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Research Article
Influence of the Background Color on the Cheese Color Parameters

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Abstract

Background and Objectives: Color measurement is important for classifying raw materials, learning how technological processes affect the sample, assessing quality of the final product and monitoring changes in the product during storage period. There are no standards regarding sample thickness and background when evaluating color of dairy products. The aim of the study was to determine the minimum thickness of the analyzed Gouda cheese sample in which the background color would not affect color coordinates. **Materials and Methods:** Color coordinates of Gouda cheese in the CIE L*a*b* system were measured with respect to two background colors and for different sample thicknesses. Different cheese thicknesses (1.7, 3.4, 5.1, 6.8, 8.5, 10.2, 11.9 and 13.6 mm), background colors (white and black) and two kind of spectrophotometers were used. **Results:** The background color was observed to be important for the measurement of thinner samples. In the case of cheese sample the thickness must be taken into consideration. The color of background influenced the color parameters obtained in the case of thickness up to 10.2 mm (for the X-Rite SP60 spectrophotometer) and up to 8.5 mm (for Spectro-pen). **Conclusion:** The results indicated that a minimum sample thickness of 11.9 mm can eliminate the influence of the background color. To eliminate the influence of background color on the obtained color measurement results, it is necessary to consider the thickness of the sample.

Key words: Cheese, laboratory practice, quality control, dairy products, Dutch cheese

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Cheese is the largest and the most diverse group of dairy products and its production is one of the main branches of milk processing. One of the most popular cheeses in the world is Gouda[1]. Gouda is the main representative of the class of semi-hard cheeses[2]. It is a wash-curd Dutch cheese produced from whole milk. In the United States, Gouda cheese is defined by the Code of Federal Regulation: the minimum milk fat content is 46% by weight of the solids and the maximum moisture content is 45% by weight[3].

According to Dysz and Krasnowska[4], consumer decisions when purchasing hard cheese are influenced by: taste, price, habits, presence of holes, color and appearance. Nowak *et al.*[5] analyzed customer opinions in terms of hard cheeses in Holland, Germany and Poland. Among the features of hard cheese, its freshness and taste were the most important for the respondents from these three countries. The color was "very important" or "important" for 20.5 and 48.8% of Dutch consumers, 8.1 and 30.3% of German consumers and 4.4 and 43.7% Polish consumers, respectively. In the research by Jo *et al.*[6], color, saltiness, firmness, creaminess as well as flavour intensity were correlated with the overall liking of Gouda cheeses.

Different types of cheese available on the market include sliced and 'cube' portions. Sliced cheese may be separated by paper or plastic dividers which can influence color visual effect.

There are multiple markers influencing cheese color. Scientific research on cheese includes the analysis of the technology and storage conditions[7,8], maturing[9], fat content[10] and additives[11]. There has been no research reported in relation to the background used in color analysis or thickness of the samples of cheese. Abong *et al.*[12] analyzed the effect of slice thickness on the color of potato chips, Sánchez-Zapata *et al.*[13] analyzed the thickness of tuna pâté and the background used on the color of the pâté and Sandusky and Heath[14] analyzed the effect of broiler meat thickness and background color on meat color. In cheese tests, various sample thinnesses are used, e.g., 1.0, 1.8, 2.0, 2.7 or 4 cm[15-19]. The information on the background color in the cheese color analysis is given very rarely in scientific articles[20]. Color measuring is a fast, cost-effective and commonly used method of quality control in both production plants and laboratories. Standardization of color measurement conditions would result in more reliable cheese quality results. Separation of an object from the background is the key operation in color evaluation. The purpose of the analysis was to determine the minimum thickness of the analyzed Gouda cheese sample in which the background color would not affect color coordinates and to decide whether the type of equipment used statistically significantly affected these coordinates.

MATERIALS AND METHODS

The study was carried out at the University of Szczecin and the University of Life Sciences in Poznań, Poland, from January, 2019 to February, 2020.

Experimental material: The material for this research was commercial Gouda cheese (purchased in a local shop in Poznań).

Physicochemical characteristics of cheese: In order to define the characteristics of cheese, the content of water, fat and protein were marked.

The total solid content in cheese was determined according to ISO[21]. The test sample was weighed, mixed with dried sand and kept in a drying oven set at 102°C for 3 h. Following this, the sample was cooled and weighed. The procedure was repeated until the difference between two subsequent weights was 0.0002 g or less. The total solids content was expressed as percentage by mass:

$$\text{Water content (\%)} = 100\text{-The total solid}$$

The fat content in cheese was determined using the ISO[22] method. The test sample was digested with hydrochloric acid and then ethanol was added. The acid-ethanolic solution was extracted with diethyl ether, light petroleum and the solvents were removed. The mass of the substances extracted was determined. The described method was based on the Schmidt-Bądzyński-Ratzlaff principle[22].

The protein content of cheese was determined by measuring total nitrogen using the ISO[23] method. To convert the nitrogen reading to cheese protein, the nitrogen reading was multiplied by the factor of 6.38.

Sample preparation: The Gouda cheese was cut by means of an electric cutter into slices 1.7 mm thick. The cheese slices were square. The side length of the square was 10 cm (Fig. 1). In the research, the thickness of a layer was increased from 1.7 (1 slice) to 13.6 mm (8 slices). The color was always measured on the surface of slice one. Each subsequent slice was placed at the bottom and the color was measured to determine the effect of sample thickness on color. The temperature of samples was 20°C.

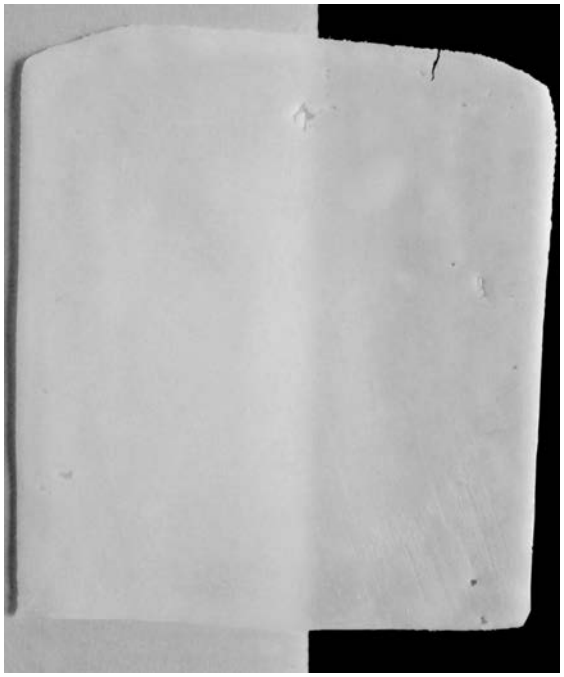

Fig. 1: One slice of cheese (1.7 mm) on the white and black background (white and black paper)

Devices and color system: The color analyses were conducted using a X-Rite SP60 spectrophotometer (Grand Rapids, Michigan, USA) and a portable spectrophotometer spectro-pen (Dr. Lange, Düsseldorf, Germany). The measurements by X-Rite SP60 were recorded by using: illuminant D65, standard observer 10°, geometry d/8, measuring area 8 mm, SPEX (Specular Component Excluded) setting. In spectro-pen the measurements were recorded by using: illuminant D65/10°, geometry 45°/0°(circular) and 5 mm measuring area. The color was measured in CIE L*a*b* system. This color model permits an objective color representation and its use is essential for applications where the results must match those of human perception[24]. In the CIE L*a*b* space, color is described by three components:

- L*: From black to white
- a*: From green to red
- b*: From blue to yellow

The colors can be described by a combination of their lightness, green/redness and blue/yellowness. CIE L*a*b* is similar to CIE LCh (L: Lightness, C: Chroma/saturation, h: Hue). The difference between them is in the different coordinate systems used to describe the two spaces: the CIE L*a*b* space is described in Cartesian coordinates, while the CIE LCh space in cylindrical coordinates. The relationships between their respective coordinates are therefore as follows[25]:

- $L^* \equiv L$
- $C = (a^{*2}+b^{*2})^{1/2}$
- $h = \text{Arctan}(b^*/a^*)$

For color measurement the X-Rite SP60 was used and the results for L*, a*, b*, C, h were obtained on the device display. In the Spectro-pen-L*, a* and b* were obtained.

Background: White and black paper were used as background. The values of L*, a*, b* for black and white papers measured with X-Rite SP60 were: 35.55, 0.01, -1.20 and 91.65, 1.10, -6.95 (±0.01), respectively and for Spectro-pen: 26.1, 0.9, -1.5 and 92.5, -0.6, -1.4 (±0.1), respectively.

In the case of L*a*b* space, the difference between two colors is calculated by the formula:

$$\Delta E\ L^*a^*b^* = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2}$$

A standard observer sees the difference in color as follows:

- 0<E<1: The observer does not notice the difference
- 1<E<2: Only an experienced observer can notice the difference
- 2<E<3.5: An unexperienced observer also notices the difference
- 3.5<E<5: A clear difference in color is noticed
- 5<E: An observer notices two different colors[25]

Statistical analysis: Four cheeses were taken and each sample was analyzed thirteen times. Means and standard deviations were calculated using Microsoft Excel spreadsheet from the Microsoft Office package. Data collected experimentally were analyzed statistically using the t-statistics. A two-sample t-test was used to determine if two population means were equal (test at a significance level of $p<0.05$). All calculations were performed in the Statistical 12.0 software package.

RESULTS AND DISCUSSION

The Gouda cheese used as material for the experiment was characterized by 44.4±0.5% water, 25.0±0.2% protein and 26.5±0.3% fat content. In the Jo *et al.*[6] study, Gouda

Table 1: Influence of the background color on L* a* and b* coordinates

		X-Rite SP60		Spectro-pen	
Coordinates	Sample thickness (mm)	White background	Black background	White background	Black background
L*	1.7	80.62±0.61[a]	74.94±0.54[b]	72.2±0.4[a]	68.5±0.4[b]
	3.4	77.79±0.62[a]	76.59±0.71[b]	70.5±0.9[a]	69.1±0.9[b]
	5.1	77.29±1.05[a]	77.43±0.97[a]	69.0±1.0[a]	69.0±1.0[a]
	6.8	77.70±1.15[a]	78.10±0.73[a]	68.9±0.6[a]	69.3±0.7[a]
	8.5	76.77±0.57[a]	76.36±0.78[a]	68.4±0.7[a]	68.7±0.5[a]
	10.2	76.16±1.11[a]	76.81±0.92[a]	68.0±0.6[a]	69.1±0.6[a]
	11.9	77.08±0.86[a]	76.94±0.67[a]	68.0±0.7[a]	67.8±0.5[a]
	13.6	77.00±0.96[a]	76.74±0.77[a]	68.0±0.7[a]	68.1±0.1[a]
a*	1.7	0.95±0.08[a]	-0.82±0.04[b]	0.6±0.1[a]	-0.5±0.1[b]
	3.4	1.89±0.05[a]	0.24±0.05[b]	0.7±0.1[a]	0.0±0.1[b]
	5.1	1.78±0.06[a]	0.81±0.06[b]	0.7±0.1[a]	0.2±0.1[b]
	6.8	1.72±0.04[a]	1.15±0.04[b]	0.6±0.0[a]	0.4±0.1[b]
	8.5	1.64±0.04[a]	1.31±0.04[b]	0.6±0.1[a]	0.5±0.1[b]
	10.2	1.58±0.06[a]	1.40±0.06[b]	0.5±0.1[a]	0.5±0.1[a]
	11.9	1.59±0.06[a]	1.57±0.05[a]	0.6±0.1[a]	0.5±0.1[a]
	13.6	1.61±0.07[a]	1.57±0.08[a]	0.6±0.1[a]	0.5±0.1[a]
b*	1.7	31.95±0.52[a]	23.14±0.30[b]	23.6±0.3[a]	17.5±0.3[b]
	3.4	30.76±0.55[a]	26.83±0.40[b]	21.5±0.3[a]	19.7±0.2[b]
	5.1	29.12±0.81[a]	28.30±0.48[b]	20.8±0.3[a]	20.2±0.4[b]
	6.8	29.60±0.60[a]	28.72±0.46[b]	20.5±0.2[a]	20.3±0.2[b]
	8.5	29.53±0.31[a]	29.33±0.38[a]	20.7±0.2[a]	20.5±0.2[a]
	10.2	29.31±0.50[a]	29.02±0.33[a]	20.3±0.2[a]	20.3±0.2[a]
	11.9	28.96±0.53[a]	28.86±0.47[a]	20.3±0.1[a]	20.3±0.2[a]
	13.6	29.11±0.73[a]	29.00±0.38[a]	20.3±0.2[a]	20.3±0.4[a]

[a,b]Different letters in a row denote statistically significant differences between results, separately for each instrument ($p<0.05$), L*: From black to white, a*: From green to red, b*: From blue to yellow

Table 2: The difference between colors of cheese for white and black background

Sample thickness (mm)	X-Rite SP60	Spectro-pen
1.7	10.65±0.27	7.2±0.2
3.4	4.45±0.40	2.4±0.3
5.1	1.78±0.51	0.8±0.3
6.8	1.21±0.29	0.6±0.3
8.5	0.88±0.63	1.0±0.4
10.2	1.17±1.09	0.6±0.4
11.9	1.01±0.74	0.6±0.4
13.6	0.90±0.50	0.6±0.3

cheeses with water content of 41.4-46.3% and fat 26.6-28.5% were characterized by L* = 83.5-84.5, a* from -1.43 to 3.27 and b* between 30.7-34.6.

Means and standard deviations for the color parameters as a function of thickness for white and black background are shown in Table 1.

The background significantly affected all parameters values up to two slices of cheese (3.4 mm).

No differences in L* coordinate were found (between white and black background) for the thickness equal to and more than 5.1 mm (for both devices), in coordinate a* for the thickness equal to 11.9 mm and 10.2 (for X-Rite and Spectro-pen, respectively) and in b* coordinate, for the thickness equal to and more than 8.5 mm.

In color evaluation, an untrained human eye would not see the difference in the influence of background on cheese color already for 3 slices of cheese, i.e., from the layer thickness of 5.1 mm ($\Delta E<2$) (Table 2). That is why an objective, instrumental evaluation of cheeses is so important.

The background had no statistically significant effect on chroma from 8.5 mm cheese thickness and on hue from 11.9 mm cheese thickness (Table 3).

Because of the pioneering character of research, there exists no dairy products literature on the impact of background colour or sample thickness on the color coordinates in the CIE L*a*b* system.

Sandusky and Heath[14] reported that background color significantly affected the meat color when the 0.5 cm thick broiler breast meat slice was used, whereas only a few differences were found by testing a thicker meat sample (1.0 and 1.5 cm). Also, in the study by Bianchi and Fletcher[26], the main effect of the background color was significant only for 1 cm thick samples. The background color did not affect meat color measurements for thicker samples.

Sánchez-Zapata *et al.*[13] found that when white paper, yellow plastic, black plastic or aluminium foil were used as background, the pâté sample thickness had no effect on the color measurement. In the case of tuna pâté, sample thickness

Table 3: Influence of the background color on chroma and hue (X-Rite)

Chroma and hue	Sample thickness (mm)	White background	Black background
C	1.7	31.96±0.52[a]	23.15±0.30[b]
	3.4	30.82±0.55[a]	26.83±0.40[b]
	5.1	29.18±0.82[a]	28.31±0.48[b]
	6.8	29.65±0.61[a]	28.75±0.47[b]
	8.5	29.57±0.30[a]	29.36±0.38[a]
	10.2	29.27±0.56[a]	28.91±0.47[a]
	11.9	29.52±0.72[a]	28.99±0.62[a]
	13.6	29.00±0.53[a]	28.90±0.47[a]
h	1.7	80.29±0.13[a]	92.04±0.12[b]
	3.4	86.49±0.07[a]	89.49±0.07[b]
	5.1	86.49±0.07[a]	88.35±0.08[b]
	6.8	86.67±0.07[a]	87.72±0.08[b]
	8.5	86.81±0.06[a]	87.43±0.08[b]
	10.2	86.90±0.11[a]	87.21±0.12[b]
	11.9	86.86±0.11[a]	86.88±0.09[a]
	13.6	86.90±0.17[a]	87.01±0.10[a]

C: Chroma, h: Hue, [a,b]Different letters in a row denote statistically significant differences between results ($p<0.05$)

Table 4: Correlation coefficient and significance levels (p) between the color coordinates and thickness of cheese (white background)

	X-Rite SP60		Spectro-pen	
Coordinates	Correlation coefficient	p-value	Correlation coefficient	p-value
L*	-0.7768	0.039917	-0.9084	0.004646
a*	0.2901	0.527909	-0.4332	0.331623
b*	-0.8191	0.024178	-0.8212	0.024178

L*: From black to white, a*: From green to red, b*: From blue to yellow

Table 5: Correlation coefficient and significance levels (p) between the color coordinates and thickness of cheese samples (black background)

	X-Rite SP60		Spectro-pen	
Coordinates	Correlation coefficient	p-value	Correlation coefficient	p-value
L*	0.422	0.345123	-0.660	0.107002
a*	0.914	0.004032	0.891	0.007110
b*	0.796	0.032170	0.715	0.071034

L*: From black to white, a*: From green to red, b*: From blue to yellow

must be taken into consideration only when white ceramic or white plastic materials are used as background.

American Meat Science Association in meat color measurement guidelines recommend using samples that are at least 12-15 mm thick, stacking wafer-type samples and evaluating them against a white background or stacking product[27].

As sample thickness increased from 1.7 mm-13.6 cm for white background, the cheese had lower L* and b*, but higher a*. For black background, the thicker the cheese sample, the lighter the cheese, for X-Rite. For Specto-pen, L* was at a similar level (68.54 vs. 68.10), whereas a* and b* increased their values.

Table 4 presented Pearson's correlation coefficient between the coordinates and the thickness of the cheese. Except for a* coordinate, all of the measured color coordinates showed strong, negative and statistically significant correlation. Data in Tables 5 presented analogous results obtained on black background. Except for L* parameter, all of the measured color coordinates showed strong, positive and statistically significant correlation (except for b* parameter obtained from Spectro-pen).

When comparing the results of color measurement received from two different pieces of equipment, statistically significant differences were obtained for all thicknesses of the cheese samples, for both white and black backgrounds. Baardseth *et al.*[28] found that the variations from one instrument (for color measurement) to another are systematic and can be described by linear regression. The regression can be used to compare color values expected from one instrument with those obtained from another.

The results obtained in this research for the tested cheese coincided with earlier scientific contributions, even though these concerned different materials. Researchers confirmed that the colour of surface, sample thickness and the type of equipment used for color measurement affect color discriminants. These results are important in evaluating and reporting cheese color.

CONCLUSION

The research showed that a minimum sample thickness of 11.9 mm can be considered satisfactory for the analyzed Gouda cheese, which can eliminate the influence of the background color. Considering different cheese composition and texture, in laboratory practice, it is recommended to take a minimum 2 cm thick sample for the evaluation of cheese color.

SIGNIFICANCE STATEMENT

This research revealed the need for using minimum cheese thickness for marking its color with an aim of eliminating background color impact on the results. The results of the research are important contributions and can be used both in scientific studies as well as in laboratory practice. This study will aid dairy researchers and controllers in obtaining objective and comparable results for cheese colors.

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