.59) + (0.32 \times 0.5) + (0.6 \times 0.5)$$

$$= 0.5072 \tag{3}$$

where

- 0.08 = weight at level 1.1 (SMK accuracy)
- 0.59 = score for improving the SMK CV
- 0.32 = summation of weights at levels 1.2 to 1.9 since these FOM all score 0.5
- 0.6 = summation of weight at levels 2 to 5 since these FOM all score 0.5

The U/R score remains 0.5 for this example. Equation 1 is now:

$$\text{Tradeoff score} = [(0.5072 + 0.5) + 2\,(0.5072 \times 0.5)] / 4$$

$$= 0.3786 \tag{4}$$

Thus, this example of a system with a lower SMK CV scores better than the average system. Of course, in reality, this improved CV can probably not be realized without affecting other FOMs such as cost and labor. This was ignored in this example. A complete description of this method of evaluating proposed solutions is given by Wymore (1993).

System Test Requirements

A test protocol for field testing any proposed grading system improvement was developed in conjunction with USDA, AMS statisticians. Two prototypes must be tested at the National Peanut Research Laboratory (NPRL) for one harvest season. Fifty samples in the low, medium, and high ranges of each quality factor affected by the proposed change must be tested. The FSIS licensed inspectors will conduct all tests. Additional years of testing may be required if the variation between crop years is determined to be greater than variations found within crop years. However, if regional weather patterns provide large variations in crop quality, one years' data will suffice. Proposed changes may be approved for each peanut type separately. Accuracy tests must be conducted by collecting multiple samples from one lot for CV measurements. The remaining tests must be conducted by obtaining samples from multiple lots. In both cases, samples must be divided into four subsamples, two subsamples must be graded using the existing system and the remaining two subsamples graded on each of the two prototypes.

Proposed Solutions

The PERF and U/R requirements established in the previous section allow comparison of any proposed improvements to the grading system. Brief descriptions of some potential solutions follow. Table 2 lists the PERF, U/R, and T/O FOM scores for each conceptual design. Scores for each component and level are not given, but general comments on strengths and weaknesses are made.

Existing System

One solution is to use the existing grading system. The T/O score (0.3354) of this system serves as a benchmark that any proposed solution must exceed. The previous discussions describe the weaknesses of the existing system such as the inherent subjectivity, excessive labor requirements, and sampling errors. The existing system strengths include its use of relatively unskilled workers, low technology, and low cost equipment.

Improved Sampling Methods

The present pneumatic sampling procedure creates FM and LSK and does not obtain FM larger than 7.6 cm (3 in.)

Table 2. Trade-off (T/O), performance (PERF), and utilization of resources (U/R) figures of merit (FOM) scores for various proposed peanut grading system changes (ordered by T/O score)

Conceptual Design	PERF Score	U/R Score	T/O Score
1. Improved Sampling	0.407616	0.50	0.328808
2. Objective Damage Detection	0.4208	0.4971032	0.33406631
3. Measure Aflatoxin	0.4499	0.4690084	0.33523054
4. Existing System	0.4208	0.50	0.3354
5. Foreign Material ID	0.425	0.50003639	0.33751683
6. Moisture Probe	0.4283	0.49843479	0.33842351
7. Single Kernel Moisture	0.4288	0.49905228	0.33895988
8. Automated Cleaning, Shelling, Sizing; Automated Data Collection; and Increase Sample Size	0.477432	0.502504	0.36493974
9. Designs 5-8 Combined	0.497132	0.50002746	0.37357969

diameter. Spout, instead of pneumatic, sampling removes peanuts and FM from material flowing past the sampler and collects more of this large FM, but requires that the load be conveyed to a holding bin or to another trailer. Other advantages, such as cleaning the lot during transfer, can be incorporated into the spout sampling procedure. Davidson et al. (1990) showed spout sampling increases the sampling CV by about 5% for some grade factors, thus the performance FOM scores decrease in comparison to the present system (table 2) and do not compensate for the improved identification of FM. The FM and LSK percentages are closer to shelling plant outturns, but not necessarily better correlated.

Damage Detection

Present damage detection procedures require inspectors to visibly examine kernels for damage. The proposed solution incorporates sensors such as machine vision, colorimeters or spectrophotometers into the inspection process (Dowell, 1990). This reduces inspector subjectivity but increases costs. However, sensor and computer costs must decrease to make this an economically viable solution.

Aflatoxin Testing

The current system identifies only *A. flavus* infected kernels. A proposed solution is chemically testing all samples using technology, like high performance liquid chromatography or immunoassays, to remove inspector bias and eliminate subjective indirect testing (Davidson et al., 1984; Dowell et al., 1992; Tsai et al., 1989, National Peanut Council, 1990). However, skilled labor requirements, health risks, and equipment costs all increase, but aflatoxin levels in edible peanuts should decrease. Despite advantages of chemical testing, benefits do not outweigh costs. However, FDA may dictate, regardless of cost, future implementation of aflatoxin testing in response to consumer demand for lower levels of carcinogens in edible peanuts.

Foreign Material Identification

The current system weighs the total FM present and ranks the two most prevalent types of FM. A proposed solution identifies particularly troublesome FM, such as high moisture FM, and reports the respective amounts. Identifying troublesome FM should reduce aflatoxin formation in storage by improving aeration and reducing high moisture concentrations, but will increase cleaning costs in order to remove this identified FM. The PERF U/R and T/O FOM increase slightly for this potential improvement (table 2).

Moisture Probe

Currently, about 10% of all grade samples are rejected for sale because of excessive moisture. The proposed solution which uses resonant frequency sensors (available from Sensortech Systems, Inc.) measures moisture content as the load is probed, thus measuring moisture without cleaning and shelling the sample. This causes only lots with acceptable moisture to be graded and results in more marketable trailers graded per day. Table 2 shows PERF benefits outweigh the cost increase of this probe.

Single Kernel Moisture

This proposed solution measures individual kernel moisture in addition to average load moisture. Individual kernel moisture can be measured using sensors such as those marketed by Shizuoka Seiki Company which correlate kernel moisture to dielectric properties (Dowell and Lamb, 1991). Loads with excessive single kernel moisture are identified and dried further to reduce aflatoxin problems in storage. The additional quality information gained offsets the equipment costs.

Increase Sample Size; Automated Cleaning, Shelling, and Sizing; and Automated Data Collection

Some proposed solutions dictate additional improvements. For example, increasing sample size requires higher-capacity equipment to handle larger samples without slowing down grading. The percentage calculations are currently based on 500 g (1.1 lb) of cleaned pods and manual calculations can be done quickly. A larger sample dictates automated data collection and calculations. This proposed solution processes a 1.8 Kg (4 lb) sample from cleaning through sizing in one step. All pods from the 1.8 Kg (4 lb) sample are shelled resulting in a pod sample size increase of about 300%. The larger pod sample size reduces sampling error, which is the largest component of total grading error (Dowell, 1992). However, more peanuts are destroyed by grading a larger sample. The cleaning mechanism of this solution is more efficient than the present cleaner, reducing hand cleaning. Small unshelled pods are recirculated through different sheller stages until all pods are shelled, reducing hand shelling. The sizing mechanism reduces variation in measuring kernel size. All data are collected on a computer interfaced to the scales and the respective calculations are made. Equipment and sample costs increase with this solution, but errors and labor requirements decrease and offset any cost increase.

Combined System

Four proposed solutions resulted in scores exceeding the present system (table 2). These four solutions are: foreign material identification; moisture probe; single kernel moisture; and automated cleaning shelling, sizing, data collection, and increased sample size. If these solutions are implemented together, the resulting scores offer the highest PERF and T/O scores of any proposed solution. A flowchart of these proposed solutions is shown in figure 2.

Implementation, Support, and Future Changes

The evaluation of the proposed solutions served to focus peanut grading research towards those areas scoring higher than the current system. Following is a summary of progress towards incorporating the four highest scoring conceptual designs.

Implementation

Those proposed solutions with T/O scores greater than the existing system are at various stages of the technology

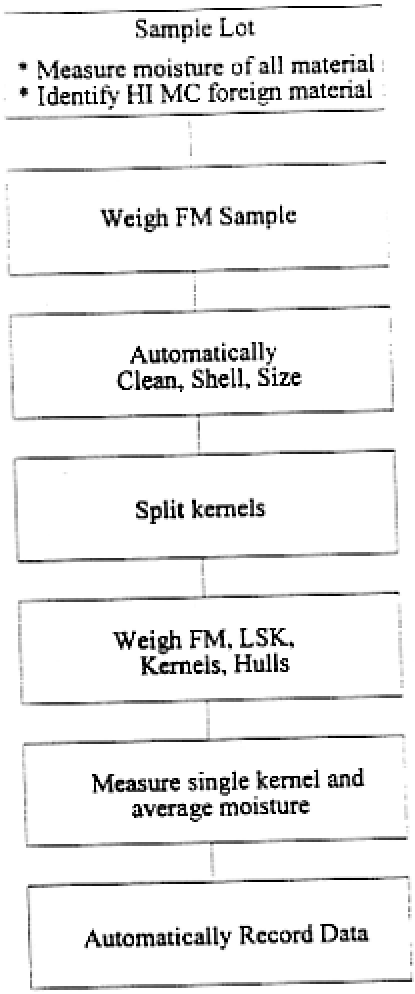

Figure 2–Proposed farmers stock grading system.

transfer process. High moisture FM identification was implemented during the 1992 harvest season. Several moisture probes are being investigated and field testing is planned for the 1994 harvest season. The single kernel moisture meter has been field tested for several years and final changes are being made on the commercial prototype. Changes in the Marketing Agreement for peanuts are being considered by the Peanut Administrative Committee to require single kernel moisture be measured on all lots.

A commercial prototype of the automated data collection system was developed through a cooperative research and development agreement and the system was approved by FSIS in 1993. This system is currently marketed by an equipment manufacturer. A commercial prototype of the automated sample cleaning, shelling, and sizing system was field tested during the 1993 harvest season.

Modifications, Retirement, and Replacement

Consumer and industry demands continually change as preferences change and crises arise, thus on-going changes to any proposed system may be requested. For example, spout sampling, objective damage detection, and aflatoxin measurement are not currently feasible solutions because of resource or performance limitations. However, changes in technology or marketing requirements may make these proposed solutions feasible in the future. Currently, requests for grading system changes requiring research are conveyed to the Agricultural Research Service (ARS) through regular meetings of the Peanut Grading Working Group, or through appropriate administrative personnel. The ARS will continue to respond to needs to modify, retire, or replace the improved system as they arise. The principles outlined in this article will be used to identify, prioritize, and address any requests.

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