ELECTRONIC COLOR SORTING OF STRAWBERRIES

N.R. Bulley
Member CSAE
Agricultural Engineering Department
University of British Columbia
Vancouver, B.C.

L.M. Staley
Member CSAE
Agricultural Engineering Department
University of British Columbia
Vancouver B.C.

H.K. Mehra
Agricultural Engineering Department
University of British Columbia
Vancouver, B.C.

INTRODUCTION

The handpicking and sorting of strawberries necessitates a seasonal labor force. The management and salaries for these workers represents a major expenditure in time and money to the strawberry grower. One of the solutions to this problem would be the automation of strawberry picking and sorting.

There are two main approaches to the mechanical picking of strawberries:

(1) the once-over harvester, which would harvest all of the strawberries at one time;
(2) the selective harvester, which would select only those berries that are ripe and leave the unripe berries to be harvested at a later date.

At the moment the once-over harvester seems to be feasible, but it would be incapable of selecting only the ready-to-pick fruit.

Normally the picking and sorting operations are carried out by a visual color judgement of fruit ripeness, which is evaluated on the basis of surface redness. If berries are to be picked mechanically and then processed in a continuous operation, some suitable criterion that correlates with the ripeness of the berry is needed for quick and accurate sorting. An instrument capable of distinguishing between a no. 1 grade of berry and a packing berry could then be used in conjunction with the mechanical once-over harvester for final sorting of the fruit. Several researchers have reported on the reflectance properties of a variety of fruits and correlated these results with different physical properties of the fruit that might indicate the degree of maturity of the fruit[b, c, d, e] (1, 4, 6, 7).

Some of this information has been used to develop instruments capable of grading lemons, tomatoes, and prunes based on color[a, c] (1, 5).

This report describes the design and testing of an instrument for the color sorting of strawberries.

DESIGN OF PROTOTYPE SORTER

Basis of Design

The recent report on the physical and rheological properties of strawberries (4) contains the information needed to design a system capable of sorting ripe from unripe berries. Strawberries were irradiated with different wavelengths of light of equal intensities, and the ratio of the reflected light intensities at different pairs of wavelengths determined. The magnitude of the ratio of the reflected light intensities at 650 and 525 nm correlated most favorably with the subjective evaluation of the percentage of the berry's surface that was red (Figure 1). This ratio of the relative light reflectances at the two wavelengths was called the maturity ratio.

Because handpicking and sorting of strawberries are also based on the overall redness of the berries, the maturity ratio can be used in place of the subjective color evaluation.

Machine Design

Based on the correlation between maturity ratio and subjective berry ripeness, a system for the sorting of strawberries would include the following components:

(1) a light source to illuminate the berry;
(2) light sensors and filters capable of measuring the intensity of reflected light in two narrow regions of the spectrum;
(3) a comparator capable of determining the magnitude of the ratio of the two signals; and
(4) a transducer that will physically separate berries based on the magnitude of this maturity ratio.

Source of Light

Because the analysis of the reflectance spectrum indicated that the maturity of the berry can be correlated with the light reflectances at 650 and 525 nm, it is evident that the reflectances at these wavelengths should be measured simultaneously and from the same spot on the berry. This was done by illuminating the strawberry with one light source and measuring the reflectances with two photo-diodes of the same sensitivity. The optical apparatus for this purpose is shown in Figure 2.

Illumination was provided by a 12-V tungsten lamp (color temperature 2854°K). The lamp was of fixed intensity and could be operated on AC or DC voltage. A focussing lens was mounted in front of the light to focus the light on the subject.

Sensors and Filters

Two available Balser Interference Filters with peak transmissions of 640 and 540 nm (9 nm half-band widths) were used in the prototype sorter. The inten-

[a] Burkhardt, T.H. and R.F. Mrozek. 1971. Light reflectance as a criterion for sorting dried prunes. Paper No. 71-313. Amer. Soc. Agr. Eng., St. Joseph, Michigan.

[b] Goddard, W.B., M. O'Brian, C. Lorenzen, and D.W. Williams. 1970. Development of criteria for mechanization of grading processing tomatoes. Paper No. 70-389. Amer. Soc. Agr. Eng., St. Joseph, Michigan.

[c] Heron, J.R., K.H. Kromer, and G.L. Zachariah. 1971. Variation of tomato reflectance properties in maturity evaluation. Paper No. 71-329. Amer. Soc. Agr. Eng., St. Joseph, Michigan.

[d] Hood, C.E., B.K. Webb, and L.O. Drew. 1968. Correlations of certain physical properties of tomatoes. Paper No. 68-120. Amer. Soc. Agr. Eng., St. Joseph, Michigan.

[e] Long, J.F. and B.W. Webb. 1972. Correlations of reflectance ratios to maturity for whole peaches. Paper No. 72-312. Amer. Soc. Agr. Eng., St. Joseph, Michigan.

RECEIVED FOR PUBLICATION JULY 17, 1973

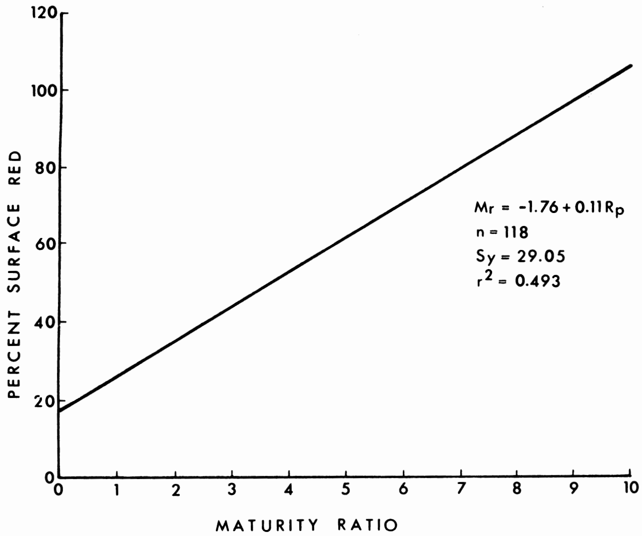

Figure 1. Least square simple regression percent surface red on maturity ratio.

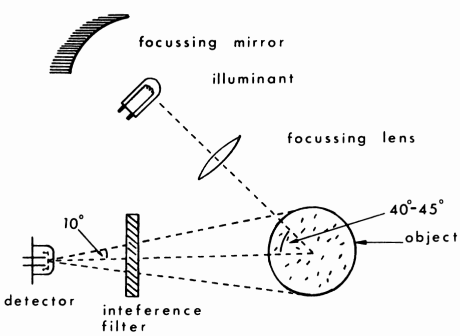

Figure 2. Optical apparatus for color measuring system.

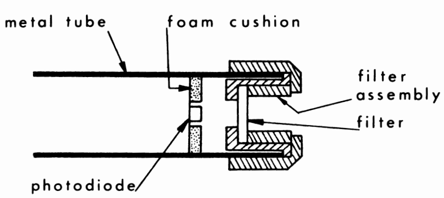

Figure 3. Cross-sectional view of the filter-probe assembly (not to scale).

sity of the reflected light that passed through the filters was measured by two Hewlett Packard HP-5082-4205 pin photo-diodes. The photo-diodes had a response time of less than 1 ns. Because of the directional sensitivity of the photo-diodes, the axis of the sensors had to be within ±10° of the direction of the reflected light.

The filters and photo-diodes were mounted in a probe (Figure 3), which also contained a field effect transistor and 10 megohm resistor. The three leads that are separated from ground by a high impedance were kept short to minimize stray electrical pickup. The filter was held in a rubber holder at one end of the probe and the photo-diode was held behind the filter on a Plexiglas mount. Foam padding was used to cushion the photo-diodes. The probe circuit was obtained from Hewlett Packard application notes (3).

Signals from the photo-diode were amplified using a circuit suggested by Hewlett Packard (2). The amplifier was mounted on a perforated circuit board and enclosed in a metal casing.

Voltage Comparator

The purpose of the comparator was to produce a signal to activate a solenoid that would be used in the actual sorting of berries. When the numerical value of maturity ratio was greater than some predetermined value, the solenoid was to close. When the value dropped below this predetermined value, the solenoid would open.

TESTING PROCEDURE

The experimental setup shown (Figure 4) was used to test the electronic system. A circular disc painted with black matte paint on its periphery was rotated by a variable speed motor. Strawberries were placed in 12 equally spaced holes along the periphery of the disc. Each berry in the hole was illuminated from the top by a 12-V tungsten lamp as it passed under the viewing field of the two photo-diodes. As the berry passed under the light the reflectances were measured by the photo-diodes.

For these trials the separation between acceptable fruit and unacceptable fruit was arbitrarily set at 80% surface redness. From the previous report (4) based on the reflectances at 650 and 525 nm a maturity ratio of 7 would give the best separation of ripe from unripe berries. Those berries having a maturity ratio greater than 7 should have more than 80% surface redness (Figure 1), and those having a maturity ratio of less than 7 would be too green and classified as unacceptable.

Because the filters being used in our prototype were 640 and 540 nm and not 650 and 525 nm, the value of the maturity ratio actually used in the testing of the equipment was set at 5. This meant that when the irradiance upon the 640-nm sensor was equal to or greater than five times that received by the 540-nm sensor, a solenoid would be triggered to close and select the berry, but if the value of this maturity ratio was less than five, the solenoid would remain open and reject the berry. To do this, the signal from the 640-nm probe was reduced to one-fifth using a variable voltage divider and the resulting voltage was subtracted from the signal from the 540-nm probe. If the resulting voltage was greater than zero, the signal activated a current flow in a zener diode, which, in turn, closed the solenoid. If the signal from the comparator was less than zero, the zener diode remained open and the solenoid remained in the open position. As the voltage divider on the signal from the red filter could be altered, any desired ratio could be set and any effective numerical value of the maturity ratio used for the sorting of the berries.

The maturity ratio was initially set at 5 for the test trials to give a separation at the mature or 80% surface redness, but since only one point on the berries was being observed and the exact percent redness is difficult to determine, a sample of 118 berries was analyzed to determine what effect changing the value of the maturity ratio being used for separation would have on the final yield of usable berries.

The berries were electronically separated using different values of the maturity ratio in the comparator.

These results were then compared with a similar separation based on a visual color judgement and the maturity ratio that would give the minimum loss of berries was found (Figure 5). The lost berries included the immature berries that the system had selected and the mature berries that the system had rejected.

RESULTS AND DISCUSSION

The percentage of lost berries de-

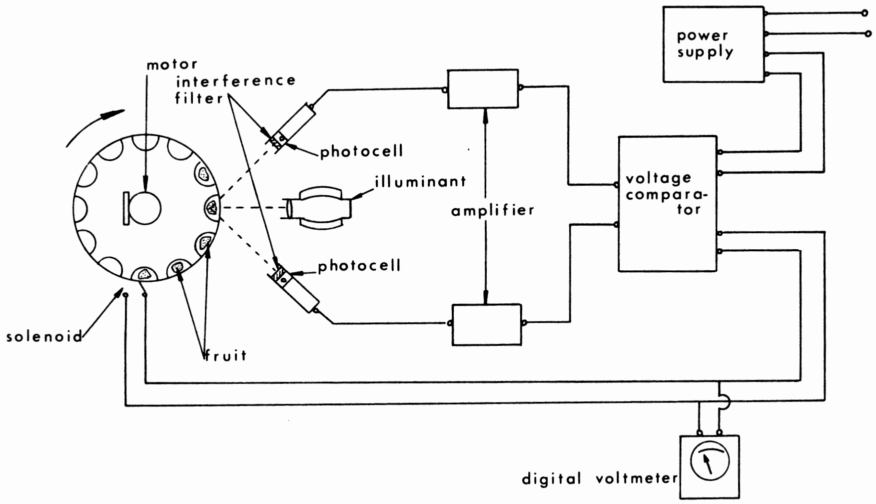

Figure 4. Schematic diagram of experimental arrangement for testing color discriminator equipment.

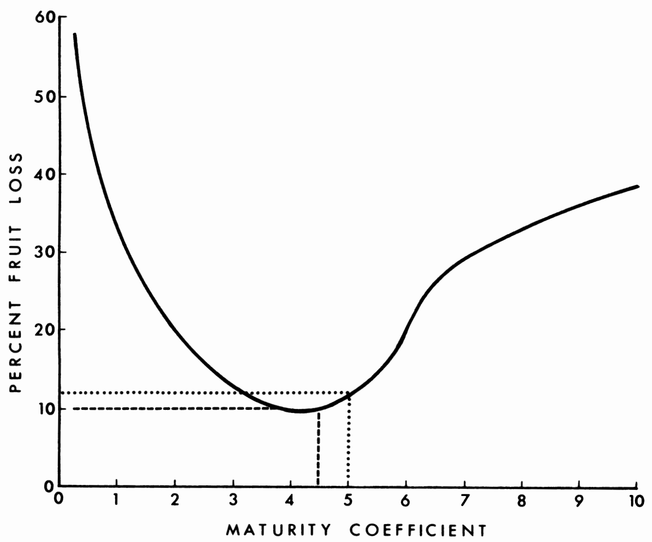

Figure 5. Theoretical loss distribution by selecting different values of maturity coefficient.

creased as the value of the maturity ratio increased to about 4.5 and then steadily increased for higher maturity ratios (Figure 5). The sample of 118 berries gave a minimum loss of 10% at the maturity ratio of 4.5.

A second larger sampling of berries was also handled in the same way in which one group was deemed not ready to pick, i.e., the average berry did not have 80% surface redness; and the second group was deemed ready to pick because in this group the average berry had 80% or more surface redness. In these two instances, using a maturity ratio of 5, the electronic sorter gave percent losses of 25 and 14.4, respectively, when compared with careful hand sorting assumed to give zero loss. The results are shown in Table I.

The losses from unripe berries being placed with the mature berries is really not a loss but represents a lessening of the overall standard of the mature grade berries. The acceptability of this problem in quality control and the acceptability of what percentage of ripe berries that could be rejected would depend on the individual operation and can be controlled to some extent by changes in the maturity ratio used as the bases for separation.

The maximum speed of response of the system was measured at the solenoid by increasing the rotational speed of the disc until the solenoid could no longer respond to the signal change. Maximum response obtained from the components used was 0.166 s per strawberry. Such a response is slow for economical performance for the sorting of strawberries. The speed could be greatly increased by using a faster response solenoid or a completely different transducer. The shape and surface conditions of the strawberries had no measurable effect upon the performance of the system. The signal produced by each berry was found to be independent of the surface conditions within the limits of the accuracy of the measurements. The overhead fluorescent laboratory lights and other stray light appeared to have no effect on the system's performance due to the directional sensitivity of the photo-diodes, but direct sunlight caused a shift in the value of the measured maturity ratio. This might have been due to glare problems but was not investigated since elimination of interference from direct sunlight was easily controlled.

TABLE I RESULTS OF THE TESTS CONDUCTED ON THE ELECTRONIC COLOR DETECTION SYSTEM FOR PERFORMANCE EFFICIENCY USING NORTHWEST CULTIVAR OF STRAWBERRIES

	Total berries	No. of lost berries unripe accepted† or ripe rejected‡	% loss
Immature (<80% red)	207	52†	25
Mature (>80% red)	177	25‡	14.4
Total	384	77	20

The angle of viewing of the sensors to the berry had no effect on the sorting when the measurements were confined between 10° and 60° from the incident illumination on the berry surface. The maximum output signal was obtained when the reflectance was measured at an angle from 40° to 45° from the incident illumination.

The system was tested for its stability by comparing the results performed on the same samples at two different times. A sample of 24 berries was tested just after switching on the system and the same sample was tested after several hours. There was no appreciable shift in the signals.

CONCLUSIONS

(1) The maturity ratio for the Northwest cultivar of strawberry increases as percent surface redness increases.

(2) The maturity ratio can be used in place of the subjective color evaluation as an indicator of the percent surface redness.

(3) Strawberries can be sorted into separate grades based on their maturity ratio. The grades will be determined by the variety of strawberry, wavelengths of reflected light selected for the maturity ratio, and the numerical value of the maturity ratio selected as the criteria for ripeness.

SUMMARY

An instrument has been developed and tested that is capable of sorting ripe (greater than 80 percent surface redness) from unripe (less then 80 percent surface redness) strawberries. The berry is irradiated with light and the ratio of the reflected light intensities at 650 and 525 nanometers determined. The magnitude of this ratio (maturity ratio) correlated most favorably with the subjective evaluation of the percentage of the berry's surface that was red. This ratio was determined electronically and different values of this ratio could be used to separate strawberries into different grades based on color. Problems in color sorting due to fruit size, shape, orientation, and surface moisture have been minimized by the use of the maturity ratio as the basis of sorting.

The basic system should be adaptable to the sorting of any fruit or vegetable that undergoes a color change during ripeness and for which a correlation between this color change and maturity ratio can be established.

REFERENCES

1. Gaffrey, J.J. and O.L. John. 1970. Photoelectric color sorting of vine ripened tomatoes. Marketing Res. Rep. No. 868, U.S. Dep. Agr., Washington, D.C.

2. Hewlett Packard. 1967. Application Notes No. 915. Hewlett-Packard, Palo Alto, California 94304.

3. Hewlett Packard. 1968. Technical data, pin diodes. HP 5082-4200 series. Hewlett-Packard, Palo Alto, California 94304.

4. Mehra, H.K., N.R. Bulley, and L.M. Staley. 1972. Some physical and rheological properties of strawberries. Can. Agr. Eng. 14(2): 85-88.

5. Powers, J.B., J.T. Gunn, and F.C. Jacob. 1953. Electronic color sorting of fruits and vegetables. Agr. Eng. 34: 149-154, 158.

6. Rood, P. 1957. Development and evaluation of objective maturity indices for California freestone peaches. Proc. Amer. Soc. Hort. Sci. 70: 104-11.

7. Stephenson, K.Q. 1964. Selective fruit separation for mechanical tomato harvester. Agr. Eng. 45: 250-253.