Automatic control of a peanut grade sample inspection system

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The current US peanut grading system is labour intensive and requires human judgement at several steps in the grading process. One goal of the peanut industry is to ensure high quality peanuts by increasing grading accuracy. Developing an automated grading system will assist in attaining that goal. The development of this grading system centers around a central system which automatically controls the grading process. The system makes decisions on single objects from a sample of peanuts. A machine vision system acquires an image of the object. Kernel size is determined from the image by the system. The kernel is evaluated for damage using grey level, tristimulus and texture information, and the appropriate sorting action is taken. Other grading devices which provide inputs into the automated grading system are a single kernel moisture meter, a bulk moisture meter, a bar code reader and a chemical testing system. Each of these devices are attached to the central processing unit and provide input into the automated grading system. After the entire sample has been processed, the categories are automatically weighed and the system determines the peanut quality based on the grade values. This automated system will result in a less labour-intensive system which will ensure the quality of US peanuts for domestic and foreign buyers and consumers worldwide.

Keywords: peanut; grade; automated; food quality; grading

INTRODUCTION

Agricultural automation has not advance as rapidly as automation in newer industries such as the automotive and computer industries. An abundant work force consisting of mostly low-wage earners has contributed to this lack of automation in the agricultural industry. As labour costs and consumer demands for quality foods increase, the US peanut industry recognizes the need for automation to help reduce labour and increase grading accuracy. In addition, foreign markets are more competitive and foreign buyers can go elsewhere if the US peanut industry does not meet their standards for quality. The US peanut industry realizes that a more educated consumer, provided with alternative products, can switch to those other products if their demands for peanut quality are not met.

Recent quality problems, perceived or real, in the USA pesticide residues in apples), Chile (cyanide residues in grapes) and Europe (chemical residues in Perrier water) illustrate what can happen if adequate product quality control is not maintained. Each of these industries encountered substantial losses and may never regain their original markets. Thus, all portions of the peanut industry are striving to adopt or develop practices to ensure the quality of US peanuts and thus prevent the peanut industry from experiencing similar mishaps. Determining peanut quality accurately and objectively is therefore of importance.

The existing peanut grading system used to determine quality in samples of peanuts has evolved from a system with no mechanization (Elliott and Carmichael, 1955) to the existing system which includes operator-assisted equipment that aids in determining quality (Pattee and Young, 1982; USDA, 1988). However, this system is still labour-intensive and very subjective at several steps in the grading process. The existing system involves obtaining a 1800 g grade sample from about 4 tonnes of peanuts at farmer marketing, determining the foreign material and loose shelled kernels in this 1800 g, and determining the sound mature kernels, sound split kernels, damaged kernels, oil stock kernels and moisture content in 500 g of pods taken

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from the 1800 g grade sample. All kernels are examined for the presence of carcinogen-producing moulds.

A labour force of about 2000 workers is required each year to inspect the approximately 1.6 million tonnes of peanuts produced each year in the USA. The inspectors are required to make several judgements in determining quality and with stricter standards being imposed by domestic and foreign buyers, particularly with regard to damage and aflatoxin, it is more difficult to find and train qualified personnel to make these quality determinations. Even with properly trained personnel, variability between inspectors and variability with one inspector over several days makes it difficult to improve the existing grading system. In addition, the peanut industry is requesting a larger sample be graded to improve the accuracy of predicting peanut quality. Grading a larger sample will further increase labour requirements. Additional quality determinations, such as flavour potential, also need to be incorporated in the grading system. For the above reasons, research was undertaken to develop an automatically controlled peanut grading system.

BACKGROUND INFORMATION

Automated inspection techniques are currently used successfully in other industries and are often centered around a machine vision system. Goldstein and Nagler (1987) inspected 300 metal parts per minute for structural and textural defects with machine vision. Petty (1982) described checking pharmaceuticals for debris and contamination, inspecting printed circuit boards for holes, and aligning injection moulding tools using machine vision.

Based on the success of automated inspection in other industries, machine vision should be able to be used to inspect agricultural commodities. Casady and Paulsen (1988) developed a machine vision centered system to inspect and sort corn kernels based on surface defects. Rehkugler and Throop (1986) developed a feeding and machine vision inspection system for apples.

Barrett and Jones (1989) related how an expert system can be used to make decisions that result in the automatic control of sensors, machine vision equipment, and other machinery. Newton *et al.* (1986) described how an expert system can be used to control agricultural equipment. Clarke (1986) reviewed automated systems used in such agricultural applications as slaughtering cattle, processing pork and orienting ears of corn. He noted that the state of automation in agriculture is relatively primitive.

Although a complete system for the automated inspection of peanut samples is not commercially used in the agricultural industry, much of the technology needed to develop the system exists. Thus, the goal of developing an automatically controlled inspection system for peanut grade samples was established. Existing technology was to be used when applicable and research undertaken where technology is lacking.

SYSTEM DEVELOPMENT

The ideal peanut inspection system is one where all peanuts are inspected and accurate quality factors determined without any human intervention. A long-term research programme was started in 1987 with the goal of developing this automated objective system. Although the complete system may not be available for some time, portions of the system are being developed and implemented. The information reported here describes the completed portions of the system and the development that is in progress.

The current automated system development focuses on shelling and inspecting a sample taken from a larger population of unshelled peanuts. A sample only is graded to reduce cost and increase storability. Currently, farmer-marketed peanuts are stored in the shell to maintain quality. Once the peanuts are shelled, the quality is more likely to deteriorate when stored. Therefore, it is not desirable to inspect all peanuts unless this can be done without shelling. Also, grading a sample from the population greatly reduces the cost and requirements of the inspection system. The confidence associated with predicting the population quality can be determined (Davidson *et al.* (1988).

Software

The automated system is controlled by a program written in 'C' programming language. The program makes decisions currently made by trained experts and thus will be referred to as an expert system. The expert system controls as well as receives feedback from the instruments shown in *Figure 1*. After the grade sample inspection is completed, the program uses the appropriate information to compute the quality of the peanuts. The decisions made by the expert system are based on Federal State Inspection Service standards (USDA, 1988) and on current marketing schedules. By basing the decisions on standards, any number of automatic control systems can be built to make the same quality determinations on a set of peanuts, therefore eliminating judgement errors by inspectors.

Quality detection hardware

The following quality parameters currently provide input to the expert system: kernel damage, kernel size, single kernel moisture content, bulk moisture content and aflatoxin values. Research to include a flavour indicator and to count and identify foreign material is in progress.

Kernel size and damage are determined using a machine vision system and a colorimeter. Kernel size is determined using the machine vision system by finding the maximum diameter of the minor axis of the kernel with an accuracy of ± 0.0254 mm. The machine vision system is capable of 512×512 pixel resolution and it processes in real time. The system contains a frame buffer module, an analogue-to-digital interface module and a pipeline processor module. Two white-light projectors equiped with adjustable lenses are used to illuminate the kernels. A black-and-white tube-type camera is used to view the objects in two dimensions. About 3 s are required to calculate the kernel size.

Kernel damage is determined using grey level and texture information obtained from the digitized image of the peanut kernel. Damage computations can be made in about 3 s with the machine vision system. Additional damage information is obtained using a

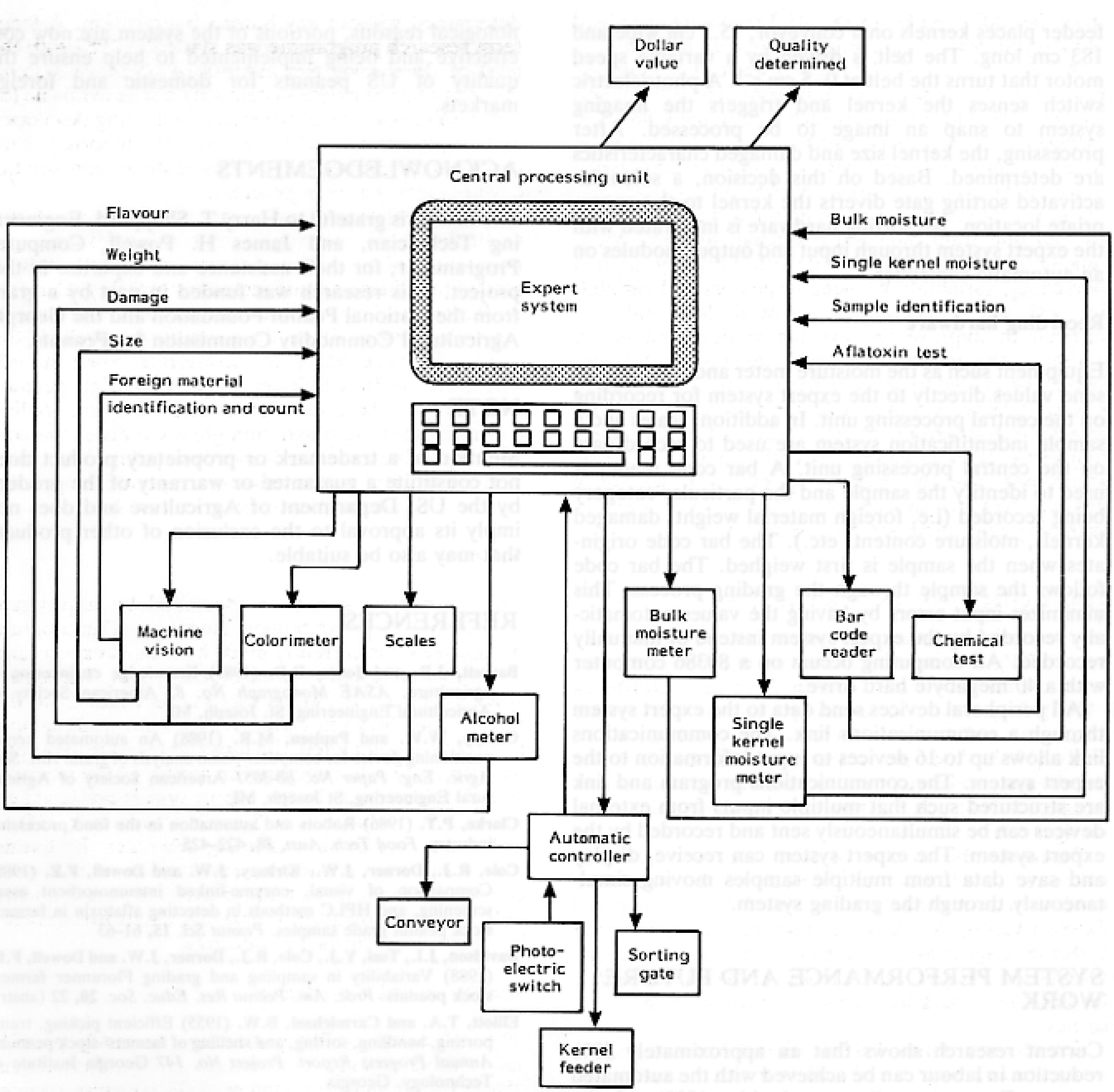

Figure 1 Control loops for an automated inspection system for peanuts

colorimeter. Hue, lightness and saturation information is used to classify several categories of kernel damage. A built in pulsed xenon arc lamp provides consistent uniform illumination. Colour values are determined in about 1 s.

Bulk peanut kernel moisture content is determined on about 150 g of kernels using a DC conductance type moisture meter and inputs to the expert system where the data is automatically recorded and the appropriate calculations made. In addition, procedures were developed and modifications are being made to adapt a DC resistance single-kernel moisture meter to peanuts. Determining single kernel moisture will indicate if peanuts have been improperly dried or if wet and dry peanuts have been mixed. About 75 g of peanuts are used in the single-kernel moisture meter. As with the bulk moisture, single-kernel moisture is automatically recorded by the expert system.

An indirect measurement of aflatoxin, a carcinogen produced by naturally occurring moulds, is made in the old grading system by visually inspecting the kernels for the mould. Cole *et al.* (1988) showed that the visual method is a poor indicator of aflatoxin. Thus, in the interest of food quality, a chemical test was included in the automated system. A fluorometer sends aflatoxin values, in parts per billion resulting from the chemical test, to the expert system.

Flavour indicators such as large kernels, split kernels and headspace volatile concentrations are planned as future inputs to the expert system. An alcohol meter (Pattee *et al.*, 1989) can be used to measure headspace volatile material.

Sorting hardware

Kernels are sorted into their respective areas depending on their size or damage characteristics using a feeder, conveyor and sorting gate. A single kernel feeder places kernels on a conveyor, 15.2 cm wide and 183 cm long. The belt is driven by a variable speed motor that turns the belt at 0–5 cm s^{-1}. A photoelectric switch senses the kernel and triggers the imaging system to snap an image to be processed. After processing, the kernel size and damaged characteristics are determined. Based on this decision, a solenoid-activated sorting gate diverts the kernel to the appropriate location. All sorting hardware is integrated with the expert system through input and output modules on an automatic controller.

Recording hardware

Equipment such as the moisture meter and fluorometer send values directly to the expert system for recording on the central processing unit. In addition, scales and a sample indentification system are used to record data on the central processing unit. A bar code reader is used to identify the sample and the particular category being recorded (i.e. foreign material weight, damaged kernels, moisture content, etc.). The bar code originates when the sample is first weighed. The bar code follows the sample through the grading process. This minimizes input errors by having the values automatically recorded by the expert system instead of manually recorded. All computing occurs on a 80386 computer with a 40 megabyte hard drive.

All peripheral devices send data to the expert system through a communications link. The communications link allows up to 16 devices to input information to the expert system. The communications program and link are structured such that multiple inputs from external devices can be simultaneously sent and recorded by the expert system. The expert system can receive, display and save data from multiple samples moving simultaneously through the grading system.

SYSTEM PERFORMANCE AND FUTURE WORK

Current research shows that an approximately 50% reduction in labour can be achieved with the automated system. From a quality standpoint, 100% of the subjectivity is removed when determining aflatoxin values and some types of kernel damage. The expert system calculates grade values and quality parameters based on the inputs. Research towards improving identification of other types of kernel damage, identifying foreign material and integration of the flavour indicators is in progress.

Food quality is increasing in importance as consumers become more quality conscious. In addition, cost saving through decreasing labour requirements is essential to keep peanut product prices at consumer acceptable levels. Thus, the automated system described here offers the potential to remove human subjectivity from the grading process to ensure the quality of peanuts and to reduce labour costs. Also, certain procedures such as more accurate kernel sizing and identification of foreign material are now possible with the recent advancements in technology. Although a completely automated grading system may be several years away from being implemented for cost and technological reasons, portions of the system are now cost effective and being implemented to help ensure the quality of US peanuts for domestic and foreign markets.

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NOTE

Mention of a trademark or proprietary product does not constitute a guarantee or warranty of the product by the US. Department of Agriculture and does not imply its approval to the exclusion of other products that may also be suitable.

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