UDC: 637.2/.3.052-026.613:635.112
Professional paper

COLOR STABILITY OF DAIRY PRODUCTS ENRICHED WITH BEETROOT (BETA VULGARIS L. SPECIES)

Tanja STOJANOVSKA[1], Tatjana KALEVSKA[1], Nevena GRUEVSKA[1], Viktorija STAMATOVSKA[1], Daniela NIKOLOVSKA NEDELKOSKA[1]

[1]*Faculty of Technology and Technical Sciences -Veles, University St. Kliment Ohridski - Bitola*
Dimitar Vlahov bb. 1400 Veles, R.N.Macedonia
[*]*Corresponding Author: e-mail: tanja.b.stojanovska@uklo.edu.mk*

Abstract

Consumer concerns about the negative impact of synthetic dyes on their health have prompted manufacturers to use natural dyes. Beetroot *(Beta vulgaris L. species)* is abundant in betalains, naturally occurring pigments that are water-soluble, with pronounced antioxidant, anti-inflammatory, antiviral, and antitumor properties. Its availability and ease of application make beetroot an attractive option for dairy producers as both a natural and functional colorant. However, betalains' chemical instability limits their wide application. Temperature, pH, water activity, oxygen, light, chelating agents, pigment concentration, storage and processing conditions are some of the factors affecting their stability. In this brief desk review, we will look at the possibilities for applications of beetroot as a natural colorant in dairy products and changes that occur under various storage and production conditions.

Keywords: Beetroot, dairy, natural color, color stability.

1. Introduction

The colour of food is the main characteristic that acts as an indicator of quality and consumer acceptability (Alshehry, 2019). The use of synthetic red pigments can have a negative impact on human health due to their carcinogenicity (Tsuda et al., 2001). Natural food coloring dyes are receiving increasing attention due to concerns about the negative impact of synthetic dyes on consumer health and the environment (Sooch et al., 2024).

The red color of *Beta vulgaris L. species* is derived from betalains, which are derivatives of betalamic acid. They are water-soluble and contain nitrogen (Georgiev et al., 2008). Depending on their color, they are divided into two structural groups: red-violet (betacyanins) and yellow (betaxanthins), (Ravichandran et al., 2013; Ben Haj Koubaier et al., 2014). The main representatives of yellow pigments are indicaxanthin and vulgaxanthin I and II, betacyanins include betanin, prebetanin, isobetanin, and neobetanin (Eyshi et al., 2024). Beets are a rich source of betalains, their content in beet powder is 24.58mg/g (Farhan et al., 2024), while sun-dried beets have 3.10 mg/g and freeze-dried beets contain 4.89 mg/g of betalains (Bunkar et al., 2020).

Betalains are phenolic chromoalkaloids with health benefits for humans, especially in terms of their antioxidant, anti-inflammatory, antiviral, and antitumor activity (Baião et al., 2020). Betanin's ability to scavenge free radicals is due to its ability to donate electrons and hydrogen due to its structure, i.e., the presence of cyclic amine and hydroxyl groups (^{-}OH), which are excellent donors of hydrogen (Kanner et al., 2001). Because of its ability to remove reactive oxygen species, betanin prevents oxidative damage to lipid macromolecules and DNA (Sakihama et al., 2012). In vascular tissue, the anti-radical activity of betanin maintains endothelial function and reduces atherogenesis. In addition, betanin may modulate signal

https://doi.org/10.62792/ut.jftn.v8.i15-16.p2983

transduction mediated by redox pathways involved in inflammatory responses in endothelial cells, resulting in antiproliferative effects in human tumor cells (Kapadia et al., 2011).
All these positive characteristics of betalains encourage producers to use beets as a natural color and functional component (Fernández-López et al., 2023). The use of betalains as antioxidant agents meets the growing demand for functional foods and should not be overlooked due to their pigmentation properties and sensory impact on the foods to which they are added (Calva-Estrada et al., 2022). The addition of natural colorants to dairy products enhances their appeal, particularly to children, thereby increasing product demand and contributing positively to children's overall health (Salman et al., 2024).
Beets in reformulated products are commonly added in the form of extracts, juice, powder, pulp, and flour (Domínguez et al., 2020). This includes products such as yogurt (Adjei et al.,-2024), milk (Kavitkar et al., 2017), cheese (Prudencio et al., 2008), albumen cheese (Stojanovska et al., 2025b), ice cream (Evstigneeva et al., 2020), candies (Dobhal & Awasthi, 2019) and biscuits (Mitrevski et al., 2023). However, their chemical instability limits their wide application. Temperature, pH, water activity, oxygen, light, chelating agents, pigment concentration, storage and processing conditions are some of the most important factors affecting their stability (Ceclu & Nistor et al., 2020).

2. Color stability of dairy products enriched with beetroot

According to Adjei et al. (2024) the color of yogurt was mainly influenced by the concentration of added beetroot puree in content of 2% (T1), 2.03% (T2), and 8% (T3). The highest value for the a* parameter was observed in the T3 sample, which had the highest beetroot puree concentration (8%). Shalaby & Hassenin, (2020) reported the highest $a*$ parameter value (3.90) for color determination, which was significantly different from the control yogurt, which exhibited the highest $b*$ parameter value (10.55), indicating the degree of yellow to blue. In probiotic yogurt with added beet juice at a content of 1%, the $L*$ parameter value was 82.84, the $a*$ value was 9.41, and the $b*$ value was 10.23 on day 0 of storage. It was observed that on the 12th day of storage of probiotic yogurt, the $L*$ value decreased to 81.89, the $a*$ value increased to 14.96, and the $b*$ value dropped to 6.726 (Salman et al., 2024). The colour changes, red (R), green (G), blue (B) and brightness (L), of the traditional Indian milk drink "Lassi" with added beets in different concentrations during cold storage for 8 days were not statistically significant. The authors believe that this is primarily due to the low pH of the beverage (4.70 to 4.48) and low storage temperature (Kavitkar et al., 2017). According to Fu et al., (2020) betalains are stable with respect to hydrolytic cleavage, in the pH range of 3 to 7, and no change in maximum absorption of betalain (537 nm) was observed, while the spectrum was identical with no color change. According to Agne et al. (2010), betocyanin is most stable at pH 4.5 but is degraded with increasing pH. The positive effect of low storage temperatures and the absence of light on the stability of betalains is confirmed by Kavitkar et al. (2017), in milk with added beet extract at different concentrations of 0, 1, 2, 3, 4 and 5 mL per 500 mL of milk. Light causes degradation of betalain but this degradation depends on the presence of oxygen, because the impact of light exposure is negligible under anaerobic conditions (Fu et al., 2020).
Betalains undergo degradation when the temperature is higher than 50 °C, while when heated to a temperature of 100 °C, the red color gradually disappears and turns to yellowish-brown (Kavitkar et al., 2017). Changes in the color values of beet-colored milk were examined when heated at a temperature of 70-90ºC. The degradation of betalains followed first-order kinetics, while changes in the $L*$, Hue angle, and Chroma values corresponded to zero- and first-order kinetics. The reaction rates for the degradation of betalain, $L*$, Hue angle, and Chroma values ranged from 1. 588–30.975 × $10^{-3}min^{-1}$, 90.50–379.75$L*min^{-1}$, 0.581–5.008 Hue angle

min^{-1} and $3.250–19.750 \times 10^{-3} min^{-1}$, respectively. Between 70 and 90 °C, activation energy for the degradation of betalains was 42.449 kJ mol^{-1}. *L** values was more stable than Hue angle and Chroma color values in colored milk during heating (Güneşer, 2016). A decrease in betalains due to exposure to high temperature confirms this (Ingle et al., 2017).
Betalains decreased during cold storage (4°C) for 14 days, from 45% to 47.46 mg/L, in a whey drink enriched with 2.5% beet peel extract. This reduction led to a decrease in red color (*a**) and an increase in yellow color (*b**) (Abdo et al., 2022). This decrease may be due to the high water content, because the hydrolytic reaction is water-dependent. Also, the activity of water (*aw*) may act as an important factor in evaluating the sensitivity of betanin to aldymine bond cleavage (Fu et al., 2020). The incorporation of organic beetroot powder (0%, 2.5%, 5%, and 7.5%) into albumin cheese (Urda) resulted in statistically significant differences ($p < 0.05$) in color parameters between the control sample and the enriched variants. The *L** value decreased with increasing levels of beetroot powder. Even the lowest concentration of beetroot powder (2.5%) induced a statistically significant change ($p < 0.05$) in the *a** parameter throughout the entire storage period of the albumin cheese. The *b** parameter values indicated a reduction in yellowness and an intensification of the blue hue as the proportion of beetroot powder increased (Stojanovska et al., 2025a). According to Prudencio et al., (2008), the stability of betalans in cheese during storage can be justified by its low pH, low water content, low temperature storage, and light-impervious packaging.

3. Conclusions

The increased demand for natural dyes has prompted dairy manufacturers to use beetroot betalains beets or betalains as natural dyes. However, their stability is questionable, especially in products that are subjected to heat treatment, contain a high percentage of water, or are exposed to light and oxygen. However, cheeses as fermented milk products have proven to be a good medium for color stability due to their pH, low water content, low-temperature storage, and light-impermeable packaging. Further research is needed regarding the added quantities of beets and the technological parameters of production and storage in order to find favorable parameters and thus enable the use of beets as a natural color and functional component in the dairy industry.

References

[1] Abdo, E. M., Allam, M. G., Gomaa, M. A., Shaltout, O. E., & Mansour, H. M. (2022). Valorization of whey proteins and beetroot peels to develop a functional beverage high in proteins and antioxidants. Frontiers in Nutrition, 9, 984891. https://doi.org/10.3389/fnut.2022.984891

[2] Adjei, M. L., Boakye, A., Deku, G., Pepra-Ameyaw, N. B., Jnr, A. S. A., Oduro, I. N., & Ellis, W. O. (2024). Development of yoghurt incorporated with beetroot puree and its effect on the physicochemical properties and consumer acceptance. *Heliyon*, 10(3) e25492. https://doi.org/10.1016/j.heliyon.2024.e25492

[3] Agne, E. B. P., Hastuti, R., & Khabibi, K. (2010). Ekstraksi dan uji kestabilan zat warna betasianin dari kulit buah naga (Hylocereus polyrhizus) serta aplikasinya sebagai pewarna alami pangan. *Jurnal Kimia Sains dan Aplikasi*, 13(2), 51-56. https://doi.org/10.14710/jksa.13.2.51-56

[4] Alshehry, G. A. (2019). Utilization of beetroot as a natural antioxidant, pigment and antimicrobial in cupcake during the storage period. *International Journal of Engineering Research & Technology*, *8*(10), 652-9. DOI: 10.17577/IJERTV8IS100053

[5] Ben Haj Koubaier, H., Snoussi, A., Essaidi, I., Chaabouni, M. M., Thonart, P., & Bouzouita, N. (2014). Betalain and phenolic compositions, antioxidant activity of Tunisian red beet (Beta vulgaris L. conditiva) roots and stems extracts. *International journal of food properties*, *17*(9), 1934-1945. https://doi.org/10.1080/10942912.2013.772196

[6] Bunkar, D. S., Anand, A., Kumar, K., Meena, M., Goyal, S. K., & Paswan, V. K. (2020). Development of production technology for preparation of beetroot powder using different drying methods. *Annals of Phytomedicine*, *9*(2), 293-301 http://dx.doi.org/10.21276/ap.2020.9.2.29

[7] Baião, dos S., D., da Silva, D. V., & Paschoalin, V. M. (2020). Beetroot, a remarkable vegetable: Its nitrate and phytochemical contents can be adjusted in novel formulations to benefit health and support cardiovascular disease therapies. *Antioxidants*, 9(10), 960. https://doi.org/10.3390/antiox9100960
[8] Calva-Estrada, S. J., Jiménez-Fernández, M., & Lugo-Cervantes, E. (2022). Betalains and their applications in food: The current state of processing, stability and future opportunities in the industry. *Food chemistry: molecular sciences*, 4, 100089. https://doi.org/10.1016/j.fochms.2022.100089
[9] Ceclu, L., & Nistor, O. V. (2020). Red beetroot: Composition and health effects—A review. *J. Nutr. Med. Diet Care*, 6(1), 1-9. DOI:10.23937/2572-3278.1510043
[10] Dobhal, A., & Awasthi, P. (2019). Formulation of beetroot candy using simple processing techniques and quality evaluation. *Journal of Pharmacognosy and Phytochemistry*, *8*(4), 913-916.
[11] Domínguez, R., Munekata, P. E., Pateiro, M., Maggiolino, A., Bohrer, B., & Lorenzo, J. M. (2020). Red beetroot. A potential source of natural additives for the meat industry. *Applied Sciences*, *10*(23), 8340. https://doi.org/10.3390/app10238340
[12] Evstigneeva, T., Iakovchenko, N., Kuzmicheva, N., & Skvortsova, N. (2020). Applying beetroot as food ingredient in ice-cream production. *Agronomy Research* 18(S3), 1662–1672, https://doi.org/10.15159/AR.20.115
[13] Eyshi, S., Ghareaghajlou, N., Afshar Mogaddam, M. R., & Ghasempour, Z. (2024). Red beet betalains extraction process: A comprehensive review of methods, applications, and physicochemical properties. *Food Science & Nutrition*, *12*(11), 8540-8558.https://doi.org/10.1002/fsn3.4458
[14] Farhan, M., Ahmad, Z., Waseem, M., Mehmood, T., Javed, M. R., Ali, M., & Goksen, G. (2024). Assessment of Beetroot powder as nutritional, antioxidant, and sensory evaluation in candies. Journal of Agriculture and Food Research, 15, 101023. https://doi.org/10.1016/j.jafr.2024.101023
[15] Fernández-López, Juana, Angel J. Ponce-Martínez, Judith Rodríguez-Párraga, Ana M. Solivella-Poveda, Jose A. Fernández-López, Manuel Viuda-Martos, and Jose A. Pérez-Alvarez. "Beetroot juices as colorant in plant-based minced meat analogues: Color, betalain composition and antioxidant activity as affected by juice type." *Food Bioscience* 56 (2023): 103156. https://doi.org/10.1016/j.fbio.2023.103156
[16] Fu, Y., Shi, J., Xie, S. Y., Zhang, T. Y., Soladoye, O. P., & Aluko, R. E. (2020). Red beetroot betalains: Perspectives on extraction, processing, and potential health benefits. Journal of Agricultural and Food Chemistry, 68(42), 11595-11611. https://dx.doi.org/10.1021/acs.jafc.0c04241
[17] Georgiev, V., Ilieva, M., Bley, T., & Pavlov, A. (2008). Betalain production in plant in vitro systems. *Acta Physiologiae Plantarum*, *30*, 581-593. DOI:10.1007/s11738-008-0170-6
[18] Güneşer, O. (2016). Pigment and color stability of beetroot betalains in cow milk during thermal treatment. *Food Chemistry*, *196*, 220-227. https://doi.org/10.1016/j.foodchem.2015.09.033
[19] Ingle, M., Thorat, S. S., Kotecha, P. M., & Nimbalkar, C. A. (2017). Nutritional assessment of beetroot (Beta vulgaris L.) powder cookies. Asian Journal of Dairy & Food Research, 36(3). https://doi.org/10.18805/ajdfr.v36i03.8963
[20] Kapadia, G.J., A Azuine, M., Subba Rao, G., Arai, T., Iida, A., & Tokuda, H. (2011). Cytotoxic effect of the red beetroot (Beta vulgaris L.) extract compared to doxorubicin (Adriamycin) in the human prostate (PC-3) and breast (MCF-7) cancer cell lines. *Anti-Cancer Agents in Medicinal Chemistry (Formerly Current Medicinal Chemistry-Anti-Cancer Agents)*, *11*(3), 280-284. **:** https://doi.org/10.2174/187152011795347504
[21] Kavitkar, R.S., Rao, K.J., Mishra, D., Chavhan, B., Deshmukh, G.P., & Prajapati, R. (2017). Utilisation of Beetroot Extract as Colouring Agent in Lassi, *Int. J. Pure App. Biosci.* 5(6), 295-299. doi: http://dx.doi.org/10.18782/2320-7051.2913
[22] Kavitkar, R.S., Rao, K.J., Mishra, D., Deshmukh, G.P., Prajapati, R., & Jadhao, S.Y. (2017). Effect of Beetroot Extract on Colour and Sensory Quality of Flavoured Milk, Int. J. Pure App. Biosci. 5(5): 1177-1182 (2017). doi: http://dx.doi.org/10.18782/2320-7051.2879
[23] Kumar, Y. (2015). Beetroot: A super food. *International Journal of Engineering Studies and Technical Approach*, 01(3), 20–26.
[24] Mitrevski, J., Pantelić, N. Đ., Dodevska, M. S., Kojić, J. S., Vulić, J. J., Zlatanović, S., & Antić, V. V. (2023). Effect of beetroot powder incorporation on functional properties and shelf life of biscuits. *Foods*, *12*(2), 322. https://doi.org/10.3390/foods12020322
[25] Prudencio, I. D., Prudêncio, E. S., Gris, E. F., Tomazi, T., & Bordignon-Luiz, M. T. (2008). Petit suisse manufactured with cheese whey retentate and application of betalains and anthocyanins. *LWT-Food Science and Technology*, *41*(5), 905-910. https://doi.org/10.1016/j.lwt.2007.05.019
[26] Ravichandran, K., Saw, N. M. M. T., Mohdaly, A. A., Gabr, A. M., Kastell, A., Riedel, H., & Smetanska, I. (2013). Impact of processing of red beet on betalain content and antioxidant activity. *Food research international*, 50(2), 670-675 https://doi.org/10.1016/j.foodres.2011.07.002
[27] Salman, K. H., Mehany, T., Zaki, K. G., & Al-Doury, M. K. (2024). Development of functional probiotic yogurt from buffalo milk supplemented with red beetroot (Beta vulgaris L.) as an antioxidant,

natural colorant, and starter growth stimulant. *Food Chemistry Advances*, *5*, 100776. https://doi.org/10.1016/j.focha.2024.100776

[28] Sakihama, Y., Maeda, M., Hashimoto, M., Tahara, S., & Hashidoko, Y. (2012). Beetroot betalain inhibits peroxynitrite-mediated tyrosine nitration and DNA strand cleavage. *Free Radical Research*, *46*(1), 93-99. https://doi.org/10.3109/10715762.2011.641157

[29] Shalaby, H. S., & Hassenin, A. S. (2020). Effects of Fortification stirred yoghurt with red beetpowder (RBP) on Hypercholesterolemia Rats. *European Journal of Agriculture and Food Sciences*, *2*(5).DOI: http://dx.doi.org/10.24018/ejfood.2020.2.5.61

[30] Sooch, B. S., Sandhu, N., Mann, M. K., & Ray, R. C. (2024). Valorization of Beetroot Waste for Extraction of Natural Dye for Textile and Food Applications. In *Roots, Tubers, and Bulb Crop Wastes: Management by Biorefinery Approaches* (pp. 237-260). Singapore: Springer Nature Singapore. https://doi.org/10.1007/978-981-99-8266-0_11

[31] Tsuda, S., Murakami, M., Matsusaka, N., Kano, K., Taniguchi, K., & Sasaki, Y. F. (2001). DNA damage induced by red food dyes orally administered to pregnant and male mice. *Toxicological Sciences*, *61*(1), 92-99. https://doi.org/10.1093/toxsci/61.1.92

[32] Stojanovska, T., Kalevska, T., Nakov, G. & Gruevska, N. (2025a). Determination of the color and sensory characteristics of albumin cheese enriched with beetroot. *Knowledge-International Journal*, 69(3) 595-599

[33] Stojanovska, T., Kalevska, T., Nakov, G. & Ivanova – Petropulos, V. (2025b). Spectrophotometric determination of betalains and total phenols in albumin cheese enriched with organic beetroot powder. *Knowledge-International Journal*, 69(3) 607-612