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Digitalization of BSA Colorimetric Sensor Data with RGB Analysis Integrated into Smartphone

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Abstract

Today, with the digitalization of data, our project has been carried out to contribute to the developments in data analysis in telemedicine. A method has been developed for the detailed analysis of Bovine serum albumin, which is also used in cancer treatment, at different concentrations, with the use of an RGB data-based software that provides more detailed information and color homogenization compared to the colorimetric sensors used under the heading of point-of-care systems (POC). In this way, diagnostic technologies have become necessary to minimize the margin of error in health technologies and develop systems that do not cause economic difficulties. It is essential for the development of the health sector in our country and in the world to realize technological innovation in bedside systems and to contribute to the formation of this field. Our project, which we developed to make more detailed analyses with digitalization, wanted to draw attention to the importance of bovine serum albumin, an antimicrobial antigen used in many examination methods today, in diagnostic methods and to increase its effectiveness.

Keywords: bovine serum albumin (BSA); colorimetric sensor; digitalization; RBG analysis; point-of-care diagnostic systems.

1. Introduction

The establishment of health and information systems in Turkey within the framework of health reforms has gained great momentum since the 2000s. These methods have become more preferred because they contain a more effective diagnosis system and method than in the 1990s [2].

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Defined under the title of health transformation program announced in 2003, digitalization has been defined as the transfer of data to the computer environment for effective access to information in the decision process and has become a necessity of our age. The e-health project, which has become multidimensional with the effect of digitalization, offers 15 development goals. In this context, the benefits of digitalization in the field of health to the decision-making process, that is, to the detection process, are discussed. Diagnosis and treatment in clinical processes are accelerated thanks to digitalized data systems, human errors that may occur are reduced and service quality is increased [12]. Integration of such studies into all types of diagnostic systems will facilitate diagnosis and thus facilitate rapid, alternative treatment directions. Soon, as a result of artificial intelligence research accelerated by the effect of the pandemic; It is foreseen that health services will become clinically virtual and the use of artificial intelligence-based systems will become widespread [10]. An increasingly global focus on healthcare issues is working to highlight the importance of point-of-care technologies and their ability to provide cost-effective solutions that address many unmet healthcare needs [4]. Moreover, the current healthcare crisis has critically highlighted the need for research and development for highly effective, yet low-cost means of delivering healthcare. Focused on providing clinically actionable information at or near the patient, point-of-care devices provide clinicians with information critical to the management of patient care while with the patient [14]. Quick information provides several advantages for POC testing in different healthcare settings. In primary care settings in developed countries, the shortened timeline between testing and obtaining results reduces the need for extra office visits or follow-up phone calls to communicate test results and adjust the clinical response [5].

This strategy can reduce costs and increase access to medical care for underserved populations. POC testing for infectious diseases can quickly facilitate treatment modalities and thus prevent further spread of infection for better and timely clinical management. In acute care settings, timely access to diagnostic information is crucial to providing an effective medical response [7]. In disaster settings, POC diagnosis can accelerate triage and enable rapid establishment and delivery of medical services[11]. In the developed world, POC testing is primarily designed as an adjunct and not a replacement to central laboratory testing, while POC testing can enable local healthcare providers to provide cost-effective care in developing countries or rural areas without central access Reference [9]. In addition, a growing number of point-of-care technologies allow clinicians to remotely assess/monitor patients who are home-bound or unable to meet with clinicians in their clinical setting. The underlying theme is to increase the effectiveness of physicians by providing better/faster information enabling timely delivery and management of healthcare services.In this context, colorimetric methods, which are defined as the bedside diagnosis system developed based on the light absorption feature of colored solutions, show that the tested materials contain clues about;

- Protein content,
- DNA content,
- Enzyme activity,
- Reproductive mechanisms.

On the other hand, deficiencies in sufficient color concentration and color homogenization were detected in the data of the sensors on which the substance was applied. In the face of such problems, it is not possible to obtain detailed data by the colorimetric sensor.

In this project, a commercial colorimetric sensor used for the determination of the BSA biomarker, which is of great clinical importance, was used and a smartphone-integrated RGB analysis method was developed to eliminate the disadvantages of colorimetric sensors such as weak colorimetric signal and inability to provide color homogeneity. In this method, a more effective analysis method has been developed by digitizing the data of each colorimetric sensor with RGB codes.

2. Method

The stage of the experiment consists of two stages: In the first stage of the experiments, the colorimetric sensors interact with BSA solutions at different concentrations, and in the second stage, the color changes that occur on the sensor surfaces with a smartphone are digitized with RGB-based software, and the BSA concentrations are determined.

2.1. BSA concentration observations with colorimetric sensors

What is bovine serum albumin(BSA)?

BSA, like other serum albumins, is a critical protein in maintaining oncotic pressure in capillaries, transporting fatty acids, bilirubin, minerals, and hormones, and functioning as an antioxidant [13]. BSA has numerous biochemical applications, including ELISAs (Enzyme-Linked Immunosorbent Assay) and immunoblotting [1].

Enzyme-linked immunosorbent assays (ELISA) are a prevalent and powerful laboratory technique for detecting proteins by antibodies [16]. Researchers frequently use bovine serum albumin (BSA) as a blocking agent to prevent the non-specific binding of antigens and antibodies to the microtiter well [6]. Moreover, BSA is frequently used as a blocking agent in immunoblotting, which is the process of transferring the fractionated proteins on a gel layer in the electric field and making them visible with the help of labeled antibodies [3].

Immunohistochemical examination is a technique to search for a specific antigen or cells in a tissue [15]. In the immunohistochemistry method, the proteins sought in a tissue; can be identified by the application of an antibody and the specific binding of the antibody to the antigen. This examination system is used in tumor cell recognition, determination of cancer subtypes, and therapeutic symptom research [8]. Considering all these, bovine albumin serum is of great importance in human health and treatment methods for the diseases that occur. The main features of BSA are:

- Number of amino acid residues: 583
- Molecular weight: 66.46 Da
- Isoelectric point in water at 25°C: 4.7
- Stokes radius: 3.48nm pH value of
- 1% solution: 5.2-7

The experiment stages;

1. Interaction of colorimetric sensors with BSA solutions of different concentrations

In this study, paper-based colorimetric sensors were used for the determination of bovine serum albumin. In addition, software (Color Name AR) integrated into the smartphone with RGB-based data processing was used to minimize the problems that may occur due to poor color change and color homogenization depending on the concentration in the determination of BSA in the colorimetric sensor. To verify the applicability of the smartphone-based RGB analysis method used in the study, a commercially available paper-based colorimetric sensor that detects bovine serum albumin in the clinically BSA concentration range was used (Acon Lab-USA). BSA (Sigma Aldrich-A2153) solutions were prepared in ultrapure water at clinically determined concentrations (0.075 - 0.15 g/L) and interacted with sensor surfaces (Figure 1.) and (Figure 2.)

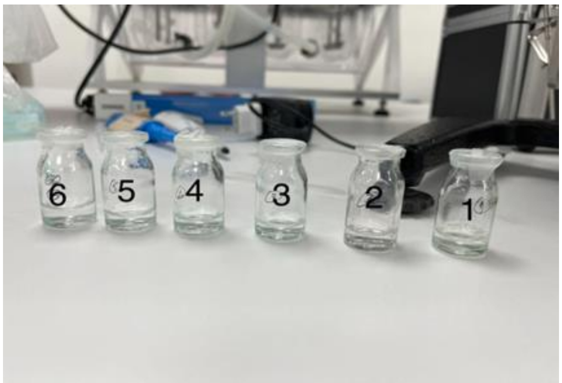

Figure 1: BSA Concentrations stored in different containers. Sample numbers and concentrations 6: 0.15 g/L, 5: 0.13 g/L, 4: 0.10 g/L, 3: 0.09 g/L, 2: 0.08 g/L, and 1: 0.075

Figure 2: For this purpose, lyophilized BSA was dissolved in ultrapure water at a concentration range of 0.075 - 0.15 g/L at room temperature and interacted with the sensor surfaces

2. Digitization of color changes on sensor surfaces with a smartphone with RGB-based software

RGB Color Name application was used for RGB analysis and RGB analysis was carried out under constant lighting from a distance of 9 cm from the sensor surfaces. Samples of 20 different RGB values of each concentration were taken and the average concentration values were calculated as a result of these data. All data were analyzed using a Samsung A52 smartphone (Figure 3).

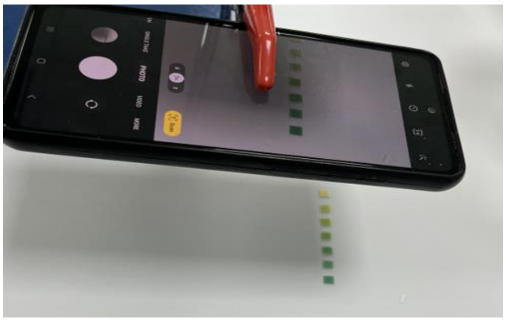

Figure 3: Demonstration of different color changes after the interaction of the concentration difference BSAwith the colorimetric sensor and digitization of the data with RGB analysis integrated into the smartphone

3. Results

For a more precise quantitative analysis of the BSA molecule, the pixel-based data point method in the RGB analysis method was used to calculate the color variations before and after the sensor images were exposed to the analyte (BSA) with the control group, and digitized RGB values were collected. In this approach, the smartphone application scans the points on each channel of the microfluidic platform in any x and y direction, giving RGB values for each point. (Fig. 5). The analysis carried out in the project showed that the pixel-based RGB analysis method collected data with high statistical accuracy at the minimum analyte volume. Here, the digitized red, green, and blue intensities of each pixel were calculated with the smartphone app (pixel-based data point method) and the RGB values changes at different BSA concentrations were measured by bar graph (Figure4).

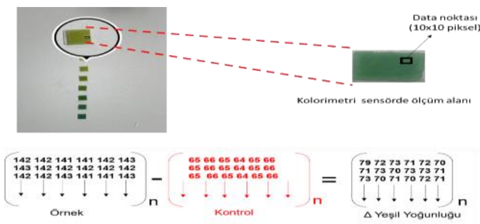

Figure 4: Changes in (A) red (R), (B) green (G), and (C) blue (B) density at different BSA concentrations, respectively

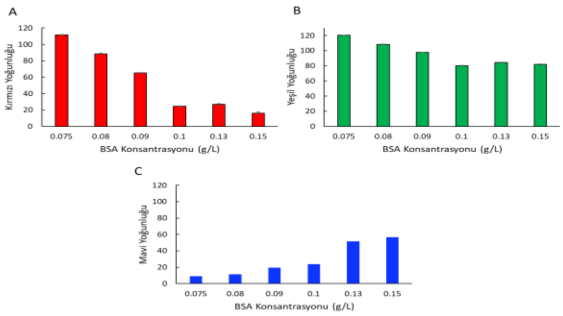

Figure 5: BSA determination with RGB analysis integrated into the smartphone

Then, separate graphs were drawn for the digitized RGB data obtained, and the correct equation and R^2 values of each graph were calculated to show the accuracy of the analysis. Accordingly, R^2 values were calculated as 0.92 for red, 0.85 for green, and 0.89 for blue (Figure 6).

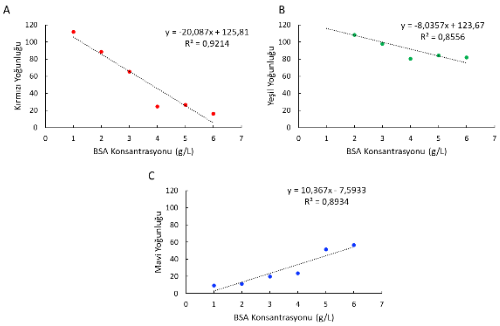

Figure 6: Calculation of (A) red (R), (B) green (G), and (C) blue (B) density changes and R2 values at different BSA concentrations, respectively

The technology preparation level of the RGB analysis data digitization method developed in the project is 6, and if the project is supported, RGB software will be developed for sensor systems from different environments. As a result, although the project is supported, it is aimed to increase the technology readiness level to9

4. Conclusion

When RGB analysis results were examined according to bovine serum albumin concentrations, it was concluded that red values showed a significant change in terms of pixel intensities compared to green and blue colors (R^2=0.92). As a result, it has been shown that red pixel intensities provide reliable and more sensitive quantitative results between BSA concentrations. These results showed that the pixel-based digitized RGB analysis method integrated into the smartphone provides reliable reading. In general, the RGB analysis method proposed in this study has been seen as a very practical method for the development of bedside diagnostic systems, for obtaining more effective data in the fields of ELISAs (Enzyme-Linked Immunosorbent Test) and immunoblotting, and for the extraction of tumor-based treatment reports and cancerous tissue detection in immunohistochemistry studies. A cost-free analysis method is presented to create a healthier database in the usage areas of BSA protein[15].

References

[1]. Berenblum, I., & Chain, E. (1938). An improved method for the colorimetric determination of phosphate. *Biochemical Journal, 32*(2), 295.

[2]. Demirci, Ş. (2019). SAĞLIĞIN DİJİTALLEŞMESİ-DIGITALIZATION OF HEALTH. *Mehmet Akif Ersoy Üniversitesi Sosyal Bilimler Enstitüsü Dergisi, 10*(26), 710-721.

[3]. Eisenberg, G. (1943). Colorimetric determination of hydrogen peroxide. *Industrial & Engineering Chemistry Analytical Edition, 15*(5), 327-328.

[4]. Erickson, K. A., & Wilding, P. (1993). Evaluation of a novel point-of-care system, the i-STAT portable clinical analyzer. *Clinical chemistry, 39*(2), 283-287.

[5]. Gjellebæk, C., Svensson, A., Bjørkquist, C., Fladeby, N., & Grundén, K. (2020). Management challenges for future digitalization of healthcare services. *Futures, 124*, 102636.

[6]. Gonzalez, E., Alvarez, O., Diaz, Y., Parra, C., & Bustacara, C. (2005). *BSA: A complete coverage algorithm.* Paper presented at the proceedings of the 2005 IEEE International Conference on Robotics and Automation.

[7]. Holland, C. A., & Kiechle, F. L. (2005). Point-of-care molecular diagnostic systems—past, present, and future. *Current opinion in microbiology, 8*(5), 504-509.

[8]. Kayışlı, Ü. A. (1997). *Sıçanlarda implantasyon evresinde blastosist trofoblastı ile uterus etkileşmesinin immunohistokimyasal tekniklerle belirlenmesi.* Akdeniz Üniversitesi,

[9]. Kozel, T. R., & Burnham-Marusich, A. R. (2017). Point-of-care testing for infectious diseases: past, present, and future. *Journal of Clinical Microbiology, 55*(8), 2313-2320.

[10]. McLoughlin, I. P., Garrety, K., & Wilson, R. (2017). *The digitalization of healthcare: Electronic records and the disruption of moral orders*: Oxford University Press.

[11]. Menvielle, L., Audrain-Pontevia, A.-F., & Menvielle, W. (2017). The digitization of healthcare: new challenges and opportunities.

[12]. Nazlı, K., & GEMLİK, N. (2021). HASTANE YÖNETİCİLERİNİN HASTANELERİN DİJİTALLEŞMESİNE BAKIŞ AÇILARI ÜZERİNE NİTEL BİR ARAŞTIRMA. *Journal of Academic Perspective on Social Studies*(1), 59-71.

[13]. Ravindran, A., Singh, A., Raichur, A. M., Chandrasekaran, N., & Mukherjee, A. (2010). Studies on the interaction of colloidal Ag nanoparticles with bovine serum albumin (BSA). *Colloids and Surfaces B: Biointerfaces, 76*(1), 32-37.

[14]. Şahinol, M., & Başkavak, G. (2020). Türkiye'de Biyomedikalizasyon: Sağlığın Dijitalleşmesi ve Öz-Takip Pratikleri. *Türkiye'de STS: Bilim ve Teknoloji Çalışmalarına Giriş içinde*, 103-117.

[15]. Weber, G., & Young, L. B. (1964). Fragmentation of bovine serum albumin by pepsin: I. The origin of the acid expansion of the albumin molecule. *Journal of Biological Chemistry, 239*(5), 1415-1423.

[16]. Xiao, Y., & Isaacs, S. N. (2012). Enzyme-linked immunosorbent assay (ELISA) and blocking with bovine serum albumin (BSA)—not all BSAs are alike. *Journal of Immunological Methods, 384*(1-2), 148-151.