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 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...
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 similarity assessed 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].
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 as compared with the CVS, noting 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 cheeses 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.

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

| Meat and meat products | Frequency of similarity | Level of similarity | CVS vs. Colorimeter | Level of difference test |
|------------------------|-------------------------|---------------------|---------------------|-------------------------|
| Beef pate              | 100.0%                  | 3.4 ± 1.4 b         | CVS (100.0%)        | 3.0 ± 1.1 b             |
| Liver pate             | 100.0%                  | 3.6 ± 1.1 b         | CVS (100.0%)        | 2.4 ± 1.1 b             |
| Chicken pate           | 92.9%                   | 3.5 ± 1.0 b         | CVS (100.0%)        | 2.1 ± 1.0 b             |
| Beef fermented sausages| 92.9%                   | 3.6 ± 1.0 b         | CVS (100.0%)        | 2.1 ± 1.0 b             |
| Pork fermented sausages| 100.0%                  | 4.0 ± 0.8 b         | CVS (100.0%)        | 2.3 ± 0.5 b             |
| Frankfurter            | 100.0%                  | 4.0 ± 1.1 b         | CVS (100.0%)        | 1.7 ± 0.5 b             |
| Saveloy sausage        | 100.0%                  | 3.8 ± 0.9 b         | CVS (100.0%)        | 1.2 ± 0.5 b             |
| Mortadella             | 100.0%                  | 2.9 ± 1.2 a         | CVS (100.0%)        | 2.1 ± 1.1 b             |
| Cooked ham             | 100.0%                  | 3.0 ± 1.2 b         | CVS (100.0%)        | 2.1 ± 1.1 b             |
| Smoked cooked bacon    | 100.0%                  | 3.5 ± 1.3 b         | CVS (100.0%)        | 2.2 ± 0.4 b             |
| Smoked cooked pork     | 100.0%                  | 3.5 ± 1.0 b         | CVS (100.0%)        | 2.8 ± 1.2 b             |
| Pork prosciutto        | 100.0%                  | 4.1 ± 0.8 b         | CVS (100.0%)        | 4.2 ± 1.0               |
| Beef prosciutto        | 100.0%                  | 3.6 ± 0.9 b         | CVS (100.0%)        | 3.1 ± 1.8 b             |
| Dry pork neck          | 92.9%                   | 3.5 ± 1.3 b         | CVS (100.0%)        | 3.0 ± 0.7 b             |
| Pancetta               | 92.9%                   | 2.8 ± 1.5 a         | CVS (100.0%)        | 2.7 ± 1.5 b             |
| Pork hamburger         | 100.0%                  | 2.8 ± 1.0 b         | CVS (100.0%)        | 2.0 ± 1.0               |
| Beef hamburger         | 100.0%                  | 3.4 ± 1.3 b         | CVS (100.0%)        | 2.7 ± 1.0 b             |
| Raw sausage            | 100.0%                  | 4.4 ± 0.6 b         | CVS (100.0%)        | 3.2 ± 1.5 b             |
| Chicken breast         | 100.0%                  | 1.7 ± 0.8 a         | CVS (100.0%)        | 3.8 ± 1.4               |
| Duck breast            | 100.0%                  | 2.4 ± 1.0 b         | CVS (100.0%)        | 1.8 ± 0.4               |
| Goose breast           | 100.0%                  | 3.1 ± 0.8 b         | CVS (100.0%)        | 1.4 ± 0.5               |
| Turkey breast          | 100.0%                  | 2.9 ± 1.03 b        | CVS (100.0%)        | 4.7 ± 0.7               |
| Quail                  | 100.0%                  | 2.7 ± 1.3 a         | CVS (100.0%)        | 3.6 ± 1.4               |
| Wild boar              | 100.0%                  | 3.4 ± 1.3 b         | CVS (100.0%)        | 1.9 ± 0.9 b             |
| Rabbit                 | 85.7%                   | 2.7 ± 1.2 b         | CVS (100.0%)        | 4.2 ± 1.2               |
| Deer                   | 100.0%                  | 4.1 ± 0.8 b         | CVS (100.0%)        | 1.0 ± 0.0               |
| Pheasent               | 100.0%                  | 3.2 ± 1.2 b         | CVS (100.0%)        | 3.4 ± 1.3 b             |
| Pork                   | 100.0%                  | 2.6 ± 0.8 a         | CVS (100.0%)        | 4.2 ± 0.7               |
| Beef                   | 100.0%                  | 4.1 ± 0.5 b         | CVS (100.0%)        | 4.0 ± 0.7               |

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”. 
(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...
were higher with the colorimeter than by CVS. There is a great color difference regarding the total color difference $\Delta E = 11.8$ [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 $\Delta E$ 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*          | CVS (100.0%)            | 3.7 ± 0.6* |
| Semi hard cheese       | 100.0%              | 3.1 ± 0.7*          | CVS (100.0%)            | 3.0 ± 0.4* |
| Pasta Filata           | 100.0%              | 3.4 ± 0.8*          | CVS (91.7%)             | 2.6 ± 0.7* |
| Brined cheese          | 100.0%              | 3.7 ± 1.1*          | CVS (100.0%)            | 3.7 ± 0.9* |
| Fresh cheese           | 100.0%              | 3.2 ± 1.3*          | CVS (100.0%)            | 3.3 ± 1.1* |
| Moldy cheese           | 100.0%              | 3.1 ± 1.0*          | CVS (100.0%)            | 3.7 ± 0.9* |
| Grana Padano           | 100.0%              | 3.6 ± 0.8*          | CVS (100.0%)            | 3.7 ± 0.7* |
| Processed cheese       | 100.0%              | 3.4 ± 1.2*          | CVS (91.7%)             | 3.7 ± 0.8* |
| Cheese spread          | 100.0%              | 3.1 ± 1.1*          | CVS (83.3%)             | 2.7 ± 1.1* |
| Fresh kajmak           | 100.0%              | 3.0 ± 1.0*          | CVS (100.0%)            | 3.4 ± 0.8* |
| Mature kajmak          | 100.0%              | 3.2 ± 0.6*          | CVS (100.0%)            | 3.4 ± 0.8* |
| Kajmak cream           | 100.0%              | 2.9 ± 1.2*          | CVS (100.0%)            | 3.0 ± 0.9* |
| Kajmak spread          | 100.0%              | 3.4 ± 1.1*          | CVS (100.0%)            | 3.2 ± 0.9* |
| Cow’s milk             | 100.0%              | 3.7 ± 1.1*          | CVS (100.0%)            | 1.7 ± 0.5* |
| Goat’s milk            | 100.0%              | 3.2 ± 1.0*          | CVS (100.0%)            | 2.5 ± 0.7* |
| Sheep’s milk           | 100.0%              | 3.2 ± 0.7*          | CVS (100.0%)            | 2.6 ± 0.5* |
| Pasteurized milk       | 100.0%              | 3.7 ± 1.3*          | CVS (100.0%)            | 1.8 ± 0.8* |
| Sterilized milk        | 100.0%              | 3.7 ± 1.1*          | CVS (100.0%)            | 2.6 ± 0.7* |
| Yoghurt                | 100.0%              | 2.9 ± 1.2*          | CVS (91.7%)             | 1.7 ± 1.0* |
| Set style yoghurt      | 100.0%              | 3.3 ± 0.9*          | CVS (83.3%)             | 1.7 ± 0.6* |
| Kefir                  | 100.0%              | 3.7 ± 1.1*          | CVS (83.3%)             | 2.6 ± 0.8* |
| Fruit yoghurt          | 100.0%              | 2.7 ± 1.1*          | CVS (100.0%)            | 3.6 ± 0.7* |
| Heat treated cream     | 100.0%              | 3.7 ± 1.0*          | CVS (100.0%)            | 2.9 ± 0.5* |
| Sour cream             | 100.0%              | 3.7 ± 1.1*          | CVS (100.0%)            | 3.0 ± 0.8* |
| Skim milk powder       | 100.0%              | 2.9 ± 0.9*          | CVS (100.0%)            | 3.6 ± 0.5* |
| Whey powder            | 100.0%              | 3.2 ± 0.8*          | CVS (100.0%)            | 4.3 ± 0.6* |

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”.

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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]**

| Sample                  | Frequency of similarity | Level of similarity | CVS vs. colorimeter | Level of difference test |
|-------------------------|-------------------------|---------------------|---------------------|--------------------------|
| Hen’s eggshell          | 100.0%                  | 3.9±0.7c            | CVS (100.0%)        | 2.7±1.3a                 |
| Goose’s egg shell       | 100.0%                  | 3.5±1.3bc           | CVS (100.0%)        | 3.2±0.5b                 |
| Duck’s egg shell        | 100.0%                  | 2.9±1.2b            | CVS (100.0%)        | 3.1±0.5c                 |
| Quail’s egg shell       | 100.0%                  | 2.3±1.1c            | CVS (100.0%)        | 4.2±0.7c                 |
| Turkey’s egg shell      | 100.0%                  | 3.3±0.8c            | CVS (100.0%)        | 3.8±0.7c                 |
| Hen’s egg yolk          | 100.0%                  | 3.8±0.9c            | CVS (100.0%)        | 4.2±0.4c                 |
| Goose’s egg yolk        | 100.0%                  | 4.1±0.8c            | CVS (100.0%)        | 4.8±0.4c                 |
| Duck’s egg yolk         | 100.0%                  | 4.3±0.5c            | CVS (100.0%)        | 4.7±0.4c                 |
| Quail’s egg yolk        | 100.0%                  | 3.9±1.0c            | CVS (100.0%)        | 4.5±0.5c                 |
| Turkey’s egg yolk       | 100.0%                  | 4.3±0.8c            | CVS (100.0%)        | 4.6±0.5c                 |
| Hen’s egg white         | 83.3%                   | 1.2±0.7c            | CVS (100.0%)        | 3.7±0.6c                 |
| Goose’s egg white       | 75.0%                   | 1.8±1.3c            | CVS (100.0%)        | 4.2±0.9c                 |
| Duck’s egg white        | 83.3%                   | 2.2±1.3c            | CVS (100.0%)        | 3.8±0.8c                 |
| Quail’s egg white       | 91.7%                   | 2.2±1.1c            | CVS (100.0%)        | 2.2±0.6c                 |
| Turkey’s egg white      | 83.3%                   | 1.2±0.7c            | CVS (100.0%)        | 4.5±0.5c                 |

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The authors were equally involved in writing the manuscript and bear the equal responsibility for plagiarism. All authors made an equal contribution to the work. All authors bear responsibility for the work and presented data.

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