

Natural Colourants in Surimi-Based Seafood Products

^{1,*}Girija Saurabh Behere, ¹Vijeta Gupta, ²Asif Umar Pagarkar, ¹Sudhanshu Raman, ¹Ganesh Kumar, ¹Pramod Kumar Pandey

^{1,*}College of Fisheries, Datia campus of Rani Lakshmi Bai Central Agricultural University, Nauner, Datia, Madhya Pradesh – 475 686, India

²College of Fisheries, DBSKKV, Dapoli, Ratnagiri, Maharashtra – 415 629, India

Corresponding Authors Email: girija_cof@yahoo.com

doi.org/10.5281/FishWorld.19457652

Abstract

Surimi-based seafood products constitute a major segment of the global value-added seafood market because of their affordability, versatility, and ability to imitate the texture and appearance of traditional shellfish products such as crab, shrimp, and lobster. Surimi is water washed mechanically deboned fish mince added with cryoprotectants and frozen wherein myofibrillar proteins are concentrated to give it good gel forming ability and water holding capacity. During water washing steps, natural pigments are also removed, resulting in a colourless or pale protein matrix. The absence of colour significantly reduces the visual attractiveness of surimi products and necessitates the addition of colourants during formulation. Colour is widely recognized as one of the most important sensory attributes influencing consumer acceptance, product identity, and perceived quality. In recent decades, the surimi industry has experienced a gradual transition from synthetic dyes toward natural colourants derived from plants, algae, microorganisms, and marine by-products. This transition has been driven by increasing consumer preference for clean-label foods, concerns regarding the safety of artificial additives, and stricter regulatory frameworks governing food colourants. In addition to providing attractive colour, many natural pigments exhibit antioxidant and bioactive properties, which may contribute to improved product stability and potential health benefits. The role of natural colourants in surimi-based seafood products, including their classification, major sources, chemical nature, mechanisms of colour expression in the surimi matrix, technological challenges, stabilization strategies, nutritional significance, regulatory considerations, and future research directions are presented in this article. These options allow for cleaner labels and improved sensory attributes compared to synthetic alternatives.

Keywords: Surimi, natural colourants, seafood analogues, carotenoids, astaxanthin, paprika oleoresin, annatto, clean-label foods, food pigmentation

1. Introduction

Surimi is a water washed minced meat of white flesh fish added with cryoprotectants and frozen. Water washing is performed to remove undesirable components such as blood, lipids, pigments, enzymes, and sarcoplasmic proteins, while retaining myofibrillar proteins, mainly myosin and actin, which are responsible for gel formation, elasticity, and water-holding capacity. Owing to these functional properties, surimi serves as an excellent base material for the manufacture of a wide variety of restructured seafood products, including crab sticks, shrimp analogues, lobster analogues, fish balls, and kamaboko-type products.

The global popularity of surimi-based products is attributed to their cost-effectiveness, long

frozen shelf life, mild flavour, and versatility in forming different textures and shapes. However, the extensive washing process that imparts these desirable functional characteristics also removes most naturally occurring pigments from fish muscle, resulting in a nearly white or colourless protein matrix. While the pale appearance of surimi is acceptable for certain products, it is unsuitable for seafood analogues intended to resemble crustaceans, which are naturally associated with red, pink, and orange hues. Colour therefore becomes a critical quality attribute in surimi-based seafood, as it directly influences consumer perception of freshness, authenticity, and overall quality. Historically, synthetic colourants were widely used in surimi formulations because of their strong colouring ability, high stability during processing, and low cost. However, increasing consumer awareness regarding the potential health concerns of artificial food dyes, along with rising demand for clean-label and minimally processed foods, has encouraged a gradual shift toward natural colourants. Historically, we reached for synthetic dyes. They were cheap, stable, and predictable. But today, the tide has turned. Driven by a "clean-label" revolution and a consumer base that reads every ingredient on the back of the pack, the industry is trading the laboratory for the garden and the sea.

Natural colourants are obtained from plant, algal, microbial, and marine sources and include pigments such as carotenoids, anthocyanins, and betalains. In addition to providing colour, many of these compounds possess antioxidant and bioactive properties, which may contribute to improved product stability and potential health benefits. As a result, the incorporation of natural colourants into surimi-based seafood products has become an important area of research and industrial innovation. A clear understanding of the sources, properties, and technological behaviour of these pigments is essential for developing high-quality, visually appealing, and safe surimi products.

2. Importance of Colour in Surimi-Based Seafood Products

Colour is often the first quality attribute assessed by consumers and strongly influences purchasing decisions. Even before taste or texture is evaluated, the visual appearance of food creates expectations regarding flavour, freshness, and overall quality. In seafood analogues, colour plays a particularly important role because consumers associate specific hues with certain species (e.g., pink-red with crab and shrimp, orange with lobster).

Studies in food sensory science demonstrate that inappropriate or dull colour can reduce perceived freshness and acceptability, even if other quality attributes are satisfactory. Therefore, achieving uniform, stable, and realistic colour is essential for the commercial success of surimi-based products. From a technological perspective, colourants must be compatible with the protein matrix, withstand thermal processing, and remain stable throughout storage. Natural colourants present additional challenges compared with synthetic dyes, making careful selection and formulation necessary.

3. Classification of Natural Colourants Used in Surimi

Natural colourants used in surimi seafood can be broadly classified into three groups:

- a. Marine-derived pigments

- b. Plant-derived pigments
- c. Microbial and algal pigments

Each group differs in chemical structure, solubility, stability, and functional properties. Table 1 represents the Stability Characteristics of Selected Natural Colourants.

a. Marine-Derived Colourants

Astaxanthin

Astaxanthin is a carotenoid pigment responsible for the red and pink coloration of many marine organisms, including shrimp, crab, lobster, and salmon. It is naturally synthesized by microalgae such as *Haematococcus pluvialis* and accumulates in aquatic animals through the food chain. In surimi-based products, astaxanthin is widely used to mimic the natural colour of crustacean meat. It is available in both natural and synthetic forms; however, natural astaxanthin derived from microalgae is increasingly preferred for clean-label applications. Astaxanthin is lipid-soluble and is usually dispersed in oil or encapsulated to facilitate uniform distribution in surimi. In addition to its colouring function, astaxanthin exhibits strong antioxidant activity, which can help retard lipid oxidation and improve shelf life.

Crustacean Shell Extracts

Pigments extracted from shrimp and crab shells are another marine source of natural red-orange colour. These extracts primarily contain astaxanthin and related carotenoids bound to proteins. Utilization of shell by-products also contributes to waste valorization and sustainability.

b. Plant-Based Colourants

Paprika Oleoresin

Paprika oleoresin is obtained from dried fruits of *Capsicum annum*. It contains carotenoids such as capsanthin and capsorubin, which impart orange-red hues. Paprika oleoresin is widely used in surimi products because of its relatively good heat stability and compatibility with protein systems. It is typically dispersed in vegetable oil before incorporation into surimi paste. Paprika oleoresin provides uniform colour and contributes to clean-label claims.

Annatto

Annatto is derived from the seeds of *Bixa orellana* and contains the pigments bixin and norbixin. These compounds produce yellow to orange shades and are commonly used in dairy, bakery, and meat products. In surimi, annatto is often blended with red pigments to achieve desired hues. Annatto pigments are relatively stable to heat but may be sensitive to light and oxidation.

β-Carotene

β-Carotene is a provitamin A carotenoid found in carrots, sweet potatoes, and various fruits and vegetables. It provides yellow to orange colour and is used in surimi formulations to enhance brightness and colour depth.

Beetroot Extract (Betalains)

Beetroot (*Beta vulgaris*) contains betalain pigments, primarily betacyanins, which impart red-

purple colour. Beetroot extract is water-soluble and offers antioxidant properties. However, betalains are sensitive to heat and pH, limiting their direct application in thermally processed surimi unless protective techniques are used.

c. Microbial and Algal Pigments

Microorganisms such as *Monascus* species and microalgae can produce a wide range of pigments, including carotenoids and polyketide-derived colours. Algal pigments such as phycocyanin (blue) and chlorophyll derivatives (green) are being explored for specialty surimi products and decorative effects.

Table 1. Stability Characteristics of Selected Natural Colourants

Colourant	Heat Stability	Light Stability	pH Sensitivity
Astaxanthin	Moderate	Moderate	Low
Paprika oleoresin	High	Moderate	Low
Annatto	Moderate	Low	Moderate
Beetroot extract	Low	Low	High

Mechanism of Colour Expression in Surimi Matrix

Surimi is primarily composed of myofibrillar proteins (myosin and actin). Colourants interact physically with this protein network during chopping and mixing. Lipid-soluble pigments are usually dispersed in oil droplets, which become entrapped within the gel matrix during heating. Water-soluble pigments dissolve in the aqueous phase and distribute throughout the protein system. Uniform mixing and appropriate particle size of pigment dispersions are essential to avoid speckling and uneven colour distribution.

Technological Challenges of Natural Colourants

Despite their advantages, natural colourants present several technological limitations when compared with synthetic dyes. Understanding these challenges is essential for designing stable and commercially viable surimi products.

Thermal Degradation

Surimi products are typically subjected to thermal processing during gelation (80–95°C). Many natural pigments, especially carotenoids and betalains, are sensitive to high temperatures. Heat can cause isomerization and oxidative cleavage of pigment molecules, resulting in colour fading or browning. For example, astaxanthin may undergo oxidation, while betalains may decompose into colourless compounds. Therefore, careful control of heating time and temperature is necessary.

Oxidative Instability

Carotenoids are highly unsaturated molecules and are prone to oxidation in the presence of oxygen, light, and metal ions. Oxidative degradation leads to loss of colour intensity and formation of off-flavours. This problem is particularly relevant in surimi products containing residual lipids.

pH Sensitivity

Some natural pigments, especially anthocyanins and betalains, exhibit pH-dependent colour changes. Although surimi typically has a near-neutral pH, small variations during formulation may affect colour expression.

Interaction with Food Components

Pigments may interact with proteins, lipids, and salts in surimi, altering their solubility and colour appearance. Excessive salt, for instance, can affect pigment dispersion and stability.

Variability in Raw Materials

Natural pigments extracted from plants or algae may vary in composition depending on variety, harvest season, and processing method. This variability can lead to inconsistent colour from batch to batch.

Strategies to Improve Stability and Performance of Natural Colourants

To overcome the above challenges, several technological strategies are employed in the surimi industry.

Microencapsulation

Microencapsulation involves enclosing pigments within protective coatings such as maltodextrin, gum arabic, or modified starch. This technique protects pigments from heat, oxygen, and light and allows controlled release during processing.

Use of Antioxidants

Natural antioxidants such as tocopherols, ascorbic acid, and rosemary extract are added to prevent oxidative degradation of pigments. Antioxidants also help maintain lipid stability, indirectly preserving colour quality.

Optimized Processing Conditions

Lower processing temperatures, shorter heating times, and reduced exposure to oxygen can significantly improve pigment retention.

Packaging Technologies

Vacuum packaging and modified atmosphere packaging (MAP) reduce oxygen availability and slow down pigment oxidation.

Nutritional and Functional Benefits of Natural Colourants

Many natural colourants are not merely aesthetic additives but also bioactive compounds with potential health benefits. Carotenoids such as astaxanthin and β -carotene exhibit strong antioxidant activity, which helps neutralize free radicals and reduce oxidative stress. β -Carotene is also a precursor of vitamin A, essential for vision, immune function, and growth. Astaxanthin has been associated with anti-inflammatory, cardioprotective, and immune-enhancing effects. Beetroot betalains possess antioxidant and anti-inflammatory properties and may contribute to protection against chronic diseases. Thus, incorporation of natural colourants can enhance the functional value of surimi products, supporting their positioning as healthier food choices. Functional benefits of natural colourants are listed in Table 2.

Table 2. Functional Benefits of Natural Colourants

Colourant	Bioactivity	Health Benefit
Astaxanthin	Antioxidant	Anti-inflammatory
β -Carotene	Provitamin A	Vision, immunity
Beetroot betalains	Antioxidant	Cellular protection

Consumer Perception and Market Trends

Consumer perception has become a dominant force shaping innovation in the global seafood industry. Increasing awareness of the relationship between diet and health has encouraged consumers to seek foods that are perceived as natural, minimally processed, and free from synthetic additives. Colour additives are among the first ingredients scrutinized on product labels, making natural colourants particularly attractive for surimi-based seafood products. Market surveys consistently show that consumers associate natural colours with higher quality, greater safety, and better nutritional value. The term “naturally coloured” positively influences purchasing decisions and enhances brand trust. Furthermore, younger consumers and urban populations demonstrate strong preference for clean-label foods, which has accelerated the replacement of artificial dyes with plant- and algae-derived pigments. Another important trend is sustainability. Natural colourants derived from renewable resources or seafood by-products align with circular economy principles. For example, extraction of astaxanthin from shrimp shell waste not only provides a valuable pigment but also reduces environmental burden associated with disposal of processing residues. In developing countries, cost remains a critical factor; however, advances in large-scale cultivation of microalgae and improved extraction technologies are gradually reducing production costs of natural pigments.

Regulatory and Safety Aspects

Natural colourants intended for use in foods must undergo rigorous safety evaluation before approval by regulatory authorities. These evaluations include toxicological studies, determination of acceptable daily intake (ADI), and assessment of technological necessity. In the United States, the Food and Drug Administration (FDA) regulates colour additives under the Federal Food, Drug, and Cosmetic Act. In the European Union, the European Food Safety Authority (EFSA) conducts risk assessments and establishes specifications for food colors. In India, the Food Safety and Standards Authority of India (FSSAI) govern the use of food additives through its Food Safety and Standards Regulations. Natural colourants approved by these agencies are considered safe when used within prescribed limits. Continuous monitoring and re-evaluation are carried out as new scientific data become available.

Future Prospects and Research Directions

Future research on natural colourants in surimi seafood is expected to focus on development of highly stable pigment formulations resistant to heat and oxidation, exploration of novel pigment-producing microorganisms, application of nanotechnology and advanced encapsulation techniques,

integration of colourants with functional and nutraceutical ingredients.

Conclusion

Natural colourants play a vital role in enhancing the visual quality, consumer acceptance, and functional value of surimi-based seafood products. Their integration supports clean-label trends, sustainability goals, and nutritional improvement. Although challenges such as instability and variability persist, continuous advances in formulation, encapsulation, and biotechnology are expanding their industrial applicability. Natural pigments are expected to become the dominant coloring agents in surimi seafood in the near future.