

USE OF BEET (*Beta vulgaris L.*) AS A NATURAL COLORANT AND FUNCTIONAL INGREDIENT IN THE MEAT AND DAIRY INDUSTRY

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Abstract

- Color is a key factor influencing consumer acceptance of products. In the food industry, synthetic dyes are predominantly used to enhance and stabilize the color of food products during storage and display in retail markets. However, in recent years, the demand for natural dyes has grown significantly, driven by consumer preferences for safer, healthier products, following concerns about the toxicity and carcinogenicity of certain synthetic dyes. Natural dyes, derived from natural sources, not only provide coloring but are also rich in bioactive compounds that can enhance the functional properties of the products to which they are added. Beetroot (*Beta vulgaris L.*) contains several bioactive compounds, including betalains, which are water-soluble natural colorants with strong antioxidant potential. Over the past decade, research on the use of beetroot as a natural colorant and antioxidant in the meat industry has intensified, primarily to reduce the use of sodium nitrate. In the dairy industry, beetroot is used to stabilize the color of fruit yogurts and enhance the functional properties of reformulated products. The use of beets and the stability of betalains in the product depends on: the amount added, the food as a medium, the presence of enzymes and other additives, the activity of water - a_w , pH, heat treatment, and exposure to light and oxygen during storage.

- This review will provide a literature review on the application possibilities of beets in the meat and dairy industries, their impact on color stability, antioxidant potential, and impact on product functionality.

- **Key words:** Beets, betalains, natural dyes, dairy products, meat products.

- **Area:** Technological and technical sciences

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INTRODUCTION

- Color is one of the key factors in the acceptability of a product by consumers, which directly influences the purchase decision of the product (Resurreccion, 2004). This is partly a reaction to safety concerns about certain synthetic dyes by vendors as well as the food industry's safety assessment (Scotter, 2011). In the last decade, there has been a growing interest in researching and applying natural dyes as alternatives to synthetic ones Jadhav et al., (2020), which are derived from natural sources such as plants, animals, insects, and minerals (Devi et al., 2013). Unlike synthetic

dyes that are toxic and carcinogenic Jadhav et al., (2020), natural dyes have certain health benefits, such as antioxidant, anticarcinogenic, and anti-inflammatory effects (Singh et al., 2023).

- Many plants contain pigments responsible for their natural color Singh et al., (2023), including red beet (*Beta vulgaris L. species*) which is botanically classified herbaceous biennial of the family *Chenopodiaceae* (Varshney & Mishra, 2022). Red beet (*Beta vulgaris L. species*) is an alkaline food with a pH value of 7.5-8 Chauhan et al., (2020) with a low energy value of 43 kcal/100g, Akan et al., (2021), which includes: water 87.58%, protein 1.61%, fat 0.17%, carbohydrates 9.56%, sugars 6.76%, and dietary fiber 2.8% (USDA, 2019). Beets also contain a number of bioactive compounds Baião et al., (2017), such as betalains, flavonoids, carotenoids, polyphenols, saponins, and high nitrates Clifford et al., (2015); Deshmukh et al., (2018), as well as minerals (potassium, sodium, iron, copper, magnesium, calcium, phosphorus, and zinc) Razzak et al., (2024), and vitamins (retinol, ascorbic acid, and B-complex) (Yashwant, 2015).

- Due to the content of potent bioactive compounds, beets are added to many food products Sertdemirci & Gençlelep, (2023), to increase their nutritional value Sahni & Shere, (2016); Baião et al., (2020), and due to the presence of betalains, beets are also used as a natural colorant (Chhikara et al., 2019). In fact, the red color of beets is a result of the presence of betalains, which, depending on their coloration, are divided into two groups: red-purple betananes (betanins, prebetanines, isobetannins, and neobetanins) and yellow betaxanthines (vulgaxanthin I and II) (Ravichandran et al., 2013; Ben Haj Koubaier et al., 2014). Betalains are derivatives of betalamic acid with 3,4-dihydroxyphenylalanine (cyclo-DOPA), which can be glycosylated (Sadowska-Bartosz & Bartosz, 2021). The most abundant betacyanin in beet is bethanidine 5-O- β -glucoside, which contains phenolic and cyclic amino groups, which are good electron donors and act as antioxidants (Kanner et al., 2001). Due to their water solubility, coloring property, and antioxidant activities, betalains are increasingly incorporated/added to various foods (Calva-Estrada et al., 2022).

- Beets in reformulated products are commonly added in the form of extracts, juice, powder, pulp, and flour (Dominguez et al., 2020). The original use of beets was for dyeing products, but recent research on its technological and functional properties opens up the possibility of its use as a functional ingredient (Fernández-López et al., 2023). Beetroot betalains and polyphenols are unstable in the presence of light, high temperatures, alkaline pH, enzymatic activity, and the presence of oxygen and/or metals, which is why their use in food, however, is limited (Flores-Mancha et al., 2021).

USE OF BEETS IN THE MEAT INDUSTRY

- One of the important organoleptic indicators for the quality of meat products is the color of the finished product (Ukwo et al., 2022). Sodium nitrite is one of the permissible additives widely used in the meat industry to achieve a remarkable reddish-pink color (Lee et al., 2021). In addition, sodium nitrate gives meat products a distinctive flavor, reduces lipid oxidation, and controls the growth of some pathogens (Hwang et al., 2018). Safety of sodium nitrate is questionable due to its reaction with amines, amides, and other nitrosation precursors in the gastrointestinal tract and the formation of N-nitrosamine compounds, which are carcinogenic (Lee et al., 2021). Composition of beets includes several compounds of particular interest to the meat industry, such as: dyes (betalains), antioxidants (betalains and phenolic compounds), preservatives (nitrates), which can be applied to the reformulation of meat products (Dominguez et al., 2020).

- Sodium nitrate was substituted for beetroot powder at 0.5% and 1.0% content in emulsified pork sausages, which significantly affected the increase in moisture content and pH ($p < 0.0001$) and color corrections. The parameter value L^* decreased ($p < 0.01$), while during storage for 20 days at a temperature of 4 °C the value for L^* in treated samples increased ($p < 0.05$). The addition of beets also increased redness ($p < 0.0001$). Sensory evaluation found a significant effect of added beets on sausage color ($p < 0.05$), while the taste, softness, juiciness and overall acceptability were not affected ($p > 0.05$), (Jin SangKeun et al., 2014). The beets were prepared in powder form and used to replace

sodium nitrite (nitrite 50 and 100 ppm) at 1% levels in heat-treated sujuk-sausage, which followed during cold storage for 30 days. Added beets during the treatment period and storage period had significant product effects ($P < 0.01$) on moisture, pH, water activity a_w , residual nitrite, free fatty acids (FFA), reactive substance of 2-thiobarbituric acid (TBARS), total mesophilic aerobic bacteria (TMAB), Enterobacteriaceae, yeasts, mold, and dye (L^* , a^* and b^* values) in heat-treated sujuk sausage (Sertdemirci & Gençcelep, 2023). The use of liquid beet extract and powder extract in fermented and heat-treated sausages has been investigated (Aykın-Dinçer et al., 2021). The moisture content, pH, lightness (L^*), yellowness (b^*), and odor values of heat-treated sausages were higher than those of fermented sausages. The reactive substance values of 2-thiobarbituric acid (TBARS) were lower in sausages with liquid extract (20.51 $\mu\text{mol} \cdot \text{MDA}/\text{kg}$) and powder extract (19.03 $\mu\text{mol} \cdot \text{MDA}/\text{kg}$) compared to controls and samples with added carmine. The low TBARS values in beet-fortified sausages may be due to the antioxidant activity of betalains and phenolic compounds. TBARS values in low-salt Frankfurt sausages with varying levels (1%, 3%, and 5%) of fermented beet extract were monitored for 4 weeks by (Hwang et al., 2017). The initial TBARS values for the control and all treatments did not differ significantly ($p > 0.05$), while at the end of the storage period, sausages fortified with fermented beet powder had lower TBARS values (0.34 mg MD/kg, 0.38 mg MD/kg, and 0.36 mg MD/kg, for added fermented beet powder of 1%, 3%, and 5%, respectively) relative to the control (0.48 mg MD/kg). There is a link between TBARS and sensory odor in meat products, and a maximum TBAR value limit of 2.0 mg MDA/kg has been proposed as an indicator of quality. The addition of 1% beet powder to fermented sausages showed TBARS values above the limit for sensory perception of rancidity (2 mg/kg) after 60 days of storage (Ozaki et al., 2021). Adding 6% beet powder to turkey patties contributed to an increase in vitamin C, lutein, α and β -carotene, and tocopherol, as well as an increase in oxidative stability (Duthie et al., 2013). Analysis of the biochemical composition of vitamins in minced meat indicated that the dried beet coloring agent added improved the content of ascorbic acid (vitamin C – 0.98 mg/100 g) and β -carotene (vitamin A – 0.46 mg/100 g) in minced meat (Kriger et al., 2024).

- USE OF BEETS IN THE DAIRY INDUSTRY

- Unlike the meat industry, beets as a natural colorant are more commonly used in the dairy industry as a means of improving and stabilizing color Punia Bangar et al., (2023) of yogurt, fruit yogurts, Adjei et al., (2024); Dabija et al., (2019), milk Kirdat et al., (2019), ice cream Khider et al., (2019), and cream cheese (Sandhya & Priya, 2017). The widespread use of beets in the dairy industry is a result of the absence of heat treatment of dairy products and a favorable pH environment for the stability of betalains, which are one of the basic parameters for the stability of betalains (Ceclu & Nistor, 2020). Betalains are relatively stable at pH in the range of 3 to 7, while the optimal pH value for maximum stability of betanin is 5 to 6 (Azeredo, 2009). While temperatures above 50°C contribute to the degradation of betalains and betanin, and thus discoloration (Otálora González et al., 2020).

- Of the dairy products with added beets, commonly researched product is yogurt (Punia Bangar et al., 2023). According to Adjei et al., (2024), optimal yogurt formulations were obtained by adding 2%, 2.03%, and 8% of beet puree after an incubation of 2.5 hours. An increase in the content of added beets did not affect pH and titrating acidity, but there was little effect on the viscosity of yogurt. Yogurt incorporated with 8% beet puree was the least preferred with a mean score of 6.08, while yogurt incorporated with 2.03% was the most preferred (7.42), with higher acceptance and control (7.28). Addition of 5% beet juice contributed to greater viability of probiotic yogurt ($p < 0.05$) relative to control and values of 7.0 ± 0.08 , 7.22 ± 0.04 , 7.34 ± 0.002 log cfu/mL for streptococci, lactobacilli, and bifidobacteria, respectively, were recorded (Salman et al., 2024). While according to Flores-Mancha et al., (2021), the highest antioxidant activity was observed after 14 days in yogurt with added beet juice (ABTS 0.819 mM TE/100 g and DPPH 0.343 mM TE/100 g), compared to the control on day 14 (ABTS 0.526 mM TE/100 g and DPPH 0.094 mM TE/100 g). Also, applying of

beet syrup to Greek yogurt increased the mineral content (de Oliveira et al., 2024). In a sample mixture of 50 ml of yogurt, 50 ml of beet juice, the content of magnesium was 0.40 mg/100mL, calcium 63 mg/100mL, sodium 1.6 mg/100mL, potassium 15 mg/100mL, and vitamin C 15.0 mg/mL under control where the magnesium content was 0.20 mg/100mL, calcium 77 mg/100mL, sodium 1 mg/100mL, potassium 14 mg/100mL and vitamin C 7.15 mg/mL (Damunupola et al., 2014).

- The addition of beetroot extract (liquid or freeze-dried) affected the discoloration of the yogurt. In general, the added beets reduced the value to L^* , indicating a darker product in color. The values for the parameter a^* and the parameter b^* showed an increase over the storage period ($p < 0.05$). The color change depends on the type of treatment (liquid or lyophilized extract added) as well as storage time ($p < 0.05$), (Flores-Mancha et al., 2021). According to Herbach et al., (2006), degradation of betaines leads to the formation of yellow-colored compounds that are reflected in an increase in the b^* parameter. The degradation of betalines may be due to water activity and increased water content in the product (Fu et al., 2020). While the low pH (4.70 to 4.48) and low storage temperature contributed to statistically insignificant color changes in the traditional fermented milk beverage "Lassi" (Kavitkar et al., 2017).

- The addition of beet betalains to cheese did not have a major effect on fat content, ash, and pH, but did affect a decrease in protein content (Prudencio et al., 2008). While Junqueira-Goncalves et al., (2011), suggest the use of gamma irradiated beet powder with radiation doses of 4.0 and 5.0 kGy for effective microbiological preservation of the extract and its use in cream cheese. Other authors Ashraf et al., (2022), and Evstigneeva et al., (2017) reported the use of beets in milk and ice cream, while Kamate & Padghan (2018) evaluated the sensory characteristics of beetroot whey.

CONCLUSION

- In recent years, research on the functional properties of beets and their application in the meat and dairy industries has intensified, focusing not only on their role as a natural colorant but also as a functional ingredient. In the meat industry, beets are primarily used to replace sodium nitrate and synthetic dyes while reducing oxidation. In the dairy industry, beets are used to enhance product functionality and stabilize betalains (color). The stability and acceptability of reformulated products are influenced by the amount and form of beets added, as well as the processing and storage conditions. A review of the literature suggests that further research is needed to determine the optimal quantities and forms of beets for commercial use as a functional ingredient.

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