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COLOR MEASUREMENT OF ANIMAL SOURCE FOODS

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Abstract
Rapid and objective assessment of food color is necessary in quality control. The color evaluation of animal source foods using a computer vision system (CVS) and a traditional colorimeter is examined. With the same measurement conditions, color results deviated between these two approaches. The color returned by the CVS had a close resemblance to the perceived color of the animal source foods, whereas the colorimeter returned not typical colors. The effectiveness of the CVS is confirmed by the study results. Considering these data, it could be concluded that the colorimeter is not representative method for color analysis of animal source foods, therefore, the color read by the CVS seemed to be more similar to the real ones.

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Introduction

Animal source foods are an essential source of numerous components [1–3]. Nowadays, the color represents a decision-making criterion in the food purchasing [4]. It is a crucial tool in the food marketing [5].

In terms of meat color, lighter appearance is preferred by consumers due to their association of dark meat with quality lack [6]. This sensory property also can be an indicator of some defects in milk, such as adulteration [7], spoilage [8] and the long-term storage conditions [9]. Regarding eggs, yolk [10] and shell color [11] make the valuable quality attribute for consumers' judge. In general, customers rather desire the yellow-orange egg yolk than off-white yolk [12–13]. In case of the eggshell, consumer priority for color differs worldwide [14]. Furthermore, white-shell eggs are desired in Japan, North and Central America, Middle East, India, Taiwan, and Philippines, whereas brown-shell eggs are opting for Latin America, Europe and China [15].

Instrumental color evaluation is vital for food technology and can be performed using instruments such as colorimeters. Commonly the meat, milk and egg color measurements are evaluated using Minolta colorimeters [16–19]. These devices offer a simple and fast food color analysis, moreover, they are easy to handle and calibrate. Each colorimetric instrument has several settings influencing food color parameters such as color system, illuminant, observer, port size and calibration procedure. However, only a few percentages of papers reported all the procedures and technical parameters used for animal source foods (meat, milk and egg) color determination as stated by Tapp et al. [16], Tomasevic et al. [17], Milovanovic et al. [18], Milovanovic et al. [19,20].

On the other hand, the colorimeter has a various number of shortcomings concerning failure to capture broad spectral information in terms of internal characteristics of objects [21] as well as the incapability to measure a extend surface, with non-homogenous color [22]. To achieve consistent analysis these color instruments require the homogeneous and uniform samples [23]. Furthermore, to overcome shortcomings of colorimeters, it has developed a new alternative method known as a computer vision system (CVS). By applying the CVS, the advantage of ability to determine color readings for each pixel of a sample image provides the rapidness, budget and simplicity [24]. Additionally, CVS has been widely performed for color measurement of animal source foods [25–29].

Material and methods

Sample preparation, color evaluation equipment used, sensory tests by a trained panel and statistical analysis performed were all explained in previous publications [19] and [25–29].

Results and discussion

Meat and meat products

Instrumental color data (L*a*b*, hue and chroma) for meat and meat products were significantly different [25–28].

The instrumental color assessments acquired by the colorimeter for chicken and turkey (lighter colored poultry) are in line with the previously published color results for chicken [30] and turkey breast meat [31] acquired with other colorimeters. Furthermore, the appearance of chicken and turkey meat returned from CVS was lighter, whereas duck and goose were darker [25]. Therefore, with the total color difference of ΔE = 18.5 for chicken and ΔE = 22.04 for turkey meat, it can be concluded that the two systems performed their color significantly different and even contrasting (Figure 1). The color of duck and goose breasts (darker colored poultry meat) measured with the CVS was darker and more "red" than the colour obtained with the colorimeter (Figure 1). When comparing the colorimeter-generated color readings obtained, they are in concurrence with the data available in previously published papers [32,33]. However, the total color differences between the two color devices, for goose and duck were half the values calculated for chicken and turkey [25].

The instrumental color data read by colorimeter for wild boar and deer (darker colored game meat) are in concurrence with Borilova et al. [34] and Kudrnáčová et al [35] for wild boar and deer meat, respectively. The color of wild boar and deer meat read by CVS had lower L* and higher a* values (brighter and redder color) than colorimeter (Figure 2). However, quail, pheasant and rabbit (lighter colored game meat) indicated that the color acquired by CVS had the higher lightness than the colorimeter. All redness values were much higher when measured with CVS compared to colorimeter, meant that the color acquired by CVS was more "red" (or less "green"). Total color difference was in range from 9.7 (pheasant) to 19.0 (rabbit) [26].

Regarding pork meat, the color traits measured with CVS and colorimeter were significantly different with the exception of b* reading [27]. The high lightness (L*), a less redness (a*), and relatively high yellowness (b*) indexes of pork meat were read by colorimeter in comparison to the CVS. In case of meat and fat pork parts, total color difference was 16.7 and 10.8, respectively, indicating that for meat parts even contrasting. These results are in good agreement with Girolami et al. [36], who confirmed using CVS as more precise and closer to the exact color value. Furthermore Sun et al. [37] concluded that the CVS has potential to be used as a tool in predicting pork color attributes. In addition, Sun et al. [38] also postulated that CVS can accurately evaluate pork color, a major advantage over traditional subjective evaluation and/or colorimeter devices which have their own.

Beef lightness read by the colorimeter was higher than the color obtained using the CVS. On the contrary, the color attributes such as a*, b*, chroma values, gathered through the CVS, were higher [27]. Meat and fat parts were assessed in darker colors when measured with CVS compared to the colorimeter device (Figure 3). Girolami et al. [36] assessed that the light from a colorimeter illuminates about 15–20 mm, and about 5 mm from the CVS. Similarly, Trinderup et al. [39] found that light penetrates about 20 mm from a colorimeter, and a few mm from the CVS. With regard to the results of pork and beef, they are

Figure 1.
Color of poultry meat as evaluated by the two methods [25]

Figure 2.
Color of game meat as evaluated by the two methods [26]

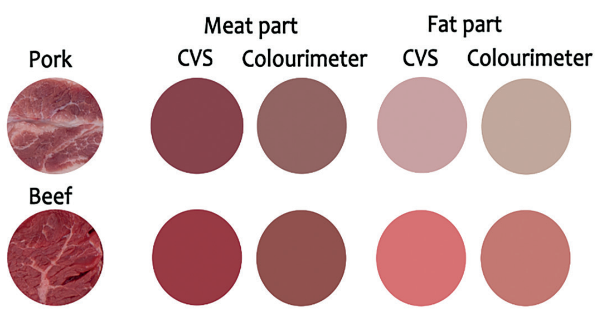

Figure 3. Color of pork and beef meat as evaluated by the two methods [27]

in good agreement with findings from previous investigation of Girolami et al. [36] that the color predicted with the CVS is closer to the sample than the color read by colorimeter, making CVS more representative for beef color analysis.

Considering meat products, uniformly-colored meat products revealed that the color gathered through CVS had higher lightness value than that obtained with the colorimeter. All the a* values were higher when measured with CVS compared to colorimeter, therefore, the color obtained with CVS was more "red" (Figure 4). This investigation is in concurrence with the conclusions of Valous et al. [40] that CVS is a tool that can objectively specify color of cooked-hams. Regarding bi-colored meat products, the total color differences between the two methods of the meat segments were in a range from 7.3 up to 14.6 and for the fat parts in a range from 7.7 up to 12.9 [28]. Meat segments were assessed in darker and fat segments in lighter colors when obtained by CVS compared to colorimeter (Figure 5a).

In terms of non-uniformly colored meat products, the color of meat parts read by CVS was significantly darker, had greater intensity and was more saturated, compared to colorimeter-measured equivalents (Figure 5b). The opposite was observed for CVS-generated fat color. Girolami et al. [36] also concluded that CVS is a method that can objectively evaluate the color of fermented sausages.

In addition, the possible reason for the color deviations between these two systems could be the interaction light source with the surface of meat which is translucent [22]. This caused light diffusion from light source resulting in less accurate analysis by the colorimeter.

Sensory tests also showed differences between these two color devices. Frequency of similarityassessed by the panelists was 100% for all poultry, game, beef and pork meat samples (Table 1).

Frequency of similarity (the first test) was very high and ranged from 85.7% for rabbit meat, 92.9% for chicken pate, beef sausage, smoked bacon, dry pork neck and pancetta, to 100% for all the other meat products. The second test (CVS vs. colorimeter) demonstrated that the CVS-produced squares were more resemble to the sample of the poultry, game, pork, beef and meat products visualized on the monitor, compared to colorimeter-produced color square in all (100%) individual trials conducted. The third test (level of difference) regarding meat products revealed that, as assessed by the assessors, the magnitude of differences between the color chips generated by CVS and colorimeter and displayed on the monitor, ranged from 1.0 („very low") for deer meat to 4.7 („high") for turkey breast meat [25–28].

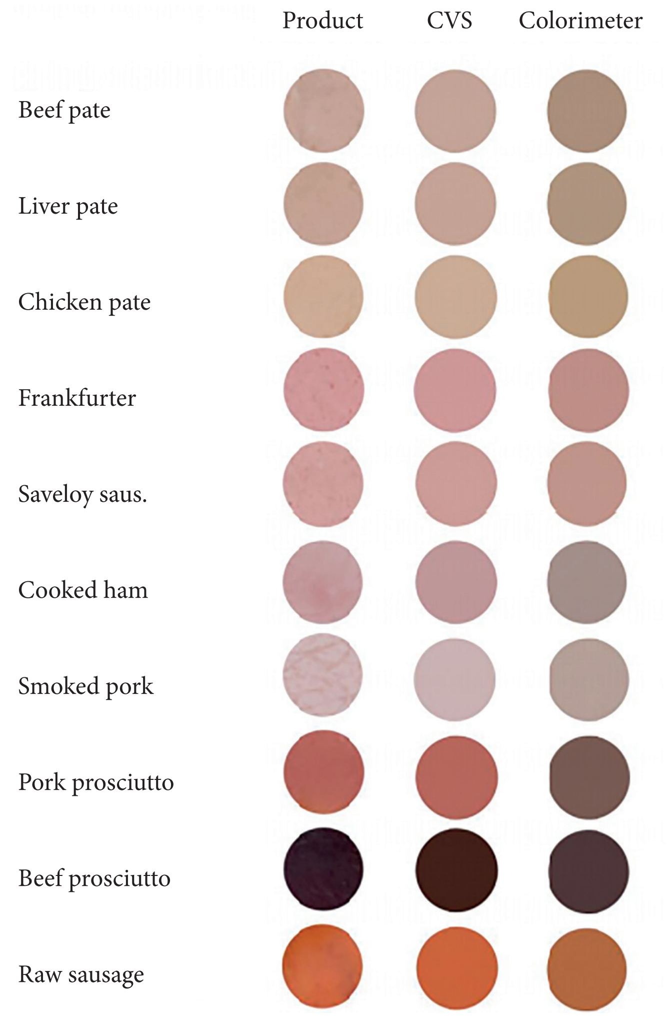

Figure 4. Color of uniformly colored meat porducts as evaluated by the two methods [28]

Figure 5. a) Color of bi-colored and b) non-uniformly colored meat products as evaluated by the two methods [28]

Table 1. Similarity test results of meat and meat products [25–28]

	Frequency of similarity	Level of similarity	CVS vs. Colorimeter	Level of difference test
Beef pate	100.0%	3.4 ± 1.4[a, b]	CVS (100.0%)	3.0 ± 1.1[a, b, c]
Liver pate	100.0%	3.6 ± 1.1[a, b]	CVS (100.0%)	2.4 ± 1.1[a, b, c]
Chicken pate	92.9%	3.5 ± 1.0[a, b]	CVS (100.0%)	2.1 ± 1.0[a, b, c]
Beef fermented sausages	92.9%	3.6 ± 1.0[a, b]	CVS (100.0%)	3.2 ± 0.4[a, b, c]
Pork fermented sausages	100.0%	4.0 ± 0.8[a, b]	CVS (100.0%)	2.3 ± 0.5[a, b, c]
Frankfurter	100.0%	4.0 ± 1.1[a, b]	CVS (100.0%)	1.7 ± 0.5[a, b]
Saveloy sausage	100.0%	3.8 ± 0.9[a, b]	CVS (100.0%)	1.2 ± 0.5[a]
Mortadella	100.0%	2.9 ± 1.2[a]	CVS (100.0%)	2.1 ± 1.1[a, b, c]
Cooked ham	100.0%	3.0 ± 1.2[a, b]	CVS (100.0%)	3.6 ± 0.3[b, c]
Smoked cooked bacon	92.9%	3.1 ± 1.3[a, b]	CVS (100.0%)	2.2 ± 0.4[a, b, c]
Smoked cooked pork	100.0%	3.5 ± 1.0[a, b]	CVS (100.0%)	2.8 ± 1.2[a, b, c]
Pork prosciutto	100.0%	4.1 ± 0.8[a, b]	CVS (100.0%)	4.2 ± 1.0[c]
Beef prosciutto	100.0%	3.6 ± 0.9[a, b]	CVS (100.0%)	3.1 ± 1.8[a, b, c]
Dry pork neck	92.9%	3.5 ± 1.3[a, b]	CVS (100.0%)	3.0 ± 0.7[a, b, c]
Pancetta	92.9%	2.8 ± 1.5[a]	CVS (100.0%)	2.7 ± 1.5[a, b, c]
Pork hamburger	100.0%	2.8 ± 1.0[a]	CVS (100.0%)	2.0 ± 1.0[a, b]
Beef hamburger	100.0%	3.4 ± 1.3[a, b]	CVS (100.0%)	2.7 ± 1.0[a, b, c]
Raw sausage	100.0%	4.4 ± 0.8[b]	CVS (100.0%)	3.2 ± 1.5[a, b, c]
Chicken breast	100.0%	1.7 ± 0.8[a]	CVS (100.0%)	3.8 ± 1.4[a]
Duck breast	100.0%	2.4 ± 1.0[a, b]	CVS (100.0%)	1.8 ± 0.4[b]
Goose breast	100.0%	3.1 ± 0.8[b]	CVS (100.0%)	1.4 ± 0.5[a]
Turkey breast	100.0%	2.9 ± 1.03[b]	CVS (100.0%)	4.7 ± 0.7[b]
Quail	100.0%	2.7 ± 1.3[a]	CVS (100.0%)	3.6 ± 1.4[a]
Wild boar	100.0%	3.4 ± 1.3[b]	CVS (100.0%)	1.9 ± 0.9[b, c]
Rabbit	85.7%	2.7 ± 1.2[a]	CVS (100.0%)	4.2 ± 1.2[a]
Deer	100.0%	4.1 ± 0.8[b]	CVS (100.0%)	1.0 ± 0.0[c]
Pheasent	100.0%	3.2 ± 1.2[a, b]	CVS (100.0%)	3.4 ± 1.3[a, b]
Pork	100.0%	2.6 ± 0.8[a]	CVS (100.0%)	4.2 ± 0.7[a]
Beef	100.0%	4.1 ± 0.5[b]	CVS (100.0%)	4.0 ± 0.7[a]

Means in the same column with different small letters are significantly different (P < 0.05)
Five-point scale ranks from 1 "very low", 2 "low", 3 "moderate", 4 "high" to 5 "very high".

Milk and milk products

The color coordinates of milk and milk products were statistically different as reported by Milovanovic et al. [29].

Regarding milks, samples seemed lighter and redder when CVS was considered, meaning they were in the red space. In contrast, all the milk samples showed higher yellowness readings read by the colorimeter as compared with the CVS, denoting more yellow milk appearance (Figure 6). Total color difference provided well perceptible difference, ranged from 4.3 (cows' milk and goats' milk) to 5.6 (sheep's milk). The color parameters of raw milks read by colorimeter are in line with the literature data reported by Milovanovic et al. [18].

The color of white chesses assessed by colorimeter was lighter than color acquired by CVS. White cheeses were closer to the red and blue region as compared to the green and yellow region read by the colorimeter (Figure 6). Color difference was according to the scale in the range of 11.3–11.8 [29]. These instrumental results obtained with the colorimeter are in agreement with findings from previous investigations determining the color of fresh cheese [41] and brined cheese [42].

As regards to the fermented products, all L* and b* readings read by Minolta were higher than by CVS, whereas a* readings were in the redness region compared with colorimeter-produced color (Figure 7). The color variations are in line with ΔE, ranged from 5.8 (yoghurt) to 6.6 (kefir) [29]. Concerning fermented products, color readings obtained by the colorimeter are in line with previously published results of color measurement for yoghurt [43], set-style yoghurt [44] and kefir [45] acquired with other colorimeters.

Color determinations using two devices for color detection of sour cream and heat treated cream were significantly different. Moreover, using the colorimeter is obtained brighter, greener and yellower appearance as compared to the color read by CVS (Figure 7). The total color difference ranged from 6.7 (heat treated cream) to 11.0 (sour cream) [29].

When it comes to the skim milk powder, there is a significant difference between colorimeter and CVS color readings. On the contrary, all a* values obtained by CVS were higher (more "red") than those measured by the colorimeter (Figure 7). Yellowness values acquired by the colorimeter were higher (yellower appearance) compared with those gained by the CVS. Total color difference was 15.4 [28].

With regard to the lightness observations of kajmak spread, the colorimeter had higher values (brighter appearance) than CVS. All a* values observed using CVS were less "green" in contrast to the colorimeter-observed color, whereas all the b* observations indicated more "yellow" color with the colorimeter, in comparison to the CVS (less "yellow" color of kajmak spread) (Figure 7). The overall color difference was 9.5, indicating the difference in color perceptible at a glance [29].

All yellow cheeses except Grana Padano indicated that color assessed with CVS was darker than the color acquired with the colorimeter. Regarding a* observations, CVS resulted in more "red" appearance or colors obtained by the colorimeter were less "green" (Figure 8). The total color difference was in a range from 6.0 for pasta filata up to 14.9 for processed cheese resulting in great color difference detection. The instrumental color measurements obtained with the colorimeter for these samples are similar to the previously published results for semi-hard cheese [46], cheese with mould [47], Pasta Filata — Mozzarella [48], Grana Padano [49], processed cheese [50].

Regarding butter color, observed a* reading using CVS was higher than by the colorimeter indicating less "red" appearance (Figure 9). In contrast, yellowness data

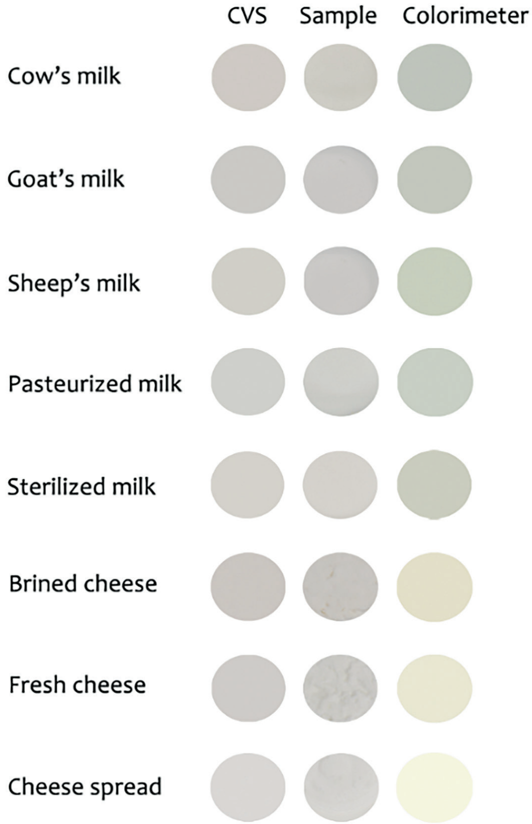

Figure 6. Color of milks and white cheeses as evaluated by the two methods [28]

Figure 7. Color of fermented products, cream products, skim milk powder and kajmak spreads evaluated by the two methods [28]

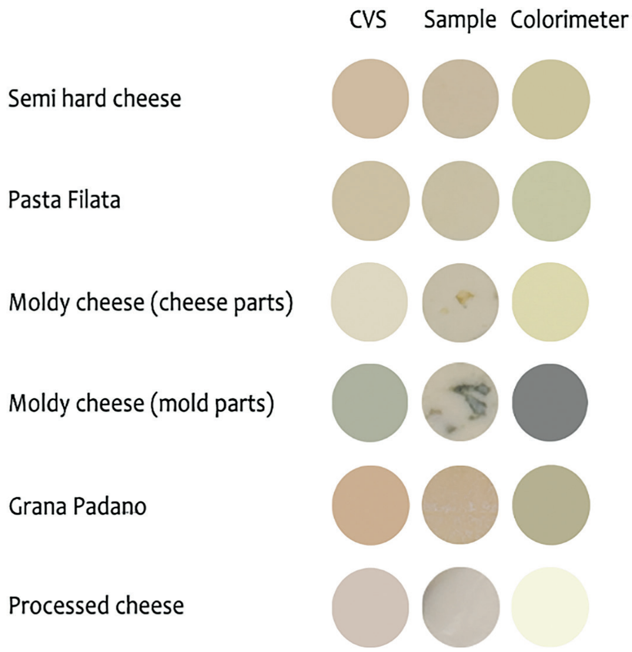

Figure 8. Color of yellow cheeses as evaluated by the two methods [29]

Figure 9. Color of butter, kajmak products, fruit yoghurt and whey powder as evaluated by the two methods [29]

were higher with the colorimeter than by CVS. There is a great color difference regarding the total color difference ΔE = 11.8 [29]. The color results read by colorimeter are in line with the study conducted by Truong, Palmer [51], whereas the color results of butter obtained by CVS are in the concurrence with the Tarlak, Ozdemir [52].

Furthermore, a* values obtained using CVS, were higher giving more "red" color for kajmak samples in contrast to the more "green" color obtained by colorimeter (Figure 9). In contrast, b* values were higher with the colorimeter, denoting yellower color than CVS, which were more "blue" [29].

Fruit (apricot) yoghurt had different color coordinates according to the colorimeter and CVS. Colorimeter-generated color was brighter. In contrast, the redness parameter was higher with CVS device than with the colorimeter. CVS-generated color was more in the redness region than greenness (Figure 9). Yellowness was higher with the colorimeter than CVS [29].

The color of whey powder measured with CVS was significantly darker, more "red" and less "yellow" compared with colorimeter-measured appearance (Figure 9). The total color difference was 17.1, indicating a large color difference [29].

The color deviations between two color systems could be affected, among other factors, by the penetration depth of the light, which is different between a colorimeter (placed on the sample surface) and CVS (a lamp located far). This, therefore, caused scattering from the illumination source, thereby colorimeter assessments were less representative [29].

CVS-produced color on display showed that the assessors found products with the same color inside a box as the samples presented on display. Frequency of similarity was 100.0% for all milk and dairy products. The level of similarity ranged from "moderate" to "high". The second test showed that CVS-observed color was more resemble to those of the actual milk product in comparison with the colorimeter-observed color [29]. Triangle test revealed that there was the difference between color returned by CVS and the colorimeter, and this is a good agreement with the instrumental data. The color difference between these two devices was ranged from 1.7 ("low") to 4.3 ("high") (Table 2).

Eggs

The color parameters of egg samples measured by the two approaches were statistically different with some exceptions (L* reading for quail's egg shell and WI for turkey's egg shell) [19].

The color of eggshell gathered through the Minolta depicted brighter, less „red" and more „yellow" appearance than CVS (Figure 10). According to ΔE scale, these two

Table 2. Sensory test results for milk and milk products [29]

	Frequency of similarity	Level of similarity	CVS vs. Colorimeter	Level of difference test
Butter	100.0%	3.3 ± 1.1^{a}	CVS (100.0%)	$3.7 \pm 0.6^{e\text{-}f}$
Semi hard cheese	100.0%	3.1 ± 0.7^{a}	CVS (100.0%)	$3.0 \pm 0.4^{c\text{-}e}$
Pasta Filata	100.0%	3.4 ± 0.8^{a}	CVS (91.7%)	$2.6 \pm 0.7^{a\text{-}d}$
Brined cheese	100.0%	3.7 ± 1.1^{a}	CVS (100.0%)	$3.7 \pm 0.9^{e\text{-}f}$
Fresh cheese	100.0%	3.2 ± 1.3^{a}	CVS (100.0%)	$3.3 \pm 1.1^{c\text{-}f}$
Moldy cheese	100.0%	3.1 ± 1.0^{a}	CVS (100.0%)	$3.7 \pm 0.9^{e\text{-}f}$
Grana Padano	100.0%	3.6 ± 0.8^{a}	CVS (100.0%)	$3.7 \pm 0.7^{e\text{-}f}$
Processed cheese	100.0%	3.4 ± 1.2^{a}	CVS (91.7%)	$3.7 \pm 0.8^{d\text{-}f}$
Cheese spread	100.0%	3.1 ± 1.1^{a}	CVS (83.3.%)	$2.7 \pm 1.1^{a\text{-}e}$
Fresh kajmak	100.0%	3.0 ± 1.0^{a}	CVS (100.0%)	$3.4 \pm 0.8^{c\text{-}f}$
Mature kajmak	100.0%	3.2 ± 0.6^{a}	CVS (100.0%)	$3.4 \pm 0.8^{c\text{-}f}$
Kajmak cream	100.0%	2.9 ± 1.2^{a}	CVS (100.0%)	$3.0 \pm 0.9^{c\text{-}e}$
Kajmak spread	100.0%	3.4 ± 1.1^{a}	CVS (100.0%)	$3.2 \pm 0.9^{c\text{-}f}$
Cow's milk	100.0%	3.7 ± 1.1^{a}	CVS (100.0%)	1.7 ± 0.5^{a}
Goat's milk	100.0%	3.2 ± 1.0^{a}	CVS (100.0%)	$2.5 \pm 0.7^{a\text{-}c}$
Sheep's milk	100.0%	3.2 ± 0.7^{a}	CVS (100.0%)	$2.6 \pm 0.5^{a\text{-}d}$
Pasteurized milk	100.0%	3.7 ± 1.3^{a}	CVS (100.0%)	$1.8 \pm 0.8^{a,b}$
Sterilized milk	100.0%	3.7 ± 1.1^{a}	CVS (100.0%)	$2.6 \pm 0.7^{a\text{-}d}$
Yoghurt	100.0%	2.9 ± 1.2^{a}	CVS (91.7%)	1.7 ± 1.0^{a}
Set style yoghurt	100.0%	3.3 ± 0.9^{a}	CVS (83.3%)	1.7 ± 0.6^{a}
Kefir	100.0%	3.7 ± 1.1^{a}	CVS (83.3%)	$2.6 \pm 0.8^{a\text{-}d}$
Fruit yoghurt	100.0%	2.7 ± 1.1^{a}	CVS (100.0%)	$3.6 \pm 0.7^{c\text{-}f}$
Heat treated cream	100.0%	3.7 ± 1.0^{a}	CVS (100.0%)	$2.9 \pm 0.5^{b\text{-}e}$
Sour cream	100.0%	3.7 ± 1.1^{a}	CVS (100.0%)	$3.0 \pm 0.8^{c\text{-}e}$
Skim milk powder	100.0%	2.9 ± 0.9^{a}	CVS (100.0%)	$3.6 \pm 0.5^{c\text{-}f}$
Whey powder	100.0%	3.2 ± 0.8^{a}	CVS (100.0%)	4.3 ± 0.6^{f}

Means in the same column with different small letters are significantly different ($P < 0.05$)
Five-point scale ranks from 1 "very low", 2 "low", 3 "moderate", 4 "high" to 5 "very high".

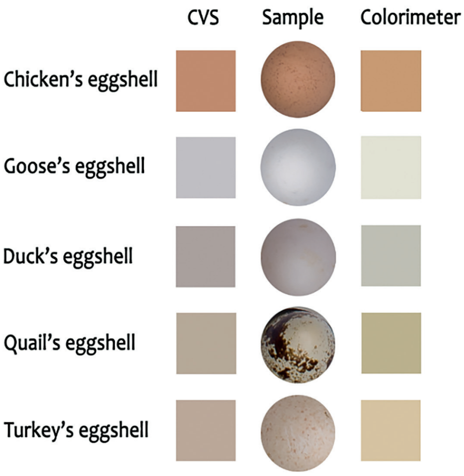

Figure 10. Color of yellow cheeses as evaluated by the two methods [19]

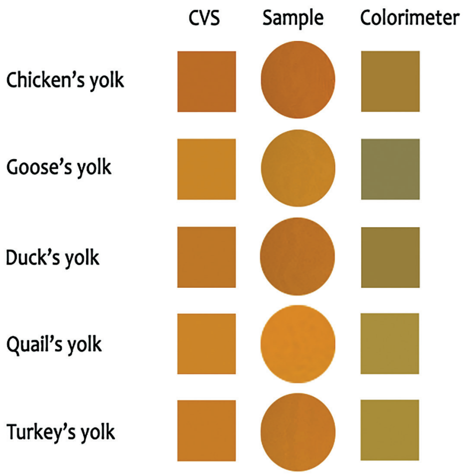

Figure 11. Color of egg yolks as evaluated by the two methods [19]

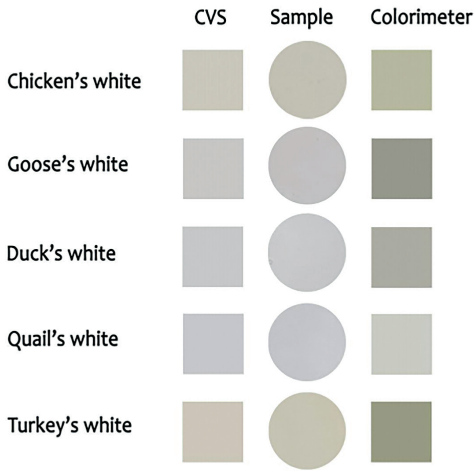

Figure 12. Color of egg white as evaluated by the two methods [19]

different devices provided greatly perceptible total color difference, ranged from 8.0 to 22.0 for quail's egg shell and quail's egg shell (spots), respectively.

Regarding the color of yolk samples, Minolta had a lighter (except the goose's yolk), more "green" and less "yellow" color (Figure 11), whereas CVS indicated the appearance of albumen as lighter (except quail's), more "red" and less "yellow" than colorimeter (Figure 12). Total color difference was in the range from 6.9 (quail's egg white) to 18.7 (goose's egg white). Those results read by Minolta showed a non-real color of egg samples, whereas CVS-obtained color was highly similar to the actual egg color sample [19].

Frequency of similarity was 75.0% (goose's egg white), 83.3% (hen's egg white, duck's egg white and turkey's egg white), 91.7% (quail's egg white) and 100% for all other egg samples. The level of similarity ranged from 1.2 ("very low") for turkey's egg white and hen's egg white to 4.3 ("very high") for duck's egg yolk and turkey's egg yolk. The second test showed that CVS was highly similar to the all egg samples in 100% all trials performed. The final test showed that the difference was large, in the range 2.2 (quail's egg white) to 4.8 (goose's egg yolk) (Table 3) [19].

Conclusion

From the above mentioned results, it can be concluded that even if the same parameters for color evaluation was conducted, significant differences were observed. Taken together, the data clearly demonstrated that the Minolta methodology is less representative and precise for measuring the color of the animal source foods, resulting in non-real appearance. Although using colorimeter for color evaluation of all samples was reliable, it proved to be less accurate. This can be ascribed the fact that Minolta requires opaque food mediums. Furthermore, the penetration depth of the illumination source could be influencing factors on the measurements carried out using two color systems. Therefore, the efficiency of a CVS should be seriously taken into account as a more powerful alternative and non-contact tool for measuring the color of the animal source foods.

Table 3. Sensory test results for eggs [19]

	Frequency of similarity	Level of similarity	CVS vs. colorimeter	Level of difference test
Hen's eggshell	100.0%	3.9 ± 0.7^{c}	CVS (100.0%)	2.7 ± 1.3^{a}
Goose's egg shell	100.0%	$3.5\pm1.3^{b,c}$	CVS (100.0%)	$3.2\pm0.5^{a,b}$
Duck's egg shell	100.0%	$2.9\pm1.2^{a,b}$	CVS (100.0%)	3.1 ± 0.5^{a}
Quail's egg shell	100.0%	2.3 ± 1.1^{a}	CVS (100.0%)	4.2 ± 0.7^{c}
Turkey's egg shell	100.0%	$3.3\pm0.8^{b,c}$	CVS (100.0%)	$3.8\pm0.7^{b,c}$
Hen's egg yolk	100.0%	3.8 ± 0.9^{a}	CVS (100.0%)	4.2 ± 0.4^{a}
Goose's egg yolk	100.0%	4.1 ± 0.8^{a}	CVS (100.0%)	4.8 ± 0.4^{b}
Duck's egg yolk	100.0%	4.3 ± 0.5^{a}	CVS (100.0%)	4.7 ± 0.4^{b}
Quail's egg yolk	100.0%	3.9 ± 1.0^{a}	CVS (100.0%)	4.5 ± 0.5^{ab}
Turkey's egg yolk	100.0%	4.3 ± 0.8^{a}	CVS (100.0%)	4.6 ± 0.5^{ab}
Hen's egg white	83.3%	1.2 ± 0.7^{a}	CVS (100.0%)	3.7 ± 0.6^{b}
Goose's egg white	75.0%	1.8 ± 1.3^{a}	CVS (100.0%)	4.2 ± 0.9^{b}
Duck's egg white	83.3%	2.2 ± 1.3^{a}	CVS (100.0%)	3.8 ± 0.8^{b}
Quail's egg white	91.7%	2.2 ± 1.1^{a}	CVS (100.0%)	2.2 ± 0.6^{a}
Turkey's egg white	83.3%	1.2 ± 0.7^{a}	CVS (100.0%)	4.5 ± 0.5^{b}

Means in the same column with different small letters are significantly different ($P < 0.05$)
Five-point scale ranks from 1 "very low", 2 "low", 3 "moderate", 4 "high" to 5 "very high".

REFERENCES

1. Sharma, S., Sheehy, T., Kolonel, L.N. (2013). Contribution of meat to vitamin B_{12}, iron and zinc intakes in five ethnic groups in the USA: implications for developing food-based dietary guidelines. *Journal of Human Nutrition and Dietetics*, 26(2), 156–168. https://doi.org/10.1111/jhn.12035
2. Mabood, F., Jabeen, F., Ahmed, M., Hussain, J., Al Mashaykhi, S.A.A., Al Rubaiey, Z.M.A., et al. (2017). Development of new NIR-spectroscopy method combined with multivariate analysis for detection of adulteration in camel milk with goat milk. *Food Chemistry*, 221, 746–750. https://doi.org/10.1016/j.foodchem.2016.11.109
3. Zaheer, K. (2015). An updated review on chicken eggs: production, consumption, management aspects and nutritional benefits to human health. *Food and Nutrition Sciences*, 6(13), 1208–1220. https://doi.org/10.4236/fns.2015.613127
4. Dufossé, L., Fernández-López, J., Galaup, P., Pérez-Alvarez, J.A. (2015). Color measurements of muscle-based and dairy foods. Chapter in a book: Handbook of Food Analysis — Two Volume Set (3rd edition). Boca Raton: CRC Press.
5. Zaki, R.S. (2013). The Significance of Color In Food Marketing. *Syracuse University Honors Program Capstone Projects*, 113.
6. Khliji, S., Van de Ven, R., Lamb, T.A., Lanza, M., Hopkins, D. L. (2010). Relationship between consumer ranking of lamb color and objective measures of color. *Meat Science*, 85(2), 224–229. https://doi.org/10.1016/j.meatsci.2010.01.002
7. Santos, P.M., Pereira-Filho, E.R., Rodriguez-Saona, L.E. (2013). Rapid detection and quantification of milk adulteration using infrared microspectroscopy and chemometrics analysis. *Food Chemistry*, 138(1), 19–24. https://doi.org/10.1016/j.foodchem.2012.10.024
8. Lakade, A. J., Sundar, K., Shetty, P. H. (2017). Nanomaterial-based sensor for the detection of milk spoilage. *LWT — Food Science and Technology*, 75, 702–709. https://doi.org/10.1016/j.lwt.2016.10.031
9. Karlsson, M. A., Langton, M., Innings, F., Malmgren, B., Höjer, A., Wikström, M. et al. (2019). Changes in stability and shelf-life of ultra-high temperature treated milk during long term storage at different temperatures. *Heliyon,* 5(9), Article e02431. https://doi.org/10.1016/j.heliyon.2019.e02431
10. Berkhoff, J., Alvarado-Gilis, C., Keim, J.P., Alcalde, J.A., Vargas-Bello-Pérez, E., Gandarillas, M. (2020). Consumer preferences and sensory characteristics of eggs from family farms. *Poultry Science*, 99(11), 6239–6246. https://doi.org/10.1016/j.psj.2020.06.064
11. Samiullah, S., Roberts, J.R., Chousalkar, K. (2015). Eggshell color in brown-egg laying hens — a review. *Poultry Science*, 94(10), 2566–2575. https://doi.org/10.3382/ps/pev202
12. Liu, Y.Q., Davis, C., Schmaelzle, S., Rocheford, T., Cook, M., Tanumihardjo, S. (2012). β-Cryptoxanthin biofortified maize (Zea mays) increases -cryptoxanthin concentration and enhances the color of chicken egg yolk. *Poultry Science*, 91(2), 432–438. https://doi.org/10.3382/ps.2011–01719
13. Lokaewmanee, K., Yamauchi, K.-E., Komori, T., Saito, K. (2010). Effects on egg yolk color of paprika or paprika combined with marigold flower extracts. *Italian Journal of Animal Science*, 9(4), 356–359. https://doi.org/10.4081/ijas.2010.e67
14. Berkhoff, J., Alvarado-Gilis, C., Keim, J.P., Alcalde, J.A., Vargas-Bello-Pérez, E., Gandarillas, M. (2020). Consumer preferences and sensory characteristics of eggs from family farms. *Poultry Science*, 99(11), 6239–6246. https://doi.org/10.1016/j.psj.2020.06.064
15. Preisinger, R. (2018). Innovative layer genetics to handle global challenges in egg production. *British Poultry Science*, 59(1), 1–6. https://doi.org/10.1080/00071668.2018.1401828
16. Tapp, W.N., Yancey, J.W.S., Apple, J.K. (2011). How is the instrumental color of meat measured? *Meat Science*, 89(1), 1–5. https://doi.org/10.1016/j.meatsci.2010.11.021
17. Tomasevic, I., Djekic, I., Font-i-Furnols, M., Terjung, N., Lorenzo, J. M. (2021). Recent advances in meat color research. *Current Opinion in Food Science*, 41, 81–87 https://doi.org/10.1016/j.cofs.2021.02.012
18. Milovanovic, B., Djekic, I., Miocinovic, J., Djordjevic, V., Lorenzo, J.M., Barba, F.J., et al. (2020). What Is the Color of Milk and Dairy Products and How Is It Measured? *Foods*, 9(11), 1629. https://doi.org/10.3390/foods9111629
19. Milovanovic, B., Tomovic, V., Djekic, I., Solowiej, B. G., Lorenzo, J. M., Barba, F. J., et al. (2021). Color assessment of the eggs using computer vision system and Minolta colorimeter. *Journal of Food Measurement and Characterization*. https://doi.org/10.1007/s11694–021–01085–4 (unpublished data)
20. Tomašević, I. B. (2021). Computer vision system for color measurements of meat and meat products: A review. *Theory and Practice of Meat Processing*, 4(4), 4–15. https://doi.org/10.21323/2414–438X-2018–3–4–4–15
21. Chlebda, D.K., Rogulska, A., Łojewski, T. (2017). Assessment of hyperspectral imaging system for color measurement. *Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy*, 185, 55–62. https://doi.org/10.1016/j.saa.2017.05.037
22. Goñi, S. M., Salvadori, V.O. (2017). Color measurement: comparison of colorimeter vs. computer vision system. *Journal of Food Measurement and Characterization*. 11, 538–547. https://doi.org/10.1007/s11694–016–9421–1
23. Grillo, O., Rizzo, V., Saccone, R., Fallico, B., Mazzaglia, A., Venora, G., et al. (2014). Use of image analysis to evaluate the shelf life of bakery products. *Food Research International*, 62, 514–522. https://doi.org/10.1016/j.foodres.2014.03.034
24. Barbin, D.F., Mastelini, S.M., Barbon Jr, S., Campos, G.F., Barbon, A.P.A., Shimokomaki, M. (2016). Digital image analyses as an alternative tool for chicken quality assessment. *Biosystems Engineering*, 144, 85–93. https://doi.org/10.1016/j.biosystemseng.2016.01.015
25. Tomasevic, I., Tomovic, V., Ikonic, P., Lorenzo Rodriguez J. M.., Barba, F.J., Djekic, I. et al. (2019). Evaluation of poultry meat colour using computer vision system and colourimeter: Is there a difference? *British Food Journal*, 121(5), 1078–1087. https://doi.org/10.1108/BFJ-06–2018–0376
26. Tomasevic, I., Tomovic, V., Barba, F.J., Vasilev, D., Jokanovic, M., Šojić, B. et al. (2018). How the color of game meat should be measured: computer vision system vs. colorimeter. *Fleischwirtschaft-Frankfurt*, 1, 85–89.
27. Milovanovic, B., Đekić, I., Solowiej, B., Novaković, S., Đorđević, V., Tomašević, I. (2020). Computer Vision System: A better tool for assessing pork and beef color than a standard colorimeter. *Meat Technology*, 61(2), 153–160. https://doi.org/10.18485/meattech.2020.61.2.5
28. Tomasevic, I., Tomovic, V., Milovanovic, B., Lorenzo, J., Đorđević, V., Karabasil, N. et al. (2019). Comparison of a computer vision system vs. traditional colorimeter for color evaluation of meat products with various physical properties. *Meat Science,* 148, 5–12. https://doi.org/10.1016/j.meatsci.2018.09.015
29. Milovanovic, B., Tomovic, V., Djekic, I., Miocinovic, J., Solowiej, B.G., Lorenzo, J.M. et al., (2021). Color assessment of milk and milk products using computer vision system and colorimeter. *International Dairy Journal*, 120, Article 105084. https://doi.org/10.1016/j.idairyj.2021.105084
30. Karunanayaka, D.S., Jayasena, D.D., Jo, C. (2016). Prevalence of pale, soft, and exudative (PSE) condition in chicken meat used for commercial meat processing and its effect on roasted chicken breast. *Journal of Animal Science and Technology*, 58(1), 1–8. https://doi.org/10.1186/s40781–016–0110–8
31. Feng, X., Moon, S.H., Lee, H.Y., Ahn, D.U. (2017). Effect of irradiation on the parameters thatinfluence quality characteristics of raw turkey breast meat. *Radiation Physics and Chemistry*, 130, 40–46. https://doi.org/10.1016/j.radphyschem.2016.07.015
32. Geldenhuys, G., Hoffman, L.C., Muller, M. (2014). Sensory profiling of Egyptian goose (*Alopochen aegyptiacus*) meat. *Food Research International*, 64, 25–33. https://doi.org/10.1016/j.foodres.2014.06.005
33. Qiao, Y., Huang, J., Chen, Y., Chen, H., Zhao, L., Huang, M. et al. (2017). Meat quality, fatty acid composition and sensory evaluation of Cherry Valley, Spent Layer and Crossbred ducks. *Animal Science Journal*, 88(1), 156–165. https://doi.org/10.1111/asj.12588
34. Borilova, G., Hulankova, R., Svobodova, I., Jezek, F., Hutarova, Z., Vecerek, V. et al. (2016). The effect of storage conditions on the hygiene and sensory status of wild boar meat. *Meat Science*, 118, 71–77. https://doi.org/10.1016/j.meatsci.2016.03.024
35. Kudrnáčová, E., Bartoň, L., Bureš, D., Hoffman, L.C. (2018). Carcass and meat characteristics from farm-raisedand wild fallow deer (Dama dama) and red deer (Cervus elaphus): A review. *Meat Science*, 141, 9–27. https://doi.org/10.1016/j.meatsci.2018.02.020
36. Girolami, A., Napolitano, F., Faraone, D., Braghieri A. (2013). Measurement of meat color using a computer vision system. *Meat Science*, 93(1), 111–118. https://doi.org/10.1016/j.meatsci.2012.08.010
37. Sun, X., Young, J., Liu, J.H., Bachmeier, L., Somers, R.M., Chen, K.J. et al. (2016). Prediction of pork color attributes using computer vision system. *Meat Science*, 113, 62–64. https://doi.org/10.1016/j.meatsci.2015.11.009

38. Sun, X., Young, J., Liu, J. H., Chen, Q., Newman, D. (2018). Predicting pork color scores using computer vision and support vector machine technology. *Meat and Muscle Biology*, 2(1), 296–302. https://doi.org/10.22175/mmb2018.06.0015
39. Trinderup, C.H., Dahl, A.B., Jensen, K., Carstensen, J.M., Conradsen, K. (2015). Comparison of a multispectral vision system and a colorimeter for the assessment of meat color. *Meat Science*, 102, 1–7. https://doi.org/10.1016/j.meatsci.2014.11.012
40. Valous, N.A., Mendoza, F., Sun, D.-W., Allen, P. (2009). Color calibration of a laboratory computer vision system for quality evaluation of pre-sliced hams. *Meat Science*, 81(1), 132–141. https://doi.org/10.1016/j.meatsci.2008.07.009
41. Aktypis, A., Christodoulou, E., Manolopoulou, E., Georgala, A., Daferera, D., Polysiou, M. (2018). Fresh ovine cheese supplemented with saffron (Crocus sativus L.): Impact on microbiological, physicochemical, antioxidant, color and sensory characteristics during storage. *Small Ruminant Research*, 167, 32–38. https://doi.org/10.1016/j.smallrumres.2018.07.016
42. Aday, S., Yuceer, Y.K. (2014). Physicochemical and sensory properties of mihalic cheese. *International Journal of Food Properties*, 17(10), 2207–2227. https://doi.org/10.1080/10942912.2013.790904
43. Siefarth, C., Tran, T., Mittermaier, P., Pfeiffer, T., Buettner, A. (2014). Effect of radio frequency heating on yoghurt. I. Technological applicability, shelf-life and sensorial quality. *Foods*, 3(2), 318–335. https://doi.org/10.3390/foods3020318
44. Li, Y., Shabani, K. I., Qin, X., Yang, R., Jin, X., Ma, X. et al. (2019). Effects of crosslinked inulin with different polymerisation degrees on physicochemical and sensory properties of set-style yoghurt. *International Dairy Journal*, 94, 46–52. https://doi.org/10.1016/j.idairyj.2019.02.009
45. Gul, O., Atalar, I., Mortas, M., Dervisoglu, M. (2018). Rheological, textural, color and sensorial properties of kefir produced with buffalo milk using kefir grains and starter culture: A comparison with cows' milk kefir. *International Journal of Dairy Technology*, 71, 73–80. https://doi.org/10.1111/1471–0307.12503
46. Avila, M., Gomez-Torres, N., Delgado, D., Gaya, P., Garde, S. (2017). Effect of high- pressure treatments on proteolysis, volatile compounds, texture, color, and sensory characteristics of semi-hard raw Ewe milk cheese. *Food Research International*, 100, 595–602. https://doi.org/10.1016/j.foodres.2017.07.043
47. Diezhandino, I., Fernández, D., González, L., McSweeney, P. L. H., Fresno, J. M. (2015). Microbiological, physico-chemical and proteolytic changes in a Spanish blue cheese during ripening (Valdeón cheese). *Food Chemistry*, 168, 134–141. https://doi.org/10.1016/j.foodchem.2014.07.039
48. Dai, S., Jiang, F., Corke, H., Shah, N.P. (2018). Physicochemical and textural properties of mozzarella cheese made with konjac glucomannan as a fat replacer. *Food Research International*, 107, 691–699. https://doi.org/10.1016/j.foodres.2018.02.069
49. Kędzierska-Matysek, M., Barłowska, J., Wolanciuk, A., Litwińczuk, Z. (2018). Physicochemical, mechanical and sensory properties of long-ripened Polish and Italian cheeses and their content of selected minerals. *Journal of Elementology*, 23(3), 985–998. https://doi.org/10.5601/jelem.2017.22.4.1452
50. Ramírez-Navas, J. S. (2010). Espectrocolorimetría: Caracterizacion de leche y quesos. *Tecnología Lactea Latinoamericana*, 61, 52–58.
51. Truong, T., Palmer, M., Bansal, N., Bhandari, B. (2018). Effects of dissolved carbon dioxide in fat phase of cream on manufacturing and physical properties of butter. *Journal of Food Engineering*, 226, 9–21. https://doi.org/10.1016/j.jfoodeng.2018.01.012
52. Tarlak, F., Ozdemir, M., Melikoglu, M. (2016). Computer vision system approach in color measurements of foods: Part II. Validation of methodology with real foods. *Food Science and Technology*, 36(3), 499–504. https://doi.org/10.1590/1678–457X.02616

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