Design, Testing, and Implementation of a Data Automation System for the Peanut Quality Inspection Process[1]

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ABSTRACT

The current manual peanut inspection system requires inspectors to hand record about 14 million pieces of grade information and hand calculate about 8 million percentages on the 600,000 lots marketed annually. This results in up to 26% of these manually recorded grade certificates having errors. An automated data collection system was developed that reduces errors in recording and calculating grade factors. In addition, labor is reduced since recording data electronically eliminates manual recording, calculating, and checking of grade data. Variability in calculating dollar value was reduced up to 11%. Depending on the type of error occurring at specific buying points, implementing the system could save the peanut industry up to $6 million annually. A commercial computer company is marketing a version of the automated data collection system for use with current grading equipment.

Key Words: Grading, inspection, peanuts, automation.

Current farmers stock peanut inspection procedures involve measuring specific grade factors of farmer marketed lots, hand-recording the grade factors, and hand-calculating results (USDA, 1990). This process occurs on each of the 600,000 lots marketed annually, requiring hand-recording about 14 million pieces of grade information and hand-calculating about 8 million percentages. This results in many errors in grading peanuts. The peanut grading system has evolved from a system with no mechanization (Elliott and Carmichael, 1955) to the existing system that includes operator-assisted equipment. However, the present system is still labor-intensive and subjective. Thus, the peanut industry requested an automated grading system to reduce labor and errors inherent in the present system as they seek to cost-effectively meet consumer demands for increased peanut quality.

Description of the Current Grading System. The Federal-State Inspection Service (FSIS) inspects peanuts at about 500 locations annually throughout the peanut belt that stretches from Arizona to Florida and Virginia using a grading system developed in the 1960s. About 2000 temporary inspectors grade these lots during the harvest season from August to November. The quality factors measured in the grading process include (a) foreign material (FM), which is debris such as sticks and rocks; (b) loose shelled kernels (LSK), which are kernels shelled by harvesting and handling before marketing; (c) moisture content; (d) sound mature kernels, which are undamaged edible kernels; (e) sound splits, which are edible kernels split in half during shelling; (f) damaged kernels, which are kernels discolored by freezing, insects, or molds like *Aspergillus flavus* Link; (g) other kernels (or oil stock), which are small inedible kernels; (h) hulls; (i) extra large kernels, that are found only in virginia-type peanuts; and (j) fancy pods, which are large pods found only in virginia-type peanuts. The four major peanut types are spanish, runner, valencia, and virginia.

Figure 1 shows a typical farmers stock grading process. The grading process produces two 1.8-kg samples by sampling five to 20 random locations within a 4540- to 18,160-kg lot using a pneumatic sampler. One sample is graded and the other held in reserve in case an error occurs in grading the first sample. FM and LSK are removed from the grade sample, weighed, hand-recorded, and the percentage of each is determined either by hand calculation or with a calculator. Penalties apply to lots with more than 4% FM, and lots with more than 10.49% must be cleaned and resampled before marketing. Penalties are about $1 per percent of FM and cleaning costs are about $16.50/t. LSKs receive an oil stock price that is about 1/10 of edible stock price. Whole pods from the cleaned sample are reduced to a 500- or 1000-g subsample, depending on initial lot size, which is presized to improve shelling efficiency. After shelling, the kernels are sampled for moisture content and sized on a screen shaker. Moisture content is hand-recorded and moisture above 10.49% requires the lot to be further dried and regraded.

During sizing, the kernels are separated into three fractions: large kernels that cannot fall through a specific size slotted screen (6.4 x 19 mm for runner-type peanuts); kernels that fall through the screen, which are oil stock; and split kernels. The weight for each category is hand-recorded and percentage hand-calculated. The kernels riding the screen and the split kernels are visually inspected to determine the percentage of discolored or damaged kernels, and this number is again hand-recorded and calculated. Undamaged kernels riding the screen and undamaged split kernels command a price of about $1.05/kg. All kernels are examined for visible *A. flavus,* which is an indication of possible aflatoxin contamination; and detection 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 the market and using the peanuts for seed or other nonfood purposes. Numerous samples can be at various stages of the cleaning, presizing, shelling, moisture measurement, kernel sizing, and damage detection process at any one time.

After recording all grade factors on a grade certificate

[1]Mention of trademark or proprietary product does not constitute a guarantee or warranty of the product by the U.S. Dept. of Agric. and does not imply its approval to the exclusion of other products that also may be suitable

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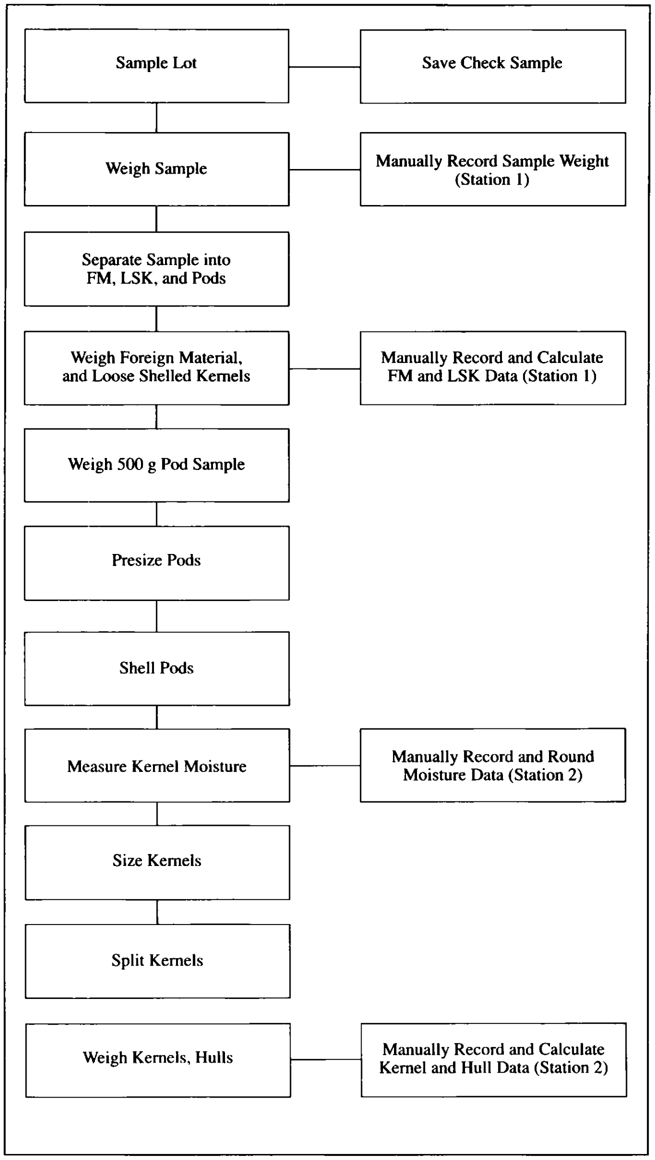

Fig. 1. Flow chart of the current farmers stock grading process that includes a manual data collection system. The sample from the lot includes foreign material (FM) and loose shelled kernels (LSK).

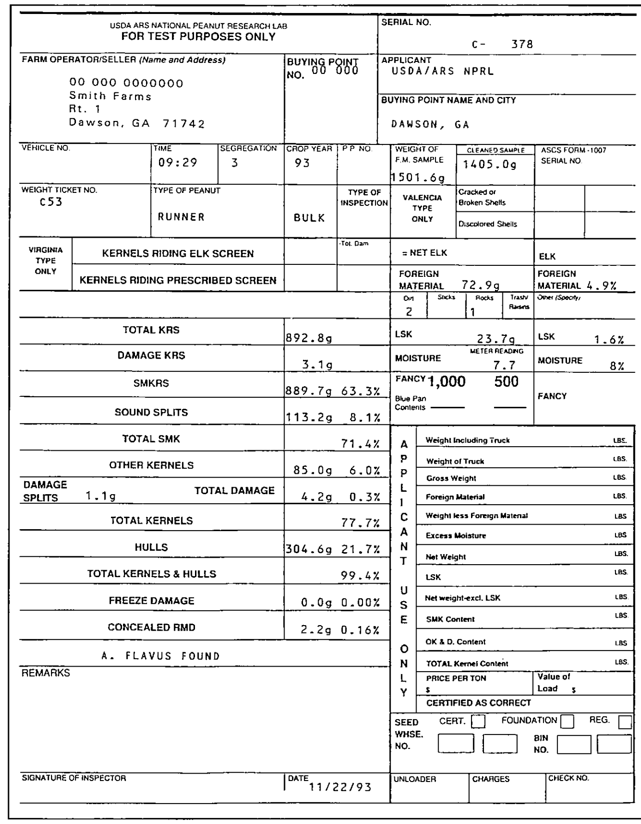

Fig. 2. Automated data collection system version of the FSIS grade certificate. The grade certificate used for manual data recording is similar.

similar to the one shown in Fig. 2, the peanuts are purchased and the lot is placed in aerated storage. Buying point personnel then keypunch the information from the grade certificate into a program that calculates the lot value. Undamaged, loose shelled, and oil stock kernels add value to the lot; whereas excessive moisture, split kernels, FM, and damaged kernels result in penalties. The lot is eventually shelled and processed into edible products or crushed for oil, depending on grade.

Problems with the Current Grading System. Sampling, equipment, and human errors contribute to inaccuracies in the current grading system. These inaccuracies can cause significant over- or under-payment 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 *et al.* (1991) reported coefficient of variation values that ranged up to 30% for all grade factors. Dowell (1992) reported that equipment and human errors accounted for approximately 24% of the total error.

Procedures requiring inspectors to account for all grade fractions can influence human error. The allowable tolerance, or amount of sample that can be lost or gained during the grading process, is 5 g, or 1%, assuming a 500-g subsample size. If this tolerance is not satisfied when adding all fractions of the graded sample, regrading is required. Due to time constraints, inspectors may use a subsample larger than 500 g to ensure the tolerance is met if some of the sample is lost; but they make calculations based on 500 g. However, this error results in an over-estimation of grade factors.

Handling the large volume of samples graded each year also contributes to human error. Inspectors hand-record up to 24 numbers and hand-calculate up to 14 percentages on each of the 600,000 lots marketed annually. Unpublished research by the Agricultural Research Service (ARS) and the Agricultural Marketing Service (AMS) during a peanut storage shrinkage study showed that up to 25% of the hand-written grade certificates contain illegible data, calculation errors, or missing data; and up to 17% of these errors cause a change in dollar value of the load. Opportunities for errors also exist during keypunching grade information from the hand-written grade certificates into the program that determines lot value.

Increasing sample size reduces sampling error since, theoretically, doubling sample size decreases sampling error by 50%. The peanut industry thus requested sample size be increased to improve grading accuracy (National Peanut Council, 1988). However, increasing sample size is difficult with the present system since graders are trained to hand-calculate grades based on a 500- or 1000-g subsample. A subsample size other than 500 or 1000 g cannot be used unless the burden of calculating grade percentages is removed from the inspector. Thus, to reduce human and sampling error, a system that eliminates hand recording, eliminates keypunching data, and makes calculations using any sample size is needed.

The specific objectives of this research were to (a) document manual data collection errors in the present grading system and (b) develop an automated data collection system for grading farmers stock peanuts.

Materials and Methods

The initial portion of this research concentrated on establishing system requirements. ARS, AMS, and FSIS developed a document establishing minimum specifications that any automated data collection system must meet (USDA, 1992). Briefly, the document says that to get FSIS approval (a) the automated data collection system must not slow the current grading system, (b) data must be accurate, (c) the system must be reliable, and (d) the system must be user-friendly. All requirements are quantified and discussed in detail in that document.

Development of the automated data collection system occurred during five phases (Table 1). Phases 1 and 2 determined the feasibility of certain types of automated data collection equipment. Phases 3, 4 and 5 determined the effects of the automated data collection system on the current grading system and when used with other proposed automated grading equipment. All programming was done in "C" language. The following discussion is broken into two sections, one section reporting the system development to complement current grading equipment and the other section reporting the system development to complement proposed automated grading equipment.

System Development for Current Grading Equipment. Phase 1 testing consisted of interfacing a digital balance to a computer as part of a larger project that evaluated the feasibility of automatically identifying and sorting damaged kernels (Dowell, 1990). Testing was limited to about 50 samples and laboratory personnel conducted all tests.

Phase 2 development and testing evaluated the concepts of interfacing a digital balance, a digital moisture meter, and a hand-operated bar code reader with one computer. Bar code readers recorded sample identification and eliminated the need for inspectors to use the computer keyboard. In field tests, systems containing only the bar code reader and computer were placed at one buying point each in Georgia, Texas, and Virginia and two buying points in Alabama. These tests determined the ease of use and reliability of using bar code readers in grading rooms. The bar code readers collected time and sample identification information on 4490 samples as part of a separate study to determine the feasibility of measuring aflatoxin in grading rooms

Table 1. Automated data collection (ADC) equipment tested during various phases of the system development.[a]

	Cost ($)
Phase 1 (1988-89): Objective: Demonstrate feasibility of ADC	
Computer - 80386 cpu, 40 MB hard drive, 2 MB RAM, 16 Mhz	4000
Total cost	**4000**
Test location - National Peanut Research Lab, Dawson, GA (50 samples)	
Phase 2 (1990): Objective: Demonstrate reliability of ADC in field conditions	
Computer - 80286 cpu, 20 MB hard drive, 1 MB RAM, 8 Mhz	900
Bar code reader - Welch Allen ST1100 (Welch Allyn, Skaneateles Falls, NY)	850
Printer - Brother M1709 (Brother Int. Corp., Piscataway, NJ)	500
Port extender - ACLII 8 port board, 10 Mhz, 80188 CPU (Stargate Tech. Inc., Solon, OH)	1200
Cables, connectors, etc.	100
Total cost per location	**3550**
Test locations - National Peanut Research Lab, Dawson, GA (880 samples); Golden Peanut Co., Ashburn, GA (2228 samples); Golden Peanut Co., Comanche, TX (457 samples); Birdsong Peanuts, Franklin, VA (739 samples); Sessions Co., Inc., Enterprise, AL (790 samples); Dothan Oil Mill Co., Newville, AL (276 samples)	
Phase 3 (1991): Objective: Compare ADC to the manual system	
Computer - 8088 cpu, 10 MB hard drive, 1 MB RAM, 8 Mhz	500
Port extender - Stargate Tech PLUS-8 multiport expansion board	770
Bar code scanner - PSC 5312-2002 (PSC, Webster, NY)	1150
Key pad - Two Technologies TT1R2-2ND (Two Tech. Inc., Horsham, PA)	175
Surge protector	65
Printer - Brother M1709	400
Cables, connectors, etc.	200
Total cost	**3260**
Test location - JACO buying point, Leesburg, GA (355 samples)	
Phase 4 (1992): Objective: Test final ADC system for use with current grading equipment	
Computer - 80286 cpu, 20 MB hard drive, 1 MB RAM, 8 Mhz	900
Monochrome monitor (2)	200
Port extender - Stargate Tech PLUS-8 multiport expansion board	770
Bar code scanner - PSC 5312-2002 (PSC, Webster, NY) (2)	2300
Key pad - Two Technologies TT1R2-2ND (3)	525
Surge protector (3)	200
Printer - Epson LQ570 (Epson America Inc., Torrance, CA)	260
Cables, connectors, etc.	200
Total cost - Research version	**5355**
Total cost - Commercial version (AutoSieve/P (Sage Systems Tech., Melbourne, FL)	**10,000**
Test location - Stevens Industries buying point, Dawson, GA (150 samples)	
Phase 5 (1993-94): Objective: Test ADC for proposed automated grading equipment	
Computer - 80286 cpu, 20 MB hard drive, 1 MB RAM, 8 Mhz	900
Monochrome monitor	100
Port extender - Stargate Tech. PLUS-8 multiport expansion board	770
Surge protector - Isobar IB-6	65
Printer - Epson LQ570	260
Cables, connectors, etc.	100
Total cost	**2195**
Test location (1993) - National Peanut Research Lab, Dawson, GA (2 systems, 622 samples)	

Table 1 (Continued)

Test locations (1994) - Birdsong Peanut Co., Suffolk, VA (864 samples); Golden Peanut Co., Comyn, TX (546 samples); Smithville Peanut Co., Smithville, GA (1178 samples)

[a]Most grading rooms already have a PM6000 balance ($1600) (Mettler Instrument Corp., Hightstown, NJ) and GACII or GAC2000 moisture meter ($3150) (DICKEY-john Corp., Auburn, IL). Thus, the cost of these is not included in the price of any system. Most current grading rooms require two balances. However, the proposed automated grading equipment requires only one balance, thus reducing cost.

(National Peanut Council, 1990). Using a hand-held wand, the inspector scanned bar codes affixed to a sample identification sheet at specific intervals in the grading process. Unlicensed inspectors conducted all tests.

Other tests in Phase 2 evaluated the feasibility of using a balance, moisture meter, bar code reader, computer and printer when grading 880 samples in a separate study in 1990 which reported sample size affects on grade accuracy (Dowell, 1992). That study reported only sample size results and did not include data collection procedures. A mulitport expansion board interfaced all components to the computer. Licensed FSIS inspectors conducted all tests. Electronic recording of weights occurred by placing a sample on the balance, scanning a bar coded sample identification number on the grade certificate, and scanning a code from a menu identifying the particular grade component (i.e., FM, split kernels, etc.) on the balance. Electronic recording of moisture occurred by scanning the sample identification code, placing the sample in the moisture meter, and then measuring the moisture. After recording all grade factors, scanning the sample identification and print command from the bar code menu generated a printed grade certificate (Fig. 2). All data were saved to an ASCII disk file. Unfinished grade sheets were stored and recalled as needed before printing, thus allowing multiple samples to be at various stages of the grading process.

Phase 3 of the automated data collection tests sought to further simplify the system by replacing the hand-held wand with a stationary bar code scanner. In addition, a 25-key pad with grade components printed on each key replaced the bar code menu. Thus, the inspector placed a particular grade component, such as FM or damaged kernels, on the balance, placed the sample identification bar code contained on the grade certificate under the scanner, and pressed the appropriate key corresponding to the grade component being weighed. When a key was pressed, the system read the bar code, polled the balance or the moisture meter, then stored the grade factor, moisture or weight reading, and sample identification in memory and on a disk file. When the inspector wished to print a grade certificate, the program first checked for critical grade factors to determine if the grade was complete. A message flashed on the screen if a critical grade factor was missing. If the grade was complete, the system paused while the inspector placed a blank grade certificate in the printer. This system allowed up to 99 samples with different sample identification bar codes to be at various stages of the grading process. Normally, no more than five samples are graded simultaneously. If a sample code was scanned, the file was searched to determine if other components for that sample already existed. If so, that file was retrieved and the grade data added. This system was tested in the field using FSIS licensed inspectors on 355 samples during the 1991 harvest season. As in Phase 2, use of the keyboard was not required, thus it was locked in a ventilated, dust-proof enclosure with the computer. During these tests, the inspectors operating the automated system also filled out a separate hand-written grade certificate according to standard procedures for later comparisons.

Thus far, the data collection system contained only one balance. However, most grading rooms with two or more inspectors place one or more inspectors at the cleaning station and the remaining inspectors at the shelling station. This allows sample staging and speeds the grading process. In addition, the previous phases did not allow entering farmer or buying point information. Phase 4 involved expanding the previous system to allow collecting grade factors for one sample from the cleaning and shelling station by connecting the two grading stations to a single computer (Fig. 3). This also allowed up to 99 samples to be at various stages of the grading process and permitted keying in farmer and buying point information.

The cleaning station consisted of an alphabetic keypad for entering farmer and buying point information, a keypad

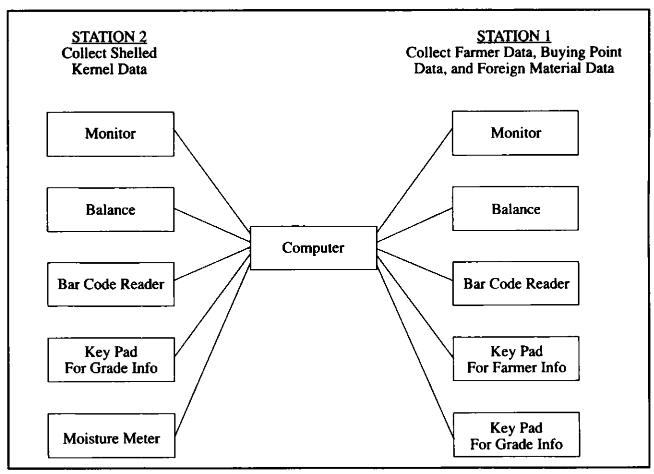

Fig. 3. Diagram of the automated data collection system developed for current grading rooms.

with all grade factors printed on it, a balance, a bar code reader, and a computer monitor. The shelling station consisted of equipment identical to the cleaning station but the keypad for entering farmer information was replaced by a moisture meter. The computer screens were split vertically with one half of the screen dedicated to each grading station. In these tests, a sample entered the grading room with a unique bar coded trailer weight ticket. The bar code scanner read the weight ticket and an inspector entered farmer and buying point information on the alphabetic keypad. The sample was then cleaned, the FM or LSK placed on the balance, either the FM or LSK key on the grade factor keypad pressed, and the sample bar code scanned and stored with the weight. The shelling station then received the sample and the remaining grade factors were measured. Both grading stations could record samples simultaneously. When the inspector wished to transfer data from the hard drive to floppy disks, the inspector selected completed grade certificates from a menu. This prevented transfer of partial or unwanted grade certificates. Testing occurred during the harvest season at a commercial buying point on 150 samples. During these tests, the inspectors filled out a separate hand-written grade certificate according to standard procedures for comparison to the automated system.

System Development for Proposed Automated Grading Equipment. A new grading system proposed for farmers stock sample cleaning, pod sizing, shelling, and kernel sizing was developed and is undergoing tests for FSIS approval (Dowell *et al.*, 1995) (Fig. 4). An automated data collection system to complement this proposed system was developed in Phase 5 (Fig. 5). The new automated grading system combines the cleaning, presizing, shelling, and sizing processes into one step. This requires only one data collection station, one set of scales, and no bar code reader which greatly simplified programming and reduced equipment costs. To further reduce cost, the computer keyboard replaced the key pads of previous versions. The program locked out any keys not required for the specific operation being performed.

The program follows a logical grading sequence requiring minimum interaction by the grader. The cursor flashes in a field waiting for a weight input from the balance. Once the enter key is pressed and that weight is received, the cursor goes to the next field for which the inspector will likely record a weight. The inspector can alter the sequence by using the arrow keys to move the cursor around the screen. In case of a power failure, a data recovery feature recovers any incomplete samples. FSIS inspectors tested two of these automated data collection systems on 622 samples in the laboratory during 1993. Inspectors field-tested three systems in 1994 on about 2500 samples in Texas, Georgia, and Virginia.

Results and Discussion

Table 2 shows errors on manually recorded official grade certificates during testing from 1991-1994. The total percentage of errors in the manual system ranged from 3.1 to 26%. The percentage of errors affecting value of the lot ranged from 2.1 to 17%. Dollar value was selected as a measure of the effect of errors since all grade factors contribute to value. If errors were random, then there should be no net effect of errors on value when averaged over a season. However, two of six locations showed buying points suffered significant losses caused by errors in calculating dollar value in the current system, particularly in Phase 4. A discussion of each Phase is given below.

Phases 1 and 2 demonstrated to FSIS the feasibility of interfacing data collection equipment to computers and the reliability of the equipment in field conditions. In addition, the tests proved FSIS inspectors with no prior knowledge of computers can successfully operate automated data collection equipment. No errors in automated data recording occurred. However, comments from inspectors about user-friendliness revealed that the hand-held bar code readers were cumbersome and sometimes difficult to operate. Occasionally, dirty bar codes or improperly held wands resulted in a failure of the system to read bar codes. This required the inspector to repeatedly rescan the bar codes, therefore slowing the grading process. The bar code scanner was eliminated in Phase 5.

The system tested in Phase 3 employed a stationary scanner and keypad that simplified the data collection process and eliminated problems encountered in Phase 2. No data collection errors occurred in the automated system and no inspector complained about the user-friendliness of the system. In field tests, the system collected only data from the shelled kernel station since this system did not accommodate multiple balances. The only data not recorded because of this limitation was FM

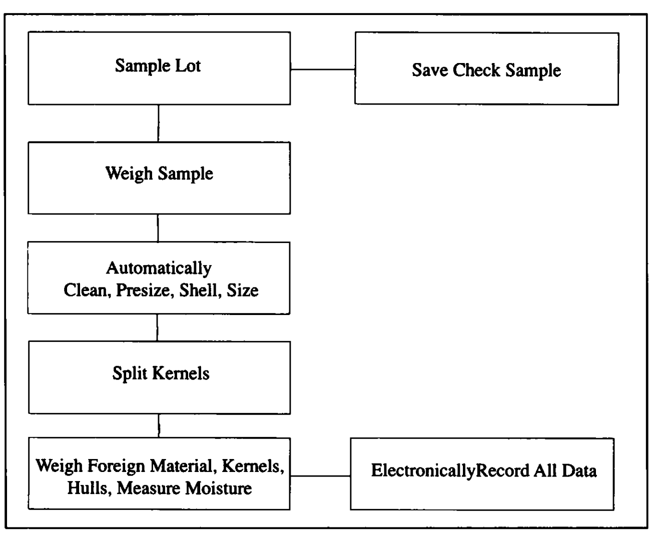

Fig. 4. Flow chart of a proposed automated cleaning, shelling and sizing system that includes an automated data collection system.

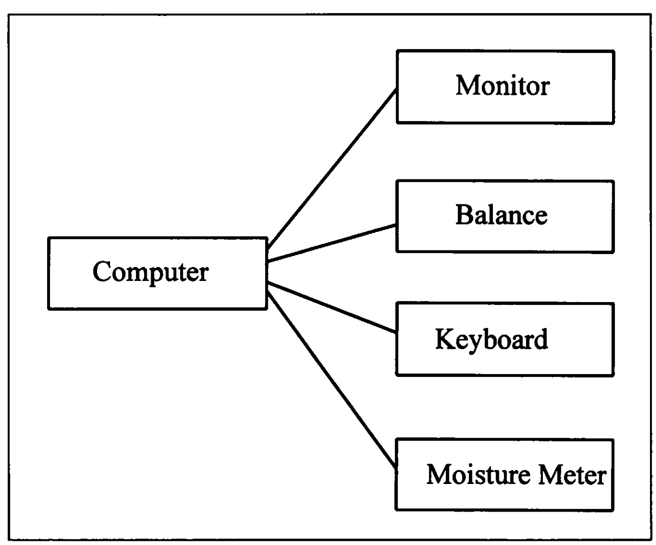

Fig. 5. Diagram of the automated data collection system developed for an automated grade sample cleaning, shelling and sizing system.

Table 2. Errors such as incorrect calculations, illegible handwriting, incorrect rounding, and missing data occurring on manually recorded official grade certificates.

	1991 (Phase 3)	1992 (Phase 4)	1993 (Phase 5)	1994 (Phase 5)		
Data Collected	GA	GA	GA	GA	VA	TX
Total samples (no.)	355	150	622	1178	864	546
No. grades with errors (%)	26	25	11.9	3.1	10.1	5.5
No. errors affecting value (%)	12.1	17	2.3	2.1	3.6	1.8
No. errors costing the farmer (%)	6.2	0	1.1	0.7	2.0	1.1
No. errors costing the buying point (%)	5.9	17	1.1	1.4	1.6	0.7
Avg. $/t lost by the farmer[a] ($)	nr[c]	0	5.19	7.86	12.64	24.87
Avg. $/t lost by buying pt.[a] ($)	nr	10.78	7.62	8.22	11.80	1.19
Max. error/t ($)	10.17	22.83	33.08	22.14	25.23	94.93
Total net effect on buying pt.[b] ($)	-10[ns]	-8150*	-124[ns]	-296*	260[ns]	1071[ns]

[a]Calculated only on those lots with errors.
[b]Assumes a 5500 t/yr buying point.
[c]nr = not recorded.
[ns]Net effect was not significantly different from $0 at P=0.10.
*Net effect was significantly different from $0 at P=0.10.

and LSK weights. In analyzing the data, accuracy of recording grade percentages and subsequent lot value was used to compare the automated system to the current system. Tests showed grade percentages differed in 26% of all lots graded (Table 2). These differences, caused by rounding errors, affected lot dollar value 12.1% of the time. Lot value was calculated from all grade factors, except FM and LSK in these tests. Differences in the percentage of undamaged kernels caused the lot value to differ in most cases. Although all grade factors contribute to price, undamaged kernels account for over 90% of lot value. The automated system exceeded the manual system by a maximum of $10.17/t. Across all lots, the net effect of the rounding errors approached zero. However, these tests showed that implementing automated data collection reduces errors in calculating price in about 12% of all lots.

In Phase 4 testing, analysis of the data revealed that the automated system and manual system differed on 25% of the grade certificates (Table 2) even after correcting for rounding errors. Differences in undamaged kernels accounted for about 63% of errors while differences in oil stock kernels and hulls accounted for the remaining errors. An incorrect cleaned subsample weight used in all manual undamaged kernel, oil stock kernel, and hull calculations accounted for all differences. For the 17% of lots with this error, the actual price was overestimated in the manual system by an average of $10.78/t with a range of $1.54 to $22.83. All errors in this phase resulted in increased cost to the buying point, resulting in a total cost of about $8150/yr for an average 5500 t/yr buying point. The experimental design in other testing did not allow measuring this error in other phases. Phase 4 completed research and testing of an automated data collection system for current grading rooms and Sage Systems Technology (Melbourne, FL) currently markets a version of the system approved by FSIS.

In Phase 5 testing, the automated data collection system was used with the proposed automated grading equipment. Thus, Table 2 shows results from examining manually recorded official grade certificates for inspector errors that would be eliminated with the automated data collection system, not from data collected with the automated system. Errors in manually recording or calculating FM, LSK, or undamaged kernels accounted for most incorrect values. An error in LSK or FM not only affects LSK value or FM penalties but, more importantly, affects the amount of material for which the farmer is paid. Thus, underestimating FM or LSK by 1% results in overestimating net weight by about 1%. Over 90% of the lot value is then determined from that overestimated net weight using the kernel estimates measured during grading. Only one of the four tests in Phase 5 showed significant buying point cash losses due to errors in the manual system.

In addition to the advantage of eliminating many recording and calculating errors, the automated system increases the accuracy of calculating grade percentages by eliminating rounding. Tables 3 and 4 show the reductions in dollar value variability achieved by eliminating rounding and other errors. Variance was calculated from dollar values determined on individual lots. Table 3 shows that, while means were not significantly different, dollar value variances were reduced by about 5 to 11% by using the automated data collection system. This reduction in variability reflects eliminating rounding errors as well as eliminating other errors associated with manual recording. Table 4 shows reductions in variability due exclusively to eliminating rounding. A reduction in variance of 3.4 to 5.6% was achieved simply by eliminating rounding. Comparing reductions in variances shown in Tables 3 and 4 reveals that about 50% of the reduction in dollar value variance achieved by the automated system was due to the elimination of rounding errors.

Dowell (1992) showed that measurement errors contributed at least 24% of the total error in measuring grade

Table 3. Comparison of lot value variability calculated from grade factors recorded manually to values calculated using an automated data collection (ADC) system. Data from individual samples was both hand and automatically recorded. The ADC carried all decimals in calculations whereas the manual method rounded calculations to the nearest integer.

Year	Samples	Manual method Avg	Manual method Var.	ADC Avg	ADC Var.	Reduction in var.
	no.	$/t	$/t	$/t	$/t	%
1991	355	751.69[a]	690.67[b]	751.41[a]	658.94[b]	4.6
1992	150	801.15[a]	791.15[b]	798.96[a]	706.85[b]	10.7

[a]Averages for the same year were not significantly different at the P=0.05 level.

[b]Variances for the same year were significantly different at the P=0.05 level.

Table 4. Reduction in variability achieved by carrying all decimal places in calculations verses the present method of rounding all percentages to the nearest integer. This comparison includes only data from the Automated Data Collection system.

Year	Samples	Value determined: Rounding Avg	Rounding Var.	No rounding Avg	No rounding Var.	Reduction in var.
	no.	$/t	$/t	$/t	$/t	%
1991	355	751.61[a]	682.37[b]	751.41[a]	658.94[b]	3.4
1992	150	799.21[a]	748.54[b]	798.96[a]	706.85[b]	5.6

[a]Averages for the same year were not significantly different at P=0.05.

[b]Variances for the same year were significantly different at P=0.05.

factors and value, with the remaining error caused by sampling. Thus, implementing an automated data collection system can reduce total error about 1 to 3% since the contribution of measurement error is reduced about 5 to 11%.

In order for the peanut industry to implement the automated data collection system, the system must show economic returns. Table 2 shows that in Phase 4 testing, the buying point could save over $8000 per year from overpayments caused by errors in the manual method. However, other Phase 5 testing in Texas showed that the buying point would lose over $1000 per year from underpayments to farmers, although this value was not statistically significant. Another source of economic return is the elimination of the manually recorded official grade certificate since data are collected electronically, resulting in a savings of about $100 annually per buying point. Also, the automated data collection system eliminates manual keypunching of the grade data into the current Buying Point Automation Program, which calculates payments to growers. The data can be electronically transferred, saving about $500 in labor annually per buying point. Labor is saved also since inspectors would not have to calculate figures on official grade certificates, and they could eliminate the current practice of checking the accuracy of manually entering the grade data into the Buying Point Automation Program. This should reduce inspection labor costs about $500 annually per buying point. Thus, reducing labor and errors could result in a savings up to about $10,000 annually at a 5500 t/year buying point, depending on the types of errors occurring at a location. Implementing the automated data collection system at all buying points could save the peanut industry up to $6 million annually.

Additional economic savings may result but are difficult to quantify. For example, implementing the automated system reduces errors in recording peanut quality factors, thus resulting in better decisions about subsequent handling of the crop. This should result in better segregation of inedible peanuts since damaged kernel calculations are more accurate, better drying practices since moisture content is more accurately recorded, fewer problems during storage since lots with excess FM are more accurately determined, and improved shelling efficiency since accurate grade information is essential to properly setting shelling plant parameters. All these benefits should help the peanut industry reduce operating costs and improve peanut quality reaching consumers, thus ultimately increasing consumer demand for peanuts.

Several buying points currently use the commercial version of the automated data collection system developed in Phases 1-4. However, cost of the system (~$10,000) is hindering further implementation. The system developed in Phase 5 (Fig. 5) for the proposed automated grading system (Fig. 4) is much less complex and uses fewer external devices, thus reducing cost. Approval for the proposed automated cleaning, shelling, and sizing equipment is currently being pursued. If the automated grading equipment is implemented, perhaps a method to implement the automated data collection system is to give the specifications for the system to the peanut buying point operators so they can install and support the system. Typically, large companies own many buying points and employ full-time computer support personnel. Allowing these personnel to support the automated data collection system should reduce costs associated with commercial computer companies installing and supporting the system.

In summary, the automated data collection system developed in this research for currently used grading rooms reduces errors in collecting and calculating grade factors while meeting all industry requirements. The data are electronically stored, thus reducing labor for subsequent keypunching of data into programs to calculate value. The automated system also reduces inspector labor by eliminating manual recording, calculating, and checking grade data. Depending on the type of error occurring at specific buying points, implementing the system could result in a return of about $10,000 annually per buying point. A separate automated data collection system developed together with proposed automated sample cleaning, shelling, and sizing equipment provides similar benefits at a lower cost.

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