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Review Article

BIOACTIVE PEPTIDES DERIVED FROM FOOD PROTEINS: BIOCHEMICAL MECHANISMS, PRODUCTION STRATEGIES, AND APPLICATIONS IN FUNCTIONAL FOODS

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ABSTRACT

Interest in functional foods has grown steadily as attention has shifted toward dietary components that may contribute to health beyond basic nutrition. In this context, food-derived bioactive peptides have received considerable attention because they are naturally present within common dietary proteins and can be released during food processing, fermentation, or digestion. Once liberated, these peptides may interact with physiological systems in ways that depend on their amino acid sequence, structure, and the food matrix in which they are consumed. This review summarizes current understanding of bioactive peptides derived from animal, plant, and marine protein sources, with particular focus on the biochemical mechanisms through which they exert biological activity. Reported mechanisms include modulation of enzymes and signaling pathways related to blood pressure regulation, oxidative balance, glucose metabolism, inflammatory responses, antimicrobial defence, and appetite regulation. The major strategies used to produce these peptides – such as enzymatic hydrolysis, microbial fermentation, and gastrointestinal digestion – are discussed, along with emerging approaches aimed at improving peptide availability and functionality. Applications of food-derived bioactive peptides in functional foods, including dairy products, cereal- and legume-based foods, beverages, and nutritional supplements, are considered from an applied food science perspective. In addition, practical issues related to peptide stability, bioavailability, safety, and regulatory considerations are highlighted. Although research in this area continues to expand, translating experimental findings into consistent and nutritionally relevant food applications remains a key challenge. A balanced and evidence-based approach is therefore essential for the responsible development of peptide-enriched functional foods.

Keywords: Bioactive peptides, Functional foods, Food protein hydrolysates, Enzymatic hydrolysis, Nutritional bioactivity.

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INTRODUCTION

In recent decades, the concept of nutrition has expanded beyond the provision of essential nutrients to encompass the role of food components that may exert additional physiological benefits. This evolution has led to increased interest in functional foods, defined as foods that provide health benefits beyond basic nutrition when consumed as part of a regular diet [1]. Within this context, bioactive compounds naturally present in foods have gained attention for their potential contribution to health maintenance and disease risk reduction.

Among these compounds, food-derived bioactive peptides have emerged as a particularly promising group. Bioactive peptides are short sequences of amino acids, typically consisting of 2–20 residues that are encrypted within the primary structure of dietary proteins [2]. In their native protein form, these peptides are biologically inactive; however, they can be released during enzymatic hydrolysis, gastrointestinal digestion, or microbial fermentation. Once liberated, they may interact with specific molecular targets and influence physiological processes relevant to human health.

A wide range of food proteins have been identified as sources of bioactive peptides, including those derived from milk, eggs, meat, fish, cereals, legumes, and marine organisms [3,4]. Peptides generated from these sources have been reported to exhibit diverse biological activities, such as antihypertensive, antioxidant, antidiabetic, anti-inflammatory, antimicrobial, and immunomodulatory effects [5-7]. Many of these effects are associated with well-characterised biochemical mechanisms, including inhibition of key metabolic enzymes, scavenging of reactive oxygen species, modulation of inflammatory mediators, and interaction with cell surface receptors. Nevertheless, the expression of these activities is influenced by peptide sequence, molecular size, hydrophobicity, and the surrounding food matrix.

The method by which bioactive peptides are produced plays a crucial role in determining their functionality and applicability. Enzymatic hydrolysis using digestive or microbial proteases remains the most widely employed approach due to its specificity, controllability, and compatibility with food processing systems [8]. In addition, microbial fermentation, particularly involving lactic acid bacteria (LAB), has attracted increasing interest as a natural and sustainable strategy for peptide generation and has been traditionally associated with fermented foods [9]. Recent advances in processing technologies and computational tools have further supported the targeted identification and production of peptides with desired bioactivities, although challenges related to reproducibility and large-scale production remain.

Despite the growing volume of research in this area, available studies are often fragmented, focusing either on biological activity, production techniques, or food applications in isolation. Moreover, while numerous bioactivities have been demonstrated *in vitro* and in animal models, their translation into practical functional food applications requires careful consideration of peptide stability, bioavailability, safety, and regulatory aspects [10]. An integrated overview that links biochemical mechanisms with production strategies and real-world applications is therefore needed.

Accordingly, the present review provides a comprehensive overview of food-derived bioactive peptides, with emphasis on their biochemical mechanisms of action, methods of production, and applications in functional foods. In addition, key challenges and future perspectives are discussed to highlight areas requiring further research for the effective utilisation of these peptides in nutrition-oriented food products.

SOURCES OF FOOD-DERIVED BIOACTIVE PEPTIDES

Food-derived bioactive peptides originate from a wide range of protein sources that are commonly consumed as part of the human diet. These peptides are not present in their active form in intact proteins; instead, they are released through enzymatic hydrolysis, fermentation, or digestion. Both animal- and plant-based proteins, as well as marine resources, have been extensively explored as precursors of bioactive peptides due to their availability, nutritional relevance, and diverse amino acid compositions.

Animal sources

Milk proteins

Milk proteins are among the most extensively studied sources of bioactive peptides. The two major fractions, casein and whey proteins, contain multiple encrypted peptide sequences with reported biological activities. Casein-derived peptides, released mainly during enzymatic hydrolysis or fermentation, have been widely associated with antihypertensive, opioid-like, and immunomodulatory effects. Whey proteins, including β-lactoglobulin and α-lactalbumin, are recognised for generating peptides with antioxidant, antimicrobial, and mineral-binding properties. The long history of dairy consumption and processing has facilitated the incorporation of milk-derived peptides into functional food products, particularly fermented dairy foods.

Egg proteins

Egg proteins, especially those derived from egg white, such as ovalbumin and ovotransferrin, have also been identified as valuable sources of bioactive peptides. Enzymatic treatment of egg proteins has been shown to release peptides with antioxidant, antihypertensive, and antimicrobial activities. Compared with dairy proteins, egg-derived peptides have received relatively less attention; however, growing interest in egg protein hydrolysates reflects their high nutritional quality and favorable amino acid profile.

Meat and fish proteins

Proteins obtained from meat and fish represent another important source of bioactive peptides. Muscle proteins, collagen, and connective tissue proteins can generate peptides with antioxidant, antihypertensive, and anti-inflammatory properties following hydrolysis. In particular, fish proteins have attracted attention due to the dual nutritional benefits of high-quality protein and bioactive peptide generation. The utilisation of meat and fish processing by-products has further highlighted the potential of these sources for sustainable peptide production.

Plant sources

Soybean

Among plant proteins, soybean proteins are the most widely investigated sources of bioactive peptides. Soy-derived peptides have been reported to exhibit antihypertensive, antioxidant, cholesterol-lowering, and antidiabetic activities. Their plant origin, combined with widespread consumption and suitability for vegetarian diets, makes soybean peptides attractive candidates for functional food development.

Cereals

Cereal proteins from wheat, rice, oats, and barley also serve as precursors of bioactive peptides, although their lower protein content compared with legumes has historically limited attention. Nevertheless, enzymatic hydrolysis and fermentation of cereal proteins have been shown to yield peptides with antioxidant and antihypertensive properties. Oats, in particular, have gained interest due to their association with cardiovascular health and their compatibility with functional food formulations.

Legumes and pulses

Legumes and pulses such as chickpea, lentil, pea, and mung bean are increasingly recognised as sustainable protein sources. Peptides derived from these proteins have demonstrated antioxidant, antihypertensive, and antidiabetic activities in several experimental studies. The growing demand for plant-based foods has further driven research into legume-derived bioactive peptides and their potential applications in functional nutrition.

Marine sources

Fish by-products

Marine by-products, including fish skin, bones, scales, and viscera, are rich in proteins such as collagen and gelatin, which can serve as excellent sources of bioactive peptides. Enzymatic hydrolysis of these materials has been reported to produce peptides with antioxidant, antihypertensive, and antimicrobial activities. The use of fish by-products not only adds value to waste materials but also aligns with sustainability and circular economy principles.

Algae

Algae represent an emerging source of bioactive peptides with growing relevance in nutrition research. Both microalgae and macroalgae contain proteins that can be hydrolyzed to release peptides with antioxidant, antihypertensive, and immunomodulatory effects. Although still at an early stage of exploration, algal peptides offer promising opportunities due to their unique amino acid composition and potential for incorporation into novel functional foods.

BIOCHEMICAL MECHANISMS OF ACTION OF FOOD-DERIVED BIOACTIVE PEPTIDES

The biological relevance of food-derived bioactive peptides lies in their ability to interact with specific molecular targets and biochemical pathways after their release from parent proteins. Rather than acting as pharmacological agents, these peptides influence physiological processes through modest but measurable effects, which may contribute to overall health when consumed regularly as part of the diet. Their mechanisms of action are closely linked to peptide structure, amino acid composition, and sequence length.

Antihypertensive peptides

Angiotensin-converting enzyme (ACE) inhibition

One of the most extensively studied mechanisms associated with bioactive peptides is the inhibition of ACE. ACE plays a central role in the regulation of blood pressure by converting angiotensin I into the vasoconstrictor angiotensin II and by inactivating bradykinin, a vasodilatory peptide. Several food-derived peptides, particularly those released from milk, fish, and plant proteins, have been shown to inhibit ACE activity *in vitro*. This inhibition is largely attributed to the presence of hydrophobic amino acids and specific residues at the C-terminal end of the peptide, which facilitate interaction with the active site of the enzyme.

Modulation of the renin-angiotensin system (RAS)

Beyond direct ACE inhibition, some bioactive peptides are thought to influence other components of the RAS. These effects include modulation of renin activity or interference with angiotensin II receptor binding. Although such mechanisms are less well characterised than ACE inhibition, they suggest that dietary peptides may exert broader regulatory effects on blood pressure homeostasis through multiple points within the RAS cascade.

Antioxidant activity

Free radical scavenging

Antioxidant peptides can neutralize reactive oxygen species by donating electrons or hydrogen atoms, thereby limiting oxidative reactions. Amino acids such as histidine, tyrosine, cysteine, and tryptophan are commonly associated with this activity due to their redox properties. The ability of peptides to scavenge free radicals has been demonstrated in various chemical and cell-based models, suggesting a potential role in maintaining redox balance when these peptides are present in the diet.

Metal ion chelation

In addition to direct radical scavenging, certain peptides can chelate transition metal ions such as iron and copper, which catalyze oxidative reactions. By binding these metals, peptides may indirectly reduce the formation of reactive oxygen species. This chelating ability is influenced by peptide length and the presence of amino acids capable of coordinating metal ions, including histidine and acidic residues.

Antidiabetic mechanisms

Dipeptidyl peptidase-IV (DPP-IV) inhibition

Some food-derived peptides have been reported to inhibit DPP-IV, an enzyme involved in the degradation of incretin hormones that regulate glucose metabolism. Peptide-mediated inhibition of DPP-IV may prolong the activity of incretins, thereby influencing postprandial glucose responses. These effects have primarily been observed in enzymatic and cellular models and are dependent on peptide sequence and stability.

Inhibition of α-amylase and α-glucosidase

Bioactive peptides may also modulate carbohydrate digestion by inhibiting enzymes such as α-amylase and α-glucosidase, which are responsible for starch breakdown and glucose release. By slowing enzymatic hydrolysis of carbohydrates, these peptides may contribute to a moderated glycemic response. Such mechanisms highlight the potential role of dietary peptides in supporting metabolic balance rather than exerting direct glucose-lowering effects.

Anti-inflammatory effects

Anti-inflammatory activity associated with food-derived peptides is often linked to their ability to influence intracellular signaling pathways. Several peptides have been shown to modulate the nuclear factor kappa B (NF-κB) pathway, a key regulator of inflammatory mediator expression. By attenuating NF-κB activation, peptides may reduce the production of pro-inflammatory cytokines and enzymes in experimental models. These observations suggest that peptides can interact with cellular signaling networks involved in inflammatory responses.

Antimicrobial and immunomodulatory actions

Certain bioactive peptides exhibit antimicrobial properties, often attributed to their ability to interact with microbial cell membranes. These peptides are typically cationic and amphipathic, allowing them to disrupt membrane integrity and inhibit microbial growth. In addition to direct antimicrobial effects, some peptides have been reported to influence immune cell activity, including modulation of cytokine release and enhancement of innate immune responses. These actions indicate a role for dietary peptides in supporting host defence mechanisms.

Opioid-like and satiety-regulating peptides

Opioid-like peptides derived from food proteins, particularly milk caseins, are known to interact with opioid receptors in the gastrointestinal tract and nervous system. These interactions have been associated with effects on gut motility, stress responses, and appetite regulation. Similarly, certain peptides may influence satiety by modulating gut hormone release or interacting with receptors involved in appetite control. Such mechanisms highlight the complex ways in which food-derived peptides can influence physiological signaling related to feeding behavior. The major dietary sources of food-derived bioactive peptides and their reported biological activities are summarized in Table 1.

PRODUCTION STRATEGIES FOR BIOACTIVE PEPTIDES

The method used to release bioactive peptides from parent food proteins is a critical determinant of their yield, sequence profile, and biological activity. From an applied nutrition and food science perspective, production strategies must balance efficiency, reproducibility, cost, and compatibility with food processing systems. Several approaches have been developed, ranging from conventional enzymatic techniques to emerging technologies designed to improve peptide recovery and functionality.

Enzymatic hydrolysis

Enzymatic hydrolysis is the most widely used and well-established method for producing bioactive peptides from food proteins. Proteolytic enzymes such as pepsin and trypsin**,** which mimic gastrointestinal digestion, as well as industrial enzymes such as alkaline and flavourzyme, are commonly employed. These enzymes differ in substrate specificity and cleavage patterns, resulting in the generation of peptides with distinct sequences and bioactivities.

One of the key advantages of enzymatic hydrolysis is its controllability. Reaction conditions such as pH, temperature, enzyme-to-substrate ratio, and hydrolysis time can be adjusted to optimize peptide release. This approach is also relatively easy to scale up and is compatible with food-grade processing requirements. However, enzymatic hydrolysis has certain limitations, including the possible generation of bitter peptides, incomplete hydrolysis, and variability in peptide profiles depending on enzyme selection and processing conditions.

Microbial fermentation

Microbial fermentation represents a natural and traditional strategy for the generation of bioactive peptides. In particular, LAB possess

Table 1: Major food sources of bioactive peptides and their reported biological activities

Food source	Parent protein	Representative bioactive activity	Reported mechanism (general)	References
Milk	Casein	Antihypertensive	ACE inhibition; modulation of vasoactive peptides	[2,5]
Milk	Whey proteins (β-lactoglobulin, α-lactalbumin)	Antioxidant, antimicrobial	Free radical scavenging; interaction with microbial membranes	[6,7]
Egg	Ovalbumin, ovotransferrin	Antioxidant, antihypertensive	Radical scavenging; enzyme inhibition	[11,12]
Meat	Muscle proteins, collagen	Antioxidant, anti-inflammatory	Metal ion chelation; modulation of inflammatory mediators	[16,21]
Fish	Muscle proteins, gelatin	Antihypertensive, antioxidant	ACE inhibition; scavenging of reactive oxygen species	[16,17]
Soybean	Glycinin, β-conglycinin	Antihypertensive, antidiabetic	ACE inhibition; DPP-IV inhibition	[12,13]
Cereals (wheat, rice, oats)	Gluten, albumins, globulins	Antioxidant, antihypertensive	Radical scavenging; enzyme inhibition	[12,20]
Legumes and pulses	Vicilin, legumin	Antioxidant, antidiabetic	α-amylase and α-glucosidase inhibition	[13,20]
Fish by-products	Collagen, gelatin	Antioxidant, antimicrobial	Metal chelation; membrane interaction	[17,19]
Algae	Algal storage proteins	Antioxidant, immunomodulatory	Radical scavenging; modulation of immune signaling	[14]

proteolytic systems capable of degrading food proteins and releasing peptides during fermentation. This process is commonly observed in fermented dairy, cereal, and legume-based foods.

LAB-mediated peptide release occurs through a coordinated system of extracellular proteinases and intracellular peptidases. Fermentation not only facilitates peptide generation but may also enhance peptide stability and sensory acceptability. Traditional fermented foods, therefore, serve as both a source and delivery matrix for bioactive peptides. Nevertheless, peptide yield and composition can vary significantly depending on microbial strain, substrate, and fermentation conditions, which presents challenges for standardization.

Gastrointestinal digestion and *in vivo* relevance

In addition to processing-based methods, gastrointestinal digestion plays an important role in the *in vivo* generation of bioactive peptides. During digestion, dietary proteins are subjected to sequential enzymatic action in the stomach and small intestine, leading to the release of peptides that may exert biological effects locally in the gut or after absorption.

Studying peptide generation under simulated gastrointestinal conditions provides valuable insight into the physiological relevance of bioactive peptides. However, not all peptides generated during digestion remain stable or bioavailable, and some may be further degraded before reaching target sites. As a result, *in vitro* findings must be interpreted cautiously when considering potential nutritional relevance.

Emerging approaches

Recent advances in food processing and computational tools have contributed to the development of emerging strategies aimed at improving peptide production efficiency.

Ultrasound-assisted hydrolysis has been explored as a means to enhance enzyme accessibility to protein substrates by altering protein structure. This approach may reduce hydrolysis time and improve peptide yield, although its application at an industrial scale requires further optimization.

Membrane separation technologies, such as ultrafiltration and nanofiltration, are commonly used to fractionate peptide mixtures based on molecular weight. These techniques allow enrichment of low-molecular-weight peptides, which are often associated with higher biological activity.

In addition, *in silico* digestion and peptide prediction tools have gained attention for their ability to identify potential bioactive sequences within protein structures. While these computational approaches can guide experimental design and reduce screening time, experimental validation remains essential to confirm biological activity. An overview of these production strategies is presented in Fig. 1, which illustrates a general workflow for the production of bioactive peptides from food proteins. Dietary proteins from animal, plant, or marine sources undergo enzymatic hydrolysis, microbial fermentation, or gastrointestinal digestion, resulting in the release of peptide fractions. These peptides are subsequently separated, characterised, and evaluated for biological activity before potential incorporation into functional food products.

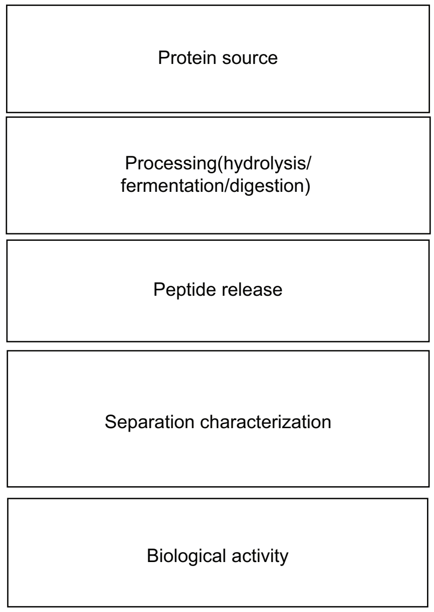

Fig. 1: Workflow for the production of food-derived bioactive peptides

STABILITY, BIOAVAILABILITY, AND SAFETY CONSIDERATIONS

While numerous food-derived peptides have demonstrated biological activity under experimental conditions, their relevance in real dietary contexts depends largely on stability, bioavailability, and safety. These factors determine whether peptides can survive food processing, digestion, and absorption in forms capable of interacting with physiological targets. Addressing these considerations is therefore essential when evaluating the potential of bioactive peptides for functional food applications.

Peptide stability during food processing

Food processing conditions such as heat treatment, pH variation, and storage can influence peptide integrity and activity. Thermal processing may lead to peptide degradation or structural modification, while interactions with other food components, including lipids, carbohydrates, and minerals, can affect peptide functionality. In some cases, processing may enhance peptide release or stability, particularly in fermented foods. However, variability introduced during processing remains a key challenge for consistent peptide delivery in functional food products.

Resistance to gastrointestinal enzymes

After ingestion, bioactive peptides are exposed to digestive enzymes in the gastrointestinal tract, which may further hydrolyze them into smaller fragments or free amino acids. Some peptides retain their activity despite partial digestion, while others act locally within the gastrointestinal lumen. Simulated digestion models have been widely used to evaluate peptide stability under physiologically relevant conditions, providing insight into which peptides are more likely to persist during digestion. Nevertheless, digestive resistance varies considerably depending on peptide sequence and structure.

Transport across the intestinal epithelium

For peptides to exert systemic effects, they must cross the intestinal epithelium and enter circulation. Several mechanisms have been proposed for peptide transport, including paracellular diffusion, transcellular transport, and uptake through specific peptide transporters. Short peptides, particularly di- and tripeptides, are more likely to be absorbed intact, whereas larger peptides may undergo further degradation before absorption. The extent to which food-derived peptides reach systemic circulation remains an area of active investigation.

Allergenicity and safety considerations

Although bioactive peptides originate from commonly consumed foods, safety assessment remains important, particularly when peptides are concentrated or incorporated into functional products. Enzymatic hydrolysis can reduce allergenicity by disrupting allergenic epitopes; however, in some cases, novel peptide fragments may retain or introduce immunoreactivity. Comprehensive safety evaluation, including assessment of allergenic potential and toxicity, is therefore necessary before application.

Regulatory perspectives

From a regulatory standpoint, bioactive peptides intended for use in functional foods must comply with existing food safety frameworks. Regulatory agencies generally evaluate such ingredients based on source, processing method, safety evidence, and intended use. While many peptides derived from traditional foods may fall under existing regulations, claims related to health benefits are subject to strict substantiation requirements. This highlights the importance of aligning peptide research with regulatory expectations to facilitate responsible product development.

APPLICATIONS OF BIOACTIVE PEPTIDES IN FUNCTIONAL FOODS

The incorporation of food-derived bioactive peptides into functional foods represents a practical route for translating laboratory findings into dietary applications. Rather than being consumed as isolated compounds, these peptides are typically delivered within familiar food matrices, where they may contribute to nutritional value while retaining acceptable sensory and technological properties. Successful application depends on factors such as peptide stability, compatibility with the food matrix, and consumer acceptance.

Dairy-based functional foods

Dairy products are among the most common carriers of bioactive peptides, largely due to the natural abundance of milk proteins and the long tradition of dairy fermentation. Fermented milk, yogurt, and cheese products have been widely explored as vehicles for peptides released during processing or fermentation. In these systems, peptides may be generated *in situ* by starter cultures or incorporated as protein hydrolysates. Dairy matrices offer advantages such as buffering capacity and favorable sensory characteristics, which can help mask bitterness often associated with peptide-rich formulations.

Cereal-and legume-based products

Cereal- and legume-based foods have gained increasing attention as platforms for delivering bioactive peptides, particularly in response to growing demand for plant-based functional foods. Products such as bread, pasta, breakfast cereals, and legume-based snacks have been investigated for their ability to carry peptides derived from wheat, oats, soy, and pulses. Fermentation and enzymatic treatment are commonly used to enhance peptide release in these matrices. However, interactions between peptides and carbohydrates or fiber components may influence bioactivity and require careful formulation.

Beverages and liquid formulations

Functional beverages offer a convenient format for peptide delivery due to ease of consumption and formulation flexibility. Protein hydrolysates containing bioactive peptides have been incorporated into dairy-based drinks, plant-based beverages, and sports nutrition products. Liquid systems may facilitate peptide dispersion and absorption, although stability during storage and potential flavor issues remain important considerations. Encapsulation and controlled-release strategies are sometimes employed to improve peptide stability and sensory quality.

Nutraceuticals and protein supplements

Beyond conventional foods, bioactive peptides are increasingly incorporated into nutraceuticals and protein supplements, including powders, capsules, and nutrition bars. These formats allow higher peptide concentrations and more controlled dosing. However, such applications require stricter attention to safety evaluation, quality control, and regulatory compliance. While supplements may offer targeted delivery, their positioning often differs from that of functional foods, which are intended for regular dietary consumption.

Challenges in food application

Despite promising opportunities, several challenges limit the widespread application of bioactive peptides in functional foods. These include peptide instability during processing and storage, bitterness and off-flavors, interactions with other food components, and variability in peptide bioavailability. Addressing these issues requires integrated approaches involving food processing optimization, formulation strategies, and sensory evaluation to ensure that functional benefits do not compromise product quality.

CHALLENGES AND FUTURE PERSPECTIVES

Despite the growing body of research on food-derived bioactive peptides, several challenges continue to limit their broader application in functional foods. One of the primary issues is the variability in peptide generation, which arises from differences in protein source, processing conditions, enzyme selection, and fermentation parameters. This variability makes it difficult to standardize peptide profiles and to ensure consistent biological activity across different products and production batches.

Another important challenge relates to peptide stability and bioavailability. Many bioactive peptides demonstrate promising activity *in vitro*, yet their behavior during food processing, storage, and gastrointestinal digestion can differ substantially. Loss of activity due to degradation or interaction with other food components remains a key concern. Future research should therefore focus on improving delivery strategies that preserve peptide integrity while remaining compatible with food systems and consumer expectations.

From a translational perspective, there is a need to bridge the gap between experimental findings and practical dietary relevance**.** While *in vitro* and animal studies provide valuable mechanistic insights, evidence from well-designed human studies remains limited. Such studies are essential to clarify the extent to which food-derived peptides contribute to physiological effects when consumed as part of a normal diet, rather than in isolated or concentrated forms.

Regulatory and communication challenges also deserve attention. The substantiation of health-related claims associated with bioactive peptides requires robust scientific evidence, and regulatory frameworks vary across regions. Clear guidance on acceptable claims, labeling, and safety assessment would facilitate responsible product development and consumer trust.

Looking ahead, future work is likely to benefit from integrated research approaches that combine food chemistry, nutrition science, and processing technology. Advances in analytical methods, *in silico* tools, and processing innovations may support more targeted peptide production and characterization. However, maintaining a realistic and evidence-based perspective will be essential to ensure that the development of peptide-enriched functional foods remains aligned with nutritional relevance and public health priorities.

CONCLUSION

Food-derived bioactive peptides have attracted sustained interest as naturally occurring components of the diet that may contribute to the functional value of foods. These peptides, released from common dietary proteins through processing, fermentation, or digestion, are characterised by a wide range of biological activities that depend on their structure, source, and mode of production. Rather than acting in isolation, their effects are closely influenced by the food matrix and the conditions under which they are consumed.

This review has brought together current knowledge on the major food sources of bioactive peptides, the biochemical mechanisms through which they interact with physiological systems, and the strategies used to generate them for food applications. Attention has also been given to practical considerations such as stability, bioavailability, and safety, which remain central to the successful incorporation of peptides into functional foods.

While experimental evidence supporting the bioactivity of these peptides continues to grow, their translation into meaningful nutritional outcomes requires a cautious and evidence-based approach. Future progress will depend on improved standardization of production methods, clearer understanding of *in vivo* behavior, and alignment with regulatory frameworks. With continued interdisciplinary research and realistic expectations, food-derived bioactive peptides can be responsibly integrated into functional food products aimed at supporting overall dietary quality and consumer well-being.

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