A RESEARCH NOTE
IDENTIFICATION OF SENSORY COLOR OPTIMA OF STRAWBERRY YOGURT

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ABSTRACT

Commercially available strawberry yogurts were subjected to preference ranking done by an untrained panel and to instrumental color analysis. Spectral reflectance data and color values expressed in the CIELAB system revealed different color properties of the yogurts, mainly with respect to the hue angle determining whether a product is, e.g., dominantly red or dominantly orange. Sensory evaluations resulted in three groups of products being significantly different from each other with respect to their preference patterns. The tomato color index originally proposed for measuring the ripening index of tomatoes appeared to be useful to reduce 3-dimensional yogurt color values to one dimension and to construct a function of preference ranks versus instrumentally measured data.

INTRODUCTION

In many cases, the consumer response to a particular food is based on visual inspection and grading of appearance properties, i.e., optical properties (including color), physical form and the mode of presentation all of which play a key role in food choice, preference and acceptability (Clydesdale *et al.* 1992; Hutchings 1994). Apart from when appearance factors cause acceptance or rejection, their potential interrelationships with other basic properties of foodstuffs cannot be ignored. It is known that there are certain relationships of food color with flavor or texture properties which cause involuntary associations and, sometimes, confusion (Rohm *et al.* 1997; Burdach 1988). Color is regularly used by consumers to infer quality about the product before tasting, and expectations may influence judgment of liking when the product is finally tasted. In the case of liquid judgment of foods and, particularly, beverages there are many examples where color influences

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pleasantness and acceptability as well as both quantitative and qualitative perception of sweetness or flavor (DuBose *et al.* 1980; Johnson *et al.* 1982, 1983; Francis 1995).

Although there are deliberate possibilities to control the color of liquid dairy products and flavored desserts by varying the concentration of fruit preparations and/or by using natural colorants or artificial dyes, there is still a lack of information on links between color properties expressed in physical terms and the quality as assessed by the consumer. Regarding flavored yogurt, information available covers, e.g., general aspects of consumer choice (McGill 1983), technological treatments (Helming and Kessler 1978), and effects of fruit pulp concentration on consumer response (Ulberth *et al.* 1993). The present study was carried out to identify color properties of strawberry yogurts available on the market and to find out whether color may affect sensory acceptability.

MATERIALS AND METHODS

A sufficient number of cups of nine strawberry yogurts from different producers encoded with A-J were purchased in retail outlets in Vienna. The samples included in the study were standard yogurt, i.e., products without any specific marketing strategies for kids or other special groups of consumers, and represent approximately 80% of the different brands of strawberry yogurts available. In order to prepare the samples for both instrumental and sensory analyses, some individual cups of one type of yogurt were mixed into a batch. Fruit pieces and strawberry granules were removed by means of a sieve and a water jet air pump the day before instrumental and sensory measurements were performed.

Color Measurements

After thermostatting to 15 ± 0.2C overnight, spectral reflectance measurements (each one made in six repetitions) were carried out with a Luci100 test station (Dr. Lange GmbH, Berlin, Germany; D65 Xenon flash lamp, 10° field size) using standard cuvettes for the assessment of liquids as provided by the manufacturer. The system was calibrated with both white and black reference standards and operated using a personal computer and the Dr. Lange Luci QC 1.00 software.

Sensory Evaluation

As young consumers represent the target group of companies distributing flavored dairy products (Rohrer 2000), an untrained panel consisting of a total of 59 students (27 male, 32 female) aged between 19 and 23 years was involved in the study. The panelists were unfamiliar with the sensory evaluation of food materials, and all of them declared to consume strawberry yogurt at least once a week.

Individual evaluations were performed in a room illuminated by normal daylight. Forty mL of the samples were portioned into 100 mL glass beakers, which were encoded with 2-digit random numbers, and the beakers were then placed in closed cardboard boxes. Prior to judging, the panelists were informed on the type of object, strawberry yogurt. Then, each of the panelists had to select one box after the other on a random basis, and was requested to place the samples in a row to obtain a ranked order of 'strawberry yogurt color' preference from 'most liked' to 'least liked'. The ranking procedure was carried out on a white table in front of a window facing northwards. No ties were allowed. Two sets of sessions were conducted on two consecutive sunny days to gather the complete set of sensory data.

For each panelist, numbers were then assigned to the products by using 1 for the most preferred yogurt and 9 for the least preferred one. After building a corresponding table, rank sums (Σ R) and mean ranks (Σ R/n) were calculated for each product. The Friedman test (two-factor ranked analysis of variance) as described by O'Mahony (1986) was then applied to estimate whether significant differences existed between the products (Friedman 1973). When finding a significant ($P < 0.01$) χ^2_R, sign tests with adjusted significance level (McCormack 1965) were used as multiple comparison tests to determine which samples were different from each other.

RESULTS AND DISCUSSION

Instrumental Measurements

For spectral reflectance colorimetry, the surface of a yogurt sample with a defined amount of volume filled in defined glass containers was illuminated by a light source of defined color temperature (6500 K) showing a spectral power distribution $E(\lambda)$ approximating daylight. The intensity of the reflected light is simultaneously measured by means of a photo diode array detector in band widths of 10 nm thus resulting in a function of reflection versus wavelength, $R(\lambda)$. The color stimulus function $\varphi(\lambda) = R(\lambda) * E(\lambda)$ is then, at each wavelength, multiplied with the CIE color matching functions $x(\lambda)$, $y(\lambda)$ and $z(\lambda)$ to yield three curves, and the areas under these curves give the dimensionless tristimulus color primaries X, Y and Z (McAdam 1985; Hunt 1991).

The spectral reflectance functions of three selected yogurt samples are plotted in Fig.1. Yogurt C is characterized by a spectral function showing an absorbance maximum at 530 nm, a steep increase in reflection from 590 nm onward and a plateau > 650 nm indicating predominantly red color quality. As another extreme, the reflection of sample F continuously increased with wavelength and showed also a pronounced response to wavelengths in the yellow-orange region of the spectrum ($540 < \lambda < 590$ nm). In line with some other of the samples, yogurt D showed an intermediate spectral reflection behavior.

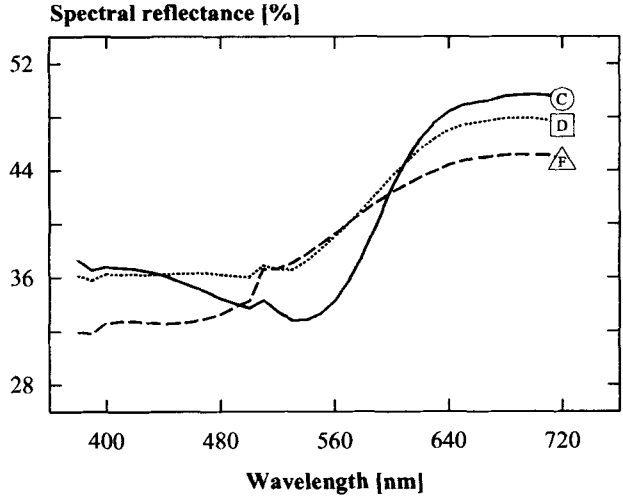

FIG.1. SPECTRAL REFLECTANCE OF SELECTED STRAWBERRY YOGURTS
Inserted codes are sample identifiers.

TABLE 1.
CIELAB VALUES OF STRAWBERRY YOGURT SAMPLES

Sample	L* [-]	a* [-]	b* [-]
A	67.7	3.91	3.90
B	65.2	18.2	0.82
C	66.4	11.9	0.27
D	69.0	5.61	3.87
E	70.2	3.25	5.10
F	67.4	4.13	5.75
G	69.6	7.92	2.41
H	66.4	6.06	2.54
J	68.7	5.72	4.98

In food science, color is mainly described by using the CIELAB system. The L*-, a*- and b*-values of the strawberry yogurt samples are summarized in Table 1. The L*-values as a measure for perceived lightness showed a variation range of 65.2-70.2. a* of strawberry yogurts, corresponding to the position on the red(+)/green(-)-axis, mainly varied between 3 and approximately 8. Only samples B and C showed higher values, and these yogurts were also low in the b* (yellow/blue) coordinate. In two other yogurts, the b*-values exceeded a*. Based on the CIELAB color difference $\Delta E = \sqrt{(\Delta L^{*2} + \Delta a^{*2} + \Delta b^{*2})}$ and averaged tolerances from technical industry (Deutsches Institut für Normung 1979) it should be mentioned that even a difference of ≈ 0.5 in only one of the coordinates

exceeds the limit for sensory perceptibility thus indicating that the yogurts exhibited different color also from a sensory point of view.

Relation of Sensory Responses to Color Measurement Results

The statistical evaluation of the sensory assessments with the Friedman test resulted in $\chi^2_R = 188.2$, which is obviously significant at $P < 0.01$ and indicates that there were significant differences in the color preference rank scores of the yogurt samples. As evaluated by a set of sign tests on a global significance level of P = 0.01, 4 groups of samples separated. The mean ranks of yogurts J, D and E (2.84, 2.96 and 3.18, respectively) were significantly lower than Σ R/n = 4.57 (yogurt H). The next group comprised products E, F and G (5.35, 5.37 and 5.64, respectively) followed by significantly higher values of yogurt C (Σ R/n = 7.64) and yogurt B (Σ R/n = 7.84). Individual ranks for the products with the low mean scores ranged between 1-6, and between 5-9 for yogurts C and B.

In order to identify any relationships between sensory responses and instrumental color estimates the mean ranks of the samples were plotted versus L*, a*, and b*-values and, alternatively, versus L*, C*, and h_{ab}. Here, C* [-] = $\sqrt{(a^{*2} + b^{*2})}$ denotes chroma or color intensity, and h_{ab} [°] = arctan (b*/a*) refers to a approximately uniform measure of hue or color quality being, e.g., 0° for pure red and 90° for pure yellow. Figure 2 shows that the mean preference ranks are obviously distinct functions of L*, C* and h_{ab} where the most preferred yogurt samples (ΣR/n < 4) may be characterized by L*-values of approximately 67-69. Samples with chroma values above 10 appeared to be less preferred, and there was a distinct relationship to the hue angle with a range of approx. 35-45° corresponding to the more preferred yogurts. The products which were significantly least preferred (ΣR/n > 6.5) appeared to be reduced in lightness, much higher in C* and exhibited a dominantly red hue ($h_{ab} \approx 0°$). The strawberry yogurts with intermediate preference scores were also intermediate with respect to chroma intensity but varied with respect to lightness and hue.

It is interesting that, especially for the hue angle and to a lesser extent for lightness, these measures are related to the preference ranks by inversely U-shaped curves implying the existence of an optimum (McBride and Anderson 1990). However, it has to be mentioned that the location of some values within the graphs are not necessarily interrelated. For example, sample F can be characterized by lightness and hue angle being lower and higher than optimum, respectively.

It has been shown in previous papers (Rohm and Jaros 1996) that, in case of color qualities covering only a limited part of the spectrum, semi-empirical and one-dimensional measures may be used to simplify the description of color to a single dimension. For reddish colors, a scaled dimensionless tomato color index TCI = 2000 a* / (L* $\sqrt{(a^{*2} + b^{*2})}$) was proposed by Hunter (1961). Originally, this measure was derived from Hunter-Lab values but, as can be concluded from the underlying theory (Yeatman *et al.* 1960), calculation from CIELAB-values with

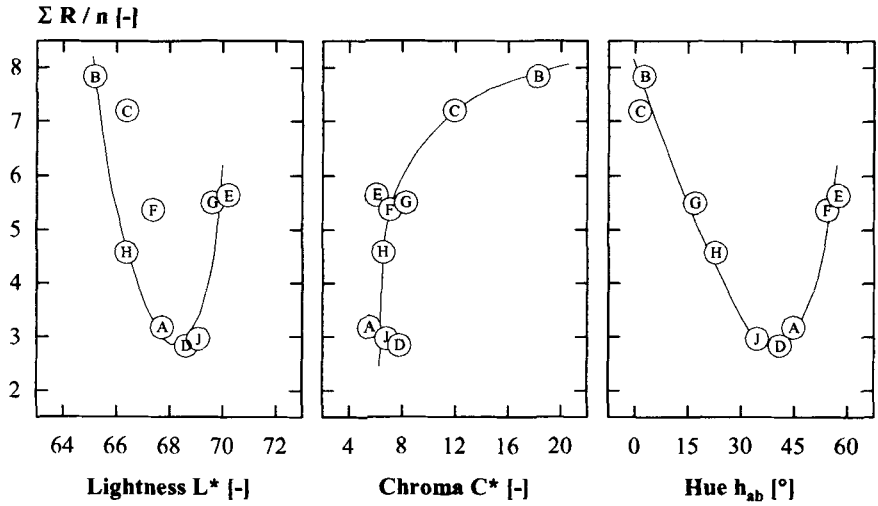

FIG. 2. PREFERENCE RANKINGS OF STRAWBERRY YOGURTS AS RELATED TO INSTRUMENTAL CIELAB COLOR MEASURES
Inserted codes are sample identifiers.

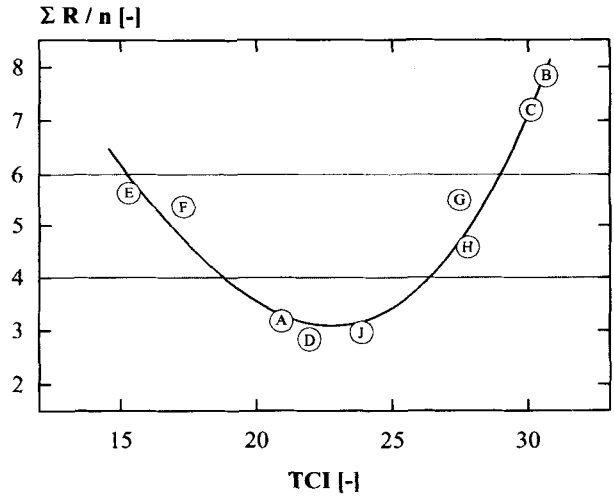

FIG. 3. PREFERENCE RANKINGS OF STRAWBERRY YOGURTS AS A FUNCTION OF THE TOMATO COLOR INDEX
Inserted codes are sample identifiers. Dotted lines separate yogurts significantly ($P < 0.01$) most preferred (A, D, J) or significantly least preferred (B, C). The fit is based on the equation $\Sigma R/n = a + b*TCI + c*TCI^2 + d*TCI^3$.

different weighting factors will only result in numerically different values. The plot of averaged preference ranks versus TCI (Fig. 3) in line with the results of the multiple comparison again leads to the conclusion that there appears to be a sensory optimum. Fitting by means of the cubic equation $\Sigma R/n = a + b*TCI + c*TCI^2 + d*TCI^3$ resulted in a coefficient of determination of $R^2 = 0.944$ with a = 16.1, b = -0.24, c = -0.054 and d = 0.0017. After identification of the samples in the plot we found that it represents an almost perfect mirror of the hedonic scores versus h_{ab} (Fig. 2). Considering panel location and composition this may lead to the conclusion that, as far as commercial products with a fruit content of approximately 7-10% are concerned, the hue dominates sensory responses to color. In case of products with extremely low or high hue angles, there were some additional replies of the panelists to the supervisor regarding an 'unnatural' appearance of the products.

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