Short Communication

A PROCEDURE TO CORRELATE COLOR MEASURING SYSTEMS USING POTATO CHIP SAMPLES

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Abstract

Measurement of potato chip color is extremely important to the potato processing industry. A procedure is described whereby finished chip samples were utilized for correlation of one spectrophotometric chip color measurement system with another. Calibration, standardization, sample preparation, randomization and prediction equation development procedures are described.

Compendio

La medición de la coloración de las papas fritas a la inglesa es extremadamente importante para la industria de procesamiento de la papa. Se describe un procedimiento donde fueron utilizadas muestras de papas fritas a la inglesa para correlacionar un sistema de medición expectrofotométrica del color de las papas procesadas con otro sistema. Se describen los procedimientos de calibración, estandarización, preparación de las muestras y los procedimientos de muestreo al azar. Una ecuación de pronóstico relaciona los dos sistemas.

Introduction

Color is one of the most important quality attributes of food products. Desirable color in finished products is strongly emphasized in the potato processing industry; in the chip processing industry it is absolutely critical.

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ADDITIONAL KEY WORDS: Spectrophotometer, calibration, randomization.

The potato chip industry uses measurement of chip color for accepting or rejecting raw potatoes, screening acceptable raw potatoes, monitoring changes in raw potato constituents, comparing frying systems, adjusting frying times, temperatures and other settings and communicating those aspects of chip production that influence final product quality.

Measurement of chip color is also a very useful research procedure. Research data concerning chip color need to be fully comparable and exchangeable.

Talburt and Smith (13) and Smith (11) provide general background information on potato processing. More recent research provides information on specific constituents in raw tubers and their related effects on chipping quality during processing (1, 5, 7, 8, 9, 12).

Potato chip color can be either subjectively evaluated or objectively measured (2, 3). Subjective methods such as the Potato Chip/Snack Food Association's[2] 5-part chip color chart generally utilize color photographs of chips to which the sample chips can be visually compared (10). Objective methods such as spectrophotometric instruments (being correlated in this study) generally utilize measurement of light reflected from the finished chip material.

In this paper, we describe a procedure for correlating one spectrophotometric system of chip color measurement with another using finished chip samples so that data can be effectively interchanged.

Materials and Methods

AGTRON M-500-A/M-300-A SYSTEM:

Instrument: The measuring instrument was an abridged spectrophotometer (Agtron, Model M-500-A, Magnuson Engineers, Inc., San Jose, CA) capable of measuring reflectance independently at four wavelengths: 1) 439 nm, 2) 546 nm, 3) 588 nm and 4) 640 nm. This unit was electrically coupled to an expanded viewer (Agtron, Model M-300-A, Magnuson Engineers, Inc., San Jose, CA) that provided 194 cm^2 of circular viewing area for use with large, non-homogenous materials such as potato chips. The instrument simultaneously lighted and viewed the sample from *beneath* the viewing stage via a circular, clear-bottomed sample cup (C69458-1).

Calibration: Calibration was accomplished with the instrument stabilized (> 1 hr warmup), set at 640 nm (red mode), black disk (Agtron, M-00) readout at zero, and white disk (Agtron, M-97) readout at 97.

Sample Preparation/Measurement: Sample preparation consisted of crushing the whole potato chips to *< 1 cm × 1 cm size* by hand within the sample

[2]Mention of the trade name or a company name does not constitute a guarantee or warranty of a 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.

bag and pouring into the viewing cup to a depth of > 2 cm. The appropriate color measurement reading (percent reflected light) was observed on the analog readout and recorded manually.

AGTRON E-5F SYSTEM:

Instrument: The measuring instrument was an abridged spectrophotometer (Agtron, Model E-5F, Magnuson Engineers, Inc., San Jose, CA) capable of measuring reflected light at 546 nm and 800 nm. This unit provided 194 cm^2 of circular viewing area via a black metal sample cup in a sliding compartment that could be moved into the spectrophotometer unit for simultaneous lighting and viewing of the sample from *above.*

Calibration: Calibration was accomplished with the instrument stabilized (> 1 hr warmup), set at 546 nm and 800 nm as a ratio (ratio mode) and the pre-installed/pre-adjusted white disk (Agtron M-100) readout at 100; then the sample cup was replaced with a special buff colored disk (Agtron, non-neutral density reflectance type target "pumpkin" disk, Part No. 330115) to obtain a readout of 53 ± 0.5.

Sample Preparation/Measurement: Sample preparation consisted of placing *whole* potato chips horizontally in the sample viewing cup to a depth > 2 cm and closing the sample compartment. The appropriate color measurement (percent reflected light) was then observed on the digital readout and recorded manually.

TEST CHIP SAMPLES:

Sample Preparation: From 22 batches of raw potatoes selected (by experience—reds, cold and warm whites, russets) to provide a range of chip color among batches, we obtained 40 tubers per batch, chipped one slice per tuber using the procedure of Lulai and Orr (4), and determined chip color using the Agtron M-500-A/M-300-A system described above. From this initial chipping, eight of the 22 batches of raw materials were selected to provide finished chips having color readings at approximately 5-point intervals between 10 and 50 on the M-500-A equipment. Then, approximately 13 kg of raw potatoes from each of the 8 selected batches were processed into potato chips on a pilot-scale chip processing line.

Chipping procedure and equipment consisted of: 1) slicing to a thickness of 0.15 cm via a rotary slicer (Knott Machine Co., Norwell, MA), 2) rinsing with flowing tap water in a rotating horizontal screened cylinder to remove surface starch from the slices, 3) de-watering via an agitating screen conveyor, and 4) frying for 90 seconds at 185°C in a blend of corn/cottonseed cooking oil in a continuous fryer (Heat and Control, San Francisco, CA). As the chips exited the fryer, any chips obviously darker or lighter than the visual "normal" color for that particular batch were manually removed and discarded.

Randomization: The eight batches were arranged from light to dark chip color, numbered from 1-8 progressively and randomized (6) for reading order.

Each batch was, in turn, spread on a flat surface in a circular pattern of approximately uniform depth and about 2 m in diameter. A thin divider (approximately 2 m in length, 0.3 m high and 0.5 cm thick) was passed through the bulk chip pile from edge-to-edge along a diameter to divide the bulk chip pile into semi-circular parts, then into quarters and eighths. From a marked position and moving clockwise, each one-eighth (section) was given a number from 1 to 8 utilizing a random number table (6). Sections randomly assigned numbers 1-4 were designated to be read via the Agtron M-500-A/M-300-A system and numbers 5-8 were designated to be read with the Agtron E-5F system.

Each of the 8 sections was further divided into 5 approximately equal amounts of chips which were bagged as samples, numbered 1-5 and randomized for reading order on the designated instrument system. Figure 1 shows Batch #5 divided into sections, one section divided into 5 samples and the final randomized assignment of each section to an instrument.

Chip Color Readings: Immediately prior to reading each section (group of 5 samples), both instruments were again checked for proper calibration and the internal portion of the sample cups were wiped clean with a dry

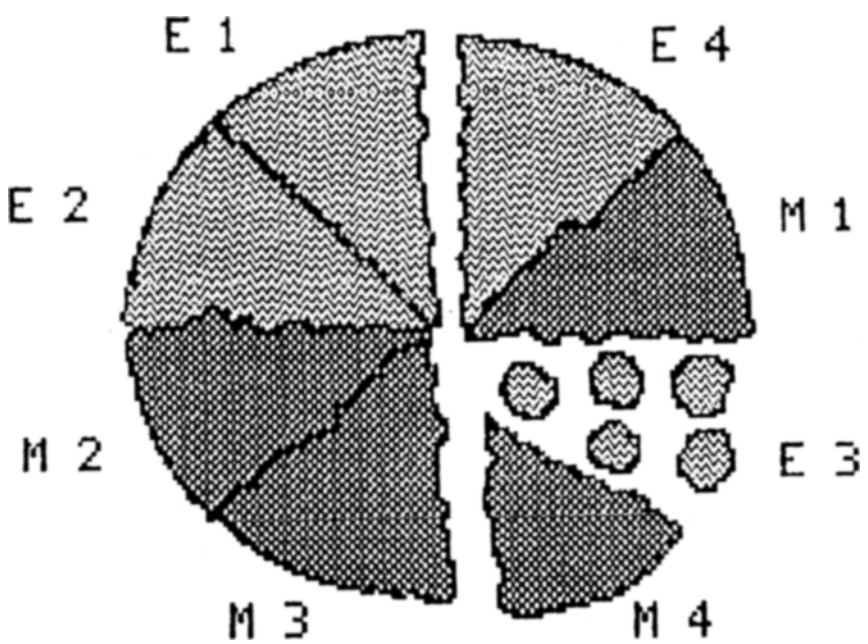

FIG. 1. The division and instrument assignment of Batch #5.

cloth. Reading the two instruments alternately, 3 readings per instrument were taken without disturbing the sample in the instrument. The samples were then discarded. The procedure was repeated until all remaining samples per section, the remaining sections per batch, and all batches were completed. The entire data set were obtained in a continuous 5-hour period.

DATA ANALYSIS:

All data were analyzed utilizing Statistical Analysis System programs (SAS Institute, Inc., Cary, NC). Initial analysis of variance utilized generalized linear models with three factors - section, sample, and instrument system to isolate variations. Graphical analyses were then used to check for patterns in the data set. Finally, curve-fitting techniques (generalized linear model and analysis of variance) were used to formulate the mathematical relationship of readings obtained on the two separate instrument systems. Coefficients of determination R^2 were used to test the fit of the various types of curves.

Results and Discussion

Quality control personnel in the chip processing industry use various types of instruments and calibration procedures. Our instrumentation and procedures were chosen to be reasonably representative of those used by industry for daily quality control, but still provide a constant standard for effective long-term screening of breeding program selections for potential processing varieties.

Because the color analysis application of concern involved a non-homogenous product having non-uniform color, a correlation procedure using potato chips rather than homogenous blanks or disks was useful, especially when the sample preparation procedures were quite different (whole chip versus crushed chip). Thus the decision to use actual product in our tests seemed appropriate.

Chip Sample Preparation: Appropriate selection of raw materials was important in order to produce and assemble discreet chip samples having uniform color within a batch, but ranging in color from dark to light among batches. Based on the 40-slice chip samples from each of the 22 initial trial batches of raw potatoes, we were able to select 8 batches of raw potatoes that provided chips with color readings at approximately 5-point intervals between 10 and 50 on the M-500-A scale. The selected sample materials yielded preliminary test readings on the M-500-A of: Norland - 10, unknown red - 20, Pontiac - 25, unknown white - 32, Lemhi - 37, Redsen - 42, unknown white - 47, and Norchip - 52.

The procedure of carefully dividing each batch of whole chips into 8 sections of 5 samples per section and then sequencing the batches, sections and samples by using random numbers was easily accomplished.

Data Analysis: Figure 2 contains a plot of the raw data. Note that the data points were concentrated for values less than, and somewhat dispersed for values greater than, approximately 30 for either instrument. In our samples, chips having color values greater than 30 (as determined with the instrument systems in the study) exhibited a non-uniformity (intermixed streaks of dark and light color) within a single chip that likely resulted in greater variability in the readings. Chips having color readings below 30 exhibited a more uniform brownish color.

Because the testing was done with complete randomization, all 3 factors (section, sample and instrument system) were significantly different at each level within each batch and over all batches. Graphical analysis revealed no pattern at the sample level, but a form of quadratic relationship was evident at the section level ($P < 0.001$).

For equation development, M represented the M-500-A/M-300-A reading and E represented the E-5F reading, each standardized and utilized as described herein. Establishing M as the dependent variable, E as the independent variable and utilizing a least-square method of fitting linear and non-linear equations to the data, the following quadratic was obtained:

$$M = -1.912 + 1.377\ E - 0.0084\ E^2$$

The R^2 value for this relationship was 0.947.

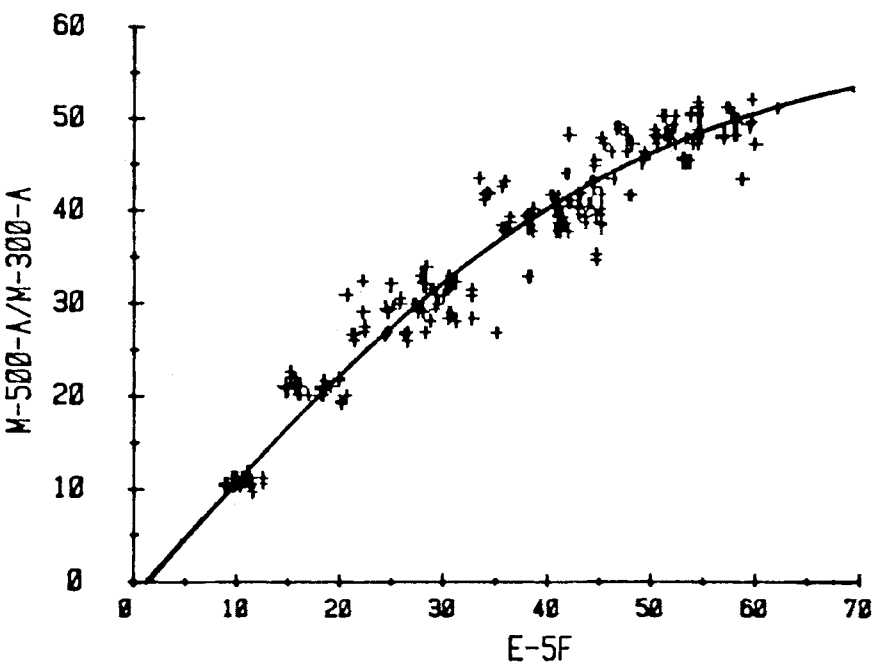

FIG. 2. Plot of the raw data overlain with the predicted relationship.

The predicted relationship for our instrument comparison is plotted along with the data points of Figure 2.

Conclusions

Data obtained from this study indicate that whenever color comparisons of processed potato products are being made, any change in instrumentation or analysis procedures requires a correlation check if data are to be interchanged.

We are confident that the method of correlation of the two instrument systems utilized herein provided a valid on-line comparison utilizing actual chipped product. However, prior to utilizing any prediction equation, it should be verified by an additional series of readings of different chip samples throughout the range of color readings of interest. Any resulting equation and curve should be limited to the instrument systems and products being compared and to the range of data over which a correlation is developed. The procedure we describe herein should be useful when correlating chip color measurement systems, particularly those obtaining the reflectance from the product in a different manner (whole chips viewed from above vs. crushed chips viewed from beneath a sample).

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