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Damage detection in peanut grade samples using chromaticity and luminance

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ABSTRACT

Peanut kernels from grade samples were sorted into damaged and undamaged categories based on their optical characteristics. A machine vision system used grey level information to detect certain types of damage. Also, color coordinate information collected from a colorimeter provided additional damage information. Certain damage categories were correctly classified with 95% accuracy.

1. INTRODUCTION

Quality evaluations are made on samples of all peanuts marketed in the U.S. These evaluations include measuring the amount of moisture, foreign material, damaged kernels, and kernels of different size categories in small samples representing larger lots. Most measurements such as kernel size and moisture content are made objectively using machines developed to determine specific quality factors. However, damaged kernels are evaluated subjectively using trained inspectors.

Kernel damage may occur any time in the production, marketing, storage, or manufacturing process. Damage may be caused by insects, fungal growth, high temperature curing, or freeze damage. Any type of damage will usually result in poor quality factors that are reflected in poor flavor or toxic residues produced by fungal growth. Inspectors are trained to identify kernel discolorations, which indicate damage, on 500 g or 1000 g samples and are provided with color charts and pictures to help in this identification. If a discoloration indicating damage is identified, then a judgement must be made to determine if the kernel is over 25% discolored.[1] Because of the burden placed on individual inspectors and the inherent variability induced by human decisions, the peanut industry has requested that an objective means of determining damage be developed. Accurate determination of kernel damage is one step toward insuring high quality peanuts in our edible markets.

2. BACKGROUND INFORMATION

Man can distinguish several million colors, however, man's ability to use the same criteria to determine the color of an object all day and every day is poor. In addition, two observers may differ in their opinion of what is, for example, dark brownish-grey. Thus, a means of removing human bias from the color determination process is needed.

Several manufactures, such as Hunter and Minolta, market meters to simulate the color response of the human eye. These meters use sensors filtered to measure the three primary colors thus enabling determination of tristimulus values. These tristimulus values can be translated into three-dimensional sets of color coordinates which indicate color perceived by the eye. The three dimensions correspond to luminance and chromaticity coordinates. Hue and saturation are the components of chromaticity. Any of the coordinates can be used to distinguish between two objects and are an estimate of the objects hue, saturation, and intensity. Hue indicates what color, such as red, dominates the object. Saturation indicates how much of the color is there, such as vivid red. Intensity indicates how bright the color is, such as light red.

Three common sets of color space coordinates are L*a*b*, L*C*H°, and Yxy. L*a*b* uses Cartesian coordinates to indicate perceived color. L* is the intensity factor, a* and b* are chromaticity coordinates. L*C*H° is similar to L*a*b* but uses cylindrical coordinates. L* is again the intensity factor, C* is chroma, and H° is the hue angle. Yxy is also similar to L*a*b* but equal distances in the chromaticity diagram do not represent equal differences in perceived color and thus less closely represents human sensitivity to color. Y is the intensity factor while x and y are chromaticity coordinates.[2]

Color machine vision systems have been used experimentally to determine the color of agricultural commodities. Machine vision systems have the advantage of extracting not only color information but also shape information. Wigger et al. classified fungal-damaged soybeans with about 98% accuracy using a color machine vision system.[3] Intensity and ratios of red to blue, red to green, and green to blue were used to classify kernels instead of hue, saturation, and intensity values. The first derivative of pixel values was used to aid in correct classification. Shyy and Misra used similar procedures to classify damaged soybeans with about 85% accuracy.[4] Miller and Delwiche graded peaches by color using red, green, and blue inputs. They normalized luminance to remove illumination effects and reduced the red, green, and blue inputs to two-dimensional chromaticity coordinates. Peaches were correctly classified with 65% accuracy and with a correlation coefficient of 0.90. Indirect diffuse lighting was used.[5]

Color filters on black and white cameras allow color information to be obtained without the expense of a color system. Gunasekaran et al. used a red filter (610 nm) on a black and white machine vision system to classify fungal-damaged soybeans and corn. The corn was classified correctly 84% of the time and soybeans 80% of the time. Front lighting and a black background provided the best illumination configuration.[6]

3. EXPERIMENTAL PROCEDURES

Three methods were used to determine damage in peanuts kernels: contact color measurement, non-contact color measurement, and luminance measurement only. Color measurement includes both chromaticity and luminance measurement. Hue and saturation are the components of chromaticity, while luminance describes the brightness or intensity of the object as perceived by the human eye.

3.1. Damage detection by contact color measurement

A Minolta Chroma Meter CR-200 with an 8 mm diameter measuring area was used to determine damage characteristics. A built in pulsed xenon arc lamp illuminated the kernel. L*a*b*, L*C*H°, and Yxy color space coordinates were collected on a computer for later analysis. CIE standard illuminant C was used to calibrate the meter.

Kernels were individually placed on a glass specimen plate directly over the viewing area. The specimen plate insured that all kernels were the same distance from the viewing area. Initial tests showed that viewing through the plate did not adversely affect meter readings. The 8 mm viewing area enabled only about one half of the kernel to be viewed.

3.2. Damage detection by non-contact color measurement

A Minolta Chroma Meter CS-100 with a viewing area of about 10 mm was used for non-contact measurement. A close-up lens was used to achieve the 10 mm viewing area. As with the CR-200 meter, only a portion of the kernel was viewed. The color coordinates described above were collected on a computer. The meter was attached to a stand so that the meter lens was about 15 cm from the kernel. An 80 cm by 130 cm Graphic Technology, Inc. viewing station with a D7500 light source provided uniform consistent illumination. CIE standard illuminant D65 was used to calibrate the meter. All ambient lighting was excluded during testing.

3.3. Damage detection by luminance measurement

Luminance was measured using a black and white machine vision system. A Dage Newvicon MTI-65 tube camera viewed objects for a Imaging Technologies, Inc. Model 151 imaging system. The camera lens was placed 11.4 cm above the viewing area. The system had 512 vertical by 512 horizontal pixel resolution. The system was controlled and data collected with a Compaq Model 40 portable 20 MHz computer with an 80386 processor. A Moritex MHF 150L fiber optic ring light attached to the camera lens provided illumination. A 120 PVC black friction belt was used as a background when viewing freeze damaged kernels whereas a Dorner #1 hard top accumulator white belt was used as a background for viewing other damaged kernels.

A grey scale value of 103 was used for classifying freeze damaged kernels and a grey scale value of 16 was used for classifying other damaged kernels. The grey scale threshold was selected by observing damaged and undamaged kernels with the machine vision system and choosing a grey level that gave minimum misclassification errors. The percentage of the discoloration on each kernel was recorded. Individual kernels were placed into the viewing area by hand.

3.4. Testing procedure

The Federal State Inspection Service (FSIS) provided samples for testing. The FSIS establishes the guidelines for determining damage and trains inspectors to identify damage in grade samples. Approximately one hundred kernels from each of five peanut categories were supplied by FSIS. These five categories were: obviously damaged, questionably damaged, questionably undamaged, obviously undamaged, and freeze damaged peanut kernels. The skins were removed from the freeze damaged kernels for comparison with undamaged kernels with the skins removed. Further separation of the undamaged kernels into discolored undamaged kernels and undamaged kernels with no discoloration occurred after receiving the samples. The average of the top and bottom viewing for each kernel was used for the chroma meter tests while only one side of the kernel was viewed for the machine vision tests. The same kernels were used for all three measurement tests.

4. RESULTS AND DISCUSSION

Both the CS-100 and CR-200 showed similar results. This similarity was expected since the meters are of similar technology, the only differences being the illumination and viewing methods. Slightly better results were obtained with the CR-200, possibly because the built-in light source on that meter enabled more control over lighting conditions. Only the results of the CR-200 are presented, however the same trends were seen with the CS-100. The three color spaces, L*a*b*, L*C*H°, and Yxy showed similar results which can be expected since the three color spaces are mathematical transformations of each other.

The meters showed considerable potential for identifying freeze damage. By examining a plot of the data, an L* value was chosen to given minimum misclassification errors for the CR-200. At this optimum L* value only one kernel was misclassified as a good kernel while no good kernels were misclassified. The a* value for the CR-200 showed the most promise for identifying damaged kernels. At the optimum cutoff level, 9% of the damaged kernels were misclassified as good undamaged kernels while 8% of the good undamaged kernels with no discoloration were misclassified as damaged. Only general trends were noted for the other damage categories.

The measure of luminance, L* or Y, showed little promise for detecting differences between any damage categories, with the exception for freeze damage as noted above. This indicates that the kernels are all of similar brightness. A general decrease in a*, C*, and x values was seen as the degree of damage increased. A slight increase in b*, H°, and y values from obviously undamaged to obviously damaged kernels was seen but much overlap between these classifications was seen. Table 1 shows the means and standard deviations for three of the color space coordinates that showed the greatest differences.

More distinct differences between damage categories were seen when using the machine vision system. All freeze damaged kernels were correctly classified. Table 1 shows the percent discolorations for all damage categories. An increase in the percent discoloration is seen as the degree of damage increases. When comparing the two extreme categories, only two good undamaged kernels were misclassified as damaged while three damaged kernels were classified as undamaged. However there was some overlap between other categories. If a value of 15% discoloration was chosen to divide all kernels into undamaged and damaged categories, 14% of the undamaged kernels were misclassified while 36% of the damaged kernels were misclassified by the machine vision system.

The machine vision system correctly classified more kernels than the chroma meters. Just the opposite was expected since the chroma meters can measure chromaticity values as well as luminance. The small viewing area of the chroma meters may account for some of the unexpected reduction in performance. Whereas the chroma meters view perhaps one quarter to one half of the side of the kernel, the machine vision system views the entire side of the kernel. None of the systems performed with the accuracy needed to enable implementation of an objective system for determining kernel damage. However, both the chroma meters and the machine vision system show considerable potential for detecting freeze damage. Future research will focus on analyzing kernels with a color machine vision system and a spectrophotometer.

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

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2. Precise Color Communication: Color Control from Feeling to Instrumentation, PCC 812E, Minolta Camera Co., Ltd, Ramsey, NJ 07446, 1988.

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Table 1. Selected color space coordinate values obtained from the Minolta CR-200 colorimeter and a machine vision system for damaged and undamaged peanut kernels.

Damage Category	Color Space Coordinates L*	a*	H°	Percent Discoloration[1]
Damaged				
Mean	50.4	2.9	77.7	26.8
Std. Deviation	7.6	3.1	10.7	22.1
Questionably Damaged				
Mean	52.2	3.3	75.3	21.7
Std. Deviation	8.3	2.9	13.2	13.4
Questionable Undamaged				
Mean	49.1	5.0	68.8	12.2
Std. Deviation	6.8	2.6	12.7	8.4
Undamaged Discolored				
Mean	48.4	7.0	63.4	6.0
Std. Deviation	4.8	2.8	12.9	5.6
Undamaged Good				
Mean	55.1	8.5	65.6	0.2
Std. Deviation	2.2	1.2	3.9	0.2
Undamaged (Skins Removed)				
Mean	73.1	-2.9	99.2	0
Std. Deviation	1.8	0.4	1.1	0
Freeze Damaged				
Mean	59.4	-0.5	91.9	100.0
Std. Deviation	4.4	2.1	6.3	0

[1]Values obtained from the machine vision system.