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The feasibility of animal source foods' color measurement using CVS

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Abstract. Color assessment of animal source foods was investigated using a computer vision system (CVS) and a traditional colorimeter. With the same measurement conditions, color readings varied between these two approaches. The color measured by CVS was highly similar to the actual color of animal source foods, and ranged from 75.0%-100.0% of actual colors, whereas colors read by a Minolta colorimeter showed non-typical appearances. The CVS-obtained colors were more similar to the color of food visualized on the monitor, compared to colorimeter-generated color chips. Considering these results, it could be concluded that the CVS is a superior alternative for replacing traditional devices by providing better accuracy.

1. Introduction

Animal source foods provide numerous essential compounds in human nutrition [1-3]. Regardless, color is still the most significant sensory attribute when it comes to consumers' food decisions [4]. It is a vital tool in marketing, especially in food marketing [5].

As far as meat color is considered, darker color is less preferred by customers, who connected it with a lack of quality [6]. This physical attribute can be a measure of some imperfection in milk, such as adulteration [7] or spoilage [8] and can indicate long-term storage conditions [9]. Moreover, consumers desire yellow-orange egg yolk rather than off-white yolk [10-11].

Objective color evaluation is crucial for food technology. Currently, the most common color measurement devices are Minolta colorimeters [12, 13]. These devices offer simple and fast food color analysis, and moreover, they are easy to handle and calibrate. Each colorimetric instrument has various settings influencing food color parameters such as color system, illuminant, observer and port size. However, only a few researchers reported all the procedures and technical parameters used for meat and milk color determination, as stated by Tapp *et al.* [12] and Milovanovic *et al.* [13]. The majority of papers reported using illuminant D65, 8 mm aperture size and 10° standard observer for instrumental color measurement of milk and meat.

However, the colorimeter has numerous drawbacks regarding inability to capture broad spectral information related to internal characteristics of subjects [14] and a requirement for subjects with homogenous color [15]. In general, these color devices require homogeneous and uniform samples to achieve consistent analysis [16]. To overcome shortcomings of colorimeters, a new, alternative method, the computer vision system (CVS), has been developed. By applying the CVS, the color readings can be determined for each pixel of a sample image, and the technique is rapid, cost-effective and simple [17]. Additionally, CVS has been widely used for color measurement of animal source foods [18-22].



2. Materials and Methods

Sample preparation, color measurement devices used, sensory tests by a trained panel and statistical analysis performed were all explained in previous publications [18-22].

3. Results and Discussion

3.1. Meat and meat products

Instrumental color data ($L^*a^*b^*$, hue and chroma) for meat and meat products were significantly different when collected by two methods (CVS and colorimeter) [18-21].

Regarding poultry meat, chicken and turkey (lighter colored poultry meat) color acquired by CVS had higher L^* , a^* and b^* coordinates as compared to the colorimeter measurements. Moreover, the color of duck and goose (darker colored poultry meat) had a lighter, more green and blue (with the exception of duck) appearance when read by colorimeter than when acquired by the CVS. The total color difference was 18.50 (chicken) and 22.04 (turkey), so it can be concluded that the two methods accessed the color of these two meats as significantly different and even contrasting. However, the total color differences between the two color devices for goose and duck were half the differences calculated for chicken and turkey [18].

As far as game meat is concerned, wild boar and deer meats (darker colored game meat) as acquired by CVS were darker, redder and yellower (with the exception of deer meat) than the color measured by the colorimeter. On the other hand, quail, pheasant and rabbit meat (lighter colored game meat) color acquired by CVS had higher lightness than the colorimeter readings. All redness values were much higher when acquired by CVS compared to colorimeter measurements, meaning the colors acquired by CVS were more red (or less green). Total color differences ranged from 9.7 (pheasant) to 19.0 (rabbit) [19].

In the study of pork, high lightness, less redness, and relatively high yellowness indexes of pork meat were measured using colorimeter compared to the CVS-acquired colors. In the case of pork meat and fat parts, total color differences were 16.7 and 10.8, respectively [20].

Considering beef meat, the color attributes of a^* , b^* , and chroma values acquired by the CVS were higher than those measured by colorimeter. Total color difference was 15.1 (beef meat parts) and 13.0 (beef fat parts), indicating that the colors assessed by the two methods were opposite [20].

Regarding meat products, uniformly-colored meat products, when color was acquired by CVS, had a lighter appearance (except beef prosciutto), or were more red and less yellow (except for pork prosciutto and raw sausage) than the color measured by colorimeter. Furthermore, when acquired by CVS, bi-colored meat products [21] had a darker color for meat segments (except for Mortadella) and brighter color for fat segments compared with the colorimeter measurements. The variance between the two systems was in line with total color differences (which in meat segments ranged from 7.3 to 14.8 and in fat segments ranged from 7.4 to 12.9). The color results of non-uniformly colored meat products also showed the large differences between the two devices. The highest total meat-parts color difference (20.3) was observed for beef fermented sausage, and maximum total fat-parts color difference (35.3) was observed for fermented pork sausage [21].

3.2. Milk and milk products

The color coordinates of milk and milk products were statistically different when determined by the two devices (CVS and colorimeter) as reported by Milovanovic *et al.* [22].

In terms of milks, the samples seemed lighter and redder when CVS was used than when the colorimeter was used. On the other hand, all milks had higher b^* readings, resulting in more yellow milk appearance, when read by the colorimeter than when acquired by CVS. According to the color difference scale, these two different devices provided easily perceptible total color difference, from 4.3 (cows' milk and goats' milk) to 5.6 (sheep's milk) [22]. The color parameters of raw milks read by colorimeter were in line with the literature color data reported by Milovanovic *et al.* [13].

Overall, dairy products with a dominant white color read by colorimeter had higher L* (brighter color), lower a* (greener color) and higher b* readings (yellowier color) as compared to the CVS-acquired colors [22].

The color of white cheeses assessed by colorimeter was lighter than color acquired by CVS. White cheeses were closer to the red and blue region when color was acquired by CVS as compared to the green and yellow region read by the colorimeter. Color differences ranged from 11.3 to 11.8 [22].

As regards liquid fermented dairy products, all L* and b* readings read by colorimeter were higher than by CVS, whereas a* readings were more in the redness region when color was acquired by CVS compared with colorimeter-produced color. The color variations were in line with the color differences and ranged from 5.8 (yoghurt) to 6.6 (kefir) [22].

Color determinations using the two devices for color detection of sour cream and heat processed cream were significantly different. Moreover, using the colorimeter resulted in a brighter, greener and yellowier appearance as compared to the color acquired by CVS. The total color differences ranged from 6.7 (heat treated cream) to 11.0 (sour cream) [22].

When it comes to the skim milk powder, there was a significant difference between colorimeter and CVS color readings. L* measured by colorimeter had higher values than L* acquired by CVS. On the contrary, all a* values acquired by CVS were higher (more red) than those measured by the colorimeter. Yellowness values measured by the colorimeter were higher (yellowier appearance) than those acquired by the CVS [22].

With regard to the lightness observations of kajmak spread, the colorimeter produced higher values (brighter appearance) than the CVS [22]. All a* values acquired using CVS were less green, in contrast to the colorimeter-measured color, whereas all the b* values indicated a more yellow color with the colorimeter, in comparison to the CVS. The overall color difference was 9.5, indicating the difference in suggested color would be perceptible at a glance.

Dairy products with a dominant yellow color, on color acquisition by the CVS, showed darker (apart from Grana Padano), more red and more blue appearance [22], as compared to the colorimeter. All yellow cheeses, except Grana Padano, on color acquisition by the CVS, showed darker color than was measured with the colorimeter. Regarding a* observations, the CVS resulted in more red appearance, or colors obtained by the colorimeter were less green. The total color difference ranged from 6.0 for pasta filata to 14.9 for processed cheese, indicating large color differences [22].

Regarding butter color, a* values acquired by CVS were higher than those measured by the colorimeter, indicating a less red appearance. In contrast, yellowness data were higher with the colorimeter than by CVS. There was a great total color difference, 11.8 [22].

Apricot fruit yoghurt had different color data as read by the colorimeter and the CVS [22]. Colorimeter-generated color was lighter in terms of L* value. Furthermore, the redness parameter was higher with the CVS than with the colorimeter. Yellowness was higher with the colorimeter than with the CVS, denoting a more yellow appearance of this fruit yoghurt.

The color of whey powder as acquired by the CVS was significantly darker, more red and less yellow compared with colorimeter-measured appearance. The total color difference was 17.1, indicating a large color difference [22].

3.3. Eggs

The color parameters of eggshell measured by the two approaches were statistically different with some exceptions (L* reading for quail's eggshell and WI for turkey's eggshell). The color of eggshell gathered through the colorimeter depicts a brighter, less red and more yellow appearance than the CVS-acquired color.

Regarding the color of egg yolk, the colorimeter produced a lighter (except goose egg's yolk), more green and less yellow color, whereas the CVS indicated the appearance of albumen as lighter (except quail's egg albumen), more red and less yellow than the colorimeter.

4. Conclusion

Even if the same subjects and parameters for color evaluation were studied, significant differences were observed in the color properties measured by the two systems. The colorimeter was less representative and less precise for measuring the color of animal source foods. The reason for this was light penetration, the amount of which related to the device used. In the CVS, the lamps are placed 50 cm above the subject and the light hits the surface and only penetrates a few mm into the subject, whereas the colorimeter is positioned onto the subject surface, and the light penetration through the food matrix must be higher than for CVS. Therefore, the CVS should be seriously taken into account as an effective and more powerful alternative to the colorimeter and as a non-contact tool for measuring the color of animal source foods.

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