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REVIEW ARTICLE

Hydrocolloids in Rice Noodle Production: Enhancing Texture, Cooking Quality, and Sustainability in Gluten-Free Formulations: A Review

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ABSTRACT

This review explores the pivotal role of hydrocolloids in rice noodle production, focusing on their impact on texture, cooking quality, shelf life, and nutritional value. Hydrocolloids such as Konjac Glucomannan, guar gum, xanthan gum, carboxymethyl cellulose (CMC), Carrageenan, and Sodium alginate are critical for improving the structural integrity and sensory attributes of rice noodles, particularly in gluten-free formulations. Their ability to bind water, form gels, and interact with starches and proteins contributes to enhanced noodle elasticity, chewiness, and overall quality. The review also highlights recent technological advancements that have revolutionized hydrocolloid application in rice noodle production, including the use of modern processing equipment, innovative drying techniques, and biodegradable packaging solutions. These advancements not only optimize production efficiency but also align with sustainability trends, addressing consumer demand for environmentally friendly and health-conscious food products. However, challenges such as balancing hydrocolloid concentrations, economic viability, and consumer acceptance remain significant. As the global demand for gluten-free and nutritious products continues to rise, the potential for hydrocolloids in improving rice noodle production remains immense. Future research will be crucial in optimizing hydrocolloid formulations to further enhance the quality and sustainability of rice noodles.

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1. Introduction

1.1 Background on Rice Noodles

Rice noodles, a staple in many Asian cuisines, have gained international popularity due to their unique texture, versatility, and wide range of culinary applications. Originating from countries such as China, Thailand, and Vietnam, rice noodles are recognized for their delicate, chewy texture, which can vary depending on the production methods and rice varieties used. These noodles come in several forms, including flat, round, and vermicelli (Fig.1), each suited to different dishes, from stir-fries to soups and salads (Hu et al., 2021). Rice noodles are primarily made from rice flour, a starch-rich ingredient whose quality and composition—particularly amylose content—significantly affect the noodles' texture and cooking properties (Hu et al., 2021; Li et al., 2015; Tong et al., 2015).

Indica rice, known for its high amylose content, is the most commonly used variety for noodle production, as it contributes to the creation of a stable gel network that imparts the preferred chewy texture (Hormdok & Noomhorm, 2007; Sandhu et al., 2010). The production process, whether traditional or modern, plays a pivotal role in determining the quality of the noodles. Traditional methods of rice noodle production involve soaking rice, grinding it into a paste, spreading the paste into thin sheets, and steaming. In contrast, modern mechanized processes often incorporate hydrocolloids and other additives to improve noodle quality and production efficiency (Kraithong & Rawdkuen, 2020; Li et al., 2021). Techniques like gelatinization of the rice flour dough, followed by extrusion or steaming, also influence the final texture (Fari et al., 2011; Choi & Koh, 2017).

Rice noodles are available in fresh, dried, and frozen forms. Fresh rice noodles typically have a softer, more delicate texture, while dried varieties, also known as rice sticks, require rehydration and are favored for their long shelf life (Tong et al., 2015). In addition to standard rice flour, manufacturers have experimented with enriching noodles using fiber-rich ingredients such as cassava or other plant sources to boost their nutritional value (Wandee et al., 2014; Poonsri et al., 2019). The use of fermented rice flour from both white and brown rice is another innovation, enhancing the sensory attributes and nutritional content of the noodles (Seo et al., 2012; Baek & Lee, 2014). Moreover, regional variations such as the traditional fermented rice noodles, like China's sour Mifen, highlight the use of lactic acid bacteria and yeasts in the production process, which alters both flavor and nutritional profiles (Lu et al., 2008). The inclusion of non-starch components and treatments such as hydrothermal processing can further modify the cooking quality and texture of rice noodles, offering additional versatility in their culinary applications (Wandee et al., 2015).

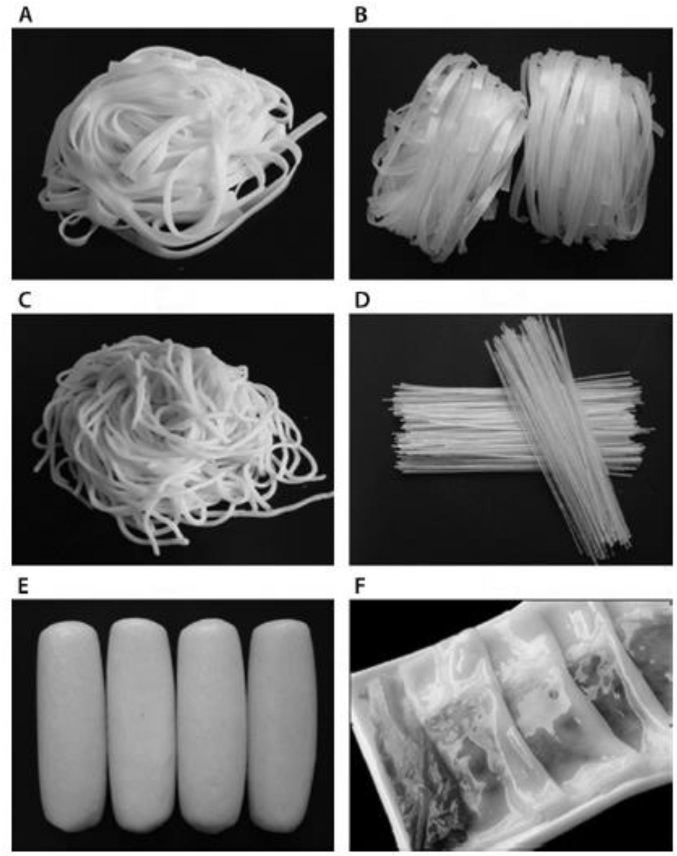

Fig.1: Major classifications of rice noodles based on shaping/molding method). **A**, fresh sheeted noodles; **B**, dried sheeted noodles; **C**, fresh extruded noodles; **D**, dried extruded noodles; **E**, fenli (extruded); **F**, spreading and rolling noodles. Source: (Li et al., 2015).

1.2 Importance and Popularity of Rice Noodles in Various Cuisines

Rice noodles are celebrated not only for their taste and texture but also for their suitability for gluten-free diets, making them an essential ingredient for people with celiac disease or gluten sensitivity. This has significantly contributed to their growing popularity in Western countries where the demand for gluten-free products is on the rise (Kraithong & Rawdkuen, 2020; Wu et al.,2018). In Asian cuisines, rice noodles are integral to many traditional dishes. For instance, "Pho" in Vietnam, "Pad Thai" in Thailand, and "Chow Fun" in China all rely on the unique properties of rice noodles to create their distinct flavors and textures. The versatility of rice noodles allows them to absorb flavors from sauces and broths effectively, making them a favorite in diverse culinary traditions (Kraithong & Rawdkuen, 2020).

1.3 Importance of Hydrocolloids in Rice Noodle Production

Hydrocolloids play an essential role in the production of rice noodles, particularly in enhancing textural properties, cooking quality, and overall sensory attributes. These water-soluble polysaccharides, including xanthan gum, guar gum, and carboxymethyl cellulose (CMC), contribute significantly to the structural integrity and mouthfeel of gluten-free noodles, which are typically made from rice flour without gluten (Kraithong et al., 2018; Gasparre & Rosell, 2019). Hydrocolloids have been shown to improve key textural properties such as tensile strength, extensibility, hardness, and chewiness, making rice noodles more appealing to consumers (Tan et al., 2018; Lubowa et al., 2021).

One of the primary functions of hydrocolloids in rice noodle production is their ability to create a robust network through hydrogen bonding among polymer chains, which enhances the cooking tolerance and textural stability of the noodles. This network not only supports the noodle structure but also helps retain moisture during cooking, thereby reducing cooking loss and improving the final product's quality (Kraithong et al., 2018; Kraithong & Rawdkuen, 2020; Dahal et al., 2020). Hydrocolloids are also vital in preventing syneresis, the expulsion of water during storage, which contributes to a better shelf life and quality retention of rice noodles (Saha & Bhattacharya, 2010). The water retention capacity of hydrocolloids is crucial in preventing rice noodles from becoming overly dry or sticky, which is especially important in gluten-free formulations where the absence of gluten typically results in less cohesive dough (Qazi et al., 2011; Ojukwu et al., 2020). Hydrocolloids help maintain the desired texture during cooking and ensure the noodles retain their shape, extending their shelf life and facilitating easier transportation and storage (Gasparre & Rosell, 2019). Additionally, hydrocolloids can contribute to the nutritional profile of rice noodles. For example, they have been linked to increased antioxidant activity, which is beneficial for health-conscious consumers (Kraithong & Rawdkuen, 2020; Culeţu et al., 2021). Hydrocolloids also influence the gelatinization and retrogradation properties of rice noodles, which affect their texture and sensory characteristics. Moreover, incorporating ingredients such as soy protein isolate and microbial transglutaminase with hydrocolloids has been shown to enhance the texture and microstructure of gluten-free rice noodles, further improving their overall quality (Gasparre & Rosell, 2019).

1.1.1.1

2. Rice Noodle Production

2.1 Traditional Methods of Rice Noodle Making

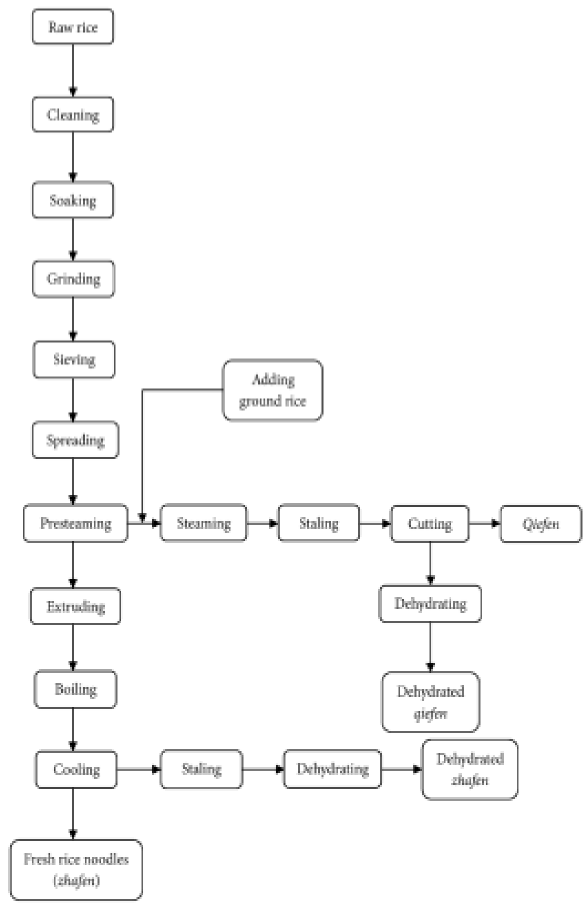

Fig.2: Primary steps in the production of different types of rice noodles

Traditional rice noodle making, which is deeply rooted in the culinary practices of various Asian cultures, is characterized by a series of meticulous steps that include soaking, wet milling, steaming, and sometimes fermentation. The choice of rice variety, particularly those with high amylose content, plays a crucial role in determining the texture and quality of the noodles. These methods not only preserve the cultural heritage of rice noodle production but also contribute to the unique sensory attributes that are cherished in various cuisines.

Table 1: Major ingredients in rice noodles and their functions

Sn	Ingredient	Purpose
1	Rice Flour: - White, non-glutenous (up to 30% amylose)	▪ For noodle texture. ▪ Source of nutrients: Carbohydrates (78%), dietary fiber (2.4%), Protein (6-7%), Fats (1.4%), Some B vitamins, Minerals (Zn, Fe).
2.	Starch: - e.g Tapioca Starch	• Noodle Texture: Strength and elasticity. • Improved noodle appearance.
3.	Hot water (at 70-80 ºC)	▪ For flour hydration. ▪ For Starch gelatinization. ▪ Texture of noodles.
4.	Table salt	▪ Flavour enhancer. ▪ Improves flavour balance. ▪ Masks other unpleasant flavours. ▪ Improves water holding capacity of noodles. ▪ Inhibits growth of microorganisms.

The first step in traditional rice noodle production is soaking the rice grains, which is essential for achieving the desired texture. Long-grain rice varieties with high amylose content (greater than 22%) are preferred, as they contribute to the firmness and elasticity of the noodles (Rungsardthong et al., 2021; Malahayati et al., 2014). High amylose rice, such as jasmine rice, is particularly valued for its ability to form a gel network during cooking, which is crucial for the structural integrity of the noodles (Sun et al., 2013). After soaking, the rice is wet-milled to produce a smooth slurry, which is a critical step that affects the final texture of the noodles. Wet milling results in a finer particle size and lower levels of damaged starch, which are desirable for noodle quality (Liu et al., 2021). Following the milling process, the rice slurry is subjected to steaming, which causes starch gelatinization. This step is vital as it disrupts the granular structure of starch, allowing it to absorb water and swell, which enhances the noodle's texture (Liu et al., 2014). The gelatinized starch forms a cohesive mass that can be shaped into noodles. Traditionally, this shaping is done by pressing the dough through a die or by spreading it onto a flat surface and cutting it into strips (Seetapan et al., 2021). The steaming process also contributes to the development of flavor, as it allows for the fermentation of the rice, which can enhance the aroma and taste of the final product (Chen et al., 2017). Moreover, the use of fermentation in some traditional rice noodle recipes introduces beneficial lactic acid bacteria, which can improve the noodles' sensory qualities, such as elasticity and flavor (Dong et al., 2020). The fermentation process typically involves allowing the rice slurry to sit for several days, promoting the growth of these bacteria before the noodles are formed and steamed (Chen et al., 2017). In terms of nutritional aspects, traditional rice noodles can be enhanced by incorporating other ingredients, such as cassava starch or hydrocolloids, which can improve texture and reduce cooking loss (Wandee et al., 2014; Kraithong & Rawdkuen, 2020). However, the traditional methods remain labor-intensive and time-consuming, often requiring skilled artisans to ensure the quality of the noodles (Seetapan et al., 2021).

2.2 Modern Advancements in Rice Noodle Production

Modern advancements in rice noodle production have significantly transformed traditional methods, improved efficiency, quality, and scalability while meeting the growing global demand for this versatile food product. Mechanized processes, such as automated systems for soaking, grinding, and steaming, have reduced labor costs and increased production capacity. These systems allow precise control of critical parameters, including temperature and moisture levels, which leads to more consistent noodle quality (Li et al., 2021). The use of extrusion technology is one of the key innovations in rice noodle production, where rice flour dough is forced through a die to form noodles. This method enables continuous production, ensuring uniform shape and size, while also allowing for the incorporation of additives such as hydrocolloids to enhance texture, shelf life, and cooking properties (Wu et al., 2018). Ingredient innovation has also played a crucial role in modern advancements. Researchers have explored alternative starch sources and functional ingredients, such as blending rice flour with pineapple stem starch, which improves the physical properties and cooking qualities of noodles by providing a firmer and more elastic texture (Pinyo, 2024). The inclusion of brown rice, rice bran, and protein sources like soy protein isolate has further enhanced the nutritional profile of rice noodles, contributing to higher fiber content, lower glycemic index, and improved health outcomes (Wu et al., 2020; Huang et al., 2021; Ojukwu et al., 2020).

Processing techniques have continued to evolve, with extrusion technology emerging as a popular method due to its ability to produce noodles with better water absorption and reduced cooking loss compared to traditional methods (Seetapan et al., 2021). Hydrothermal treatments and the use of food hydrocolloids, such as guar gum and xanthan gum, have also been shown to enhance the structural integrity and mouthfeel of rice noodles, making them more appealing to consumers (Kraithong & Rawdkuen, 2020; Liu et al., 2021).

Advancements in fermentation processes have further improved the flavor and texture of rice noodles. Controlled fermentation techniques using specific strains of lactic acid bacteria, such as *Lactobacillus plantarum*, have resulted in more consistent aroma and sensory characteristics compared to spontaneous fermentation (Dong et al., 2020; Li et al., 2015). Optimizing fermentation parameters, including temperature and time, has minimized risks associated with uncontrolled microbial growth while enhancing the noodles' quality (Dong et al., 2020). Moreover, modern rice noodle production has benefited from advancements in quality prediction and control, particularly through the use of artificial intelligence and machine learning. Techniques like backpropagation artificial neural networks have been utilized to predict the quality of whole-grain rice noodles based on various processing parameters, allowing for more precise control over production processes and enabling the development of new formulations tailored to consumer preferences (Wang, 2024).

2.3 Impact of Rice Variety on Noodle Quality

The choice of rice variety plays a crucial role in determining the quality of rice noodles, as it significantly influences the noodles' texture, cooking behavior, and sensory attributes. This impact is largely driven by the chemical composition of the rice flour, particularly the amylose and amylopectin content, protein levels, and other proximate components. High-amylose rice varieties are generally preferred for noodle production because they form a strong gel network during cooking, resulting in firmer noodles with reduced stickiness. These noodles are less prone to overcooking, making them desirable for many culinary applications (Fitzgerald et al., 2009; Malahayati et al., 2014; Nagai et al., 2019; Wu et al., 2018). Conversely, low-amylose or waxy rice varieties yield softer, more elastic noodles, which may disintegrate more easily during cooking (Huang et al., 2021).

Amylose content is a key determinant of rice noodle quality. Research has demonstrated that medium-amylose rice varieties, such as Hoshinishiki and Koshinokaori, strike a balance between firmness and elasticity, producing noodles with desirable textural attributes (Wu et al., 2018; Puhin et al., 2021). These noodles exhibit better cooking quality, with reduced cooking loss and enhanced water absorption, making them both easy to cook and pleasant to eat (Fari et al., 2011; Kang et al., 2022). In contrast, noodles made from rice varieties with lower amylose content tend to be softer, with a higher risk of disintegration during cooking (Huang et al., 2021). The overall chemical composition of the rice flour also plays a significant role in determining noodle quality. Higher protein content, for instance, improves the structural integrity of the noodles, preventing excessive swelling and cooking loss. However, an imbalance in protein levels can negatively affect noodle hardness (Park et al., 2019; Dong et al., 2021). Additionally, the branched-chain length distribution of amylopectin in different rice varieties influences the gelatinization and retrogradation processes, which are critical for determining noodle texture and digestibility (Kang et al., 2022; Denchai et al., 2019). Varieties with a higher proportion of short-chain amylopectin tend to produce noodles with better cooking qualities and a more stable structure during cooking (Puhin et al., 2021; Denchai et al., 2019).

Non-starch components, such as dietary fibers and lipids, also contribute to rice noodle quality. Higher fiber content in certain rice varieties has been associated with improved water absorption and reduced cooking time, enhancing the overall quality of the noodles (Kraithong & Rawdkuen, 2021). However, excessive lipid content may lead to undesirable textural properties, such as increased stickiness or a greasy mouthfeel, which can detract from the overall noodle experience (Kraithong et al., 2018). Therefore, understanding and selecting the right rice varieties are essential for manufacturers to optimize noodle production and meet diverse consumer preferences.

3. Hydrocolloids: An Overview

Hydrocolloids are a diverse group of substances, primarily polysaccharides and proteins, that perform gelling, thickening and stabilising functions in food. These compounds are utilized extensively in the food industry to modify the texture, viscosity, stability, and appearance of various food products. Hydrocolloids can be synthetic or natural (plant-based, or animal-based) (Liao, Chang, Nagarajan, Chen, & Chang, 2021). Natural Hydrocolloids can be derived from numerous natural sources, including plants, seaweeds, animals, and microbial fermentation (Liao et al., 2021; Pegg, 2012). Hydrocolloids play a crucial role in food formulation and processing, offering functionalities that are essential for achieving the desired product characteristics. By interacting with water molecules, hydrocolloids can influence the rheological properties of food systems, providing thickening, gelling, emulsifying, and stabilizing effects (Pegg, 2012; Saha & Bhattacharya, 2010). These properties make hydrocolloids indispensable in a wide array of food products, ranging from sauces and dressings to bakery items and dairy products. The versatility of hydrocolloids allows for their application in a multitude of food products, contributing to the desired sensory attributes and functional properties. By altering these critical aspects, hydrocolloids enhance the overall quality and consumer appeal of food items. Their ability to form gels and modify physical properties makes them invaluable in producing a wide range of food products, from dairy and bakery items to meat products and beverages (Pegg, 2012; Culetu et al., 2021).

3.1 Hydrocolloids Commonly Applied in Rice Noodle Production

Hydrocolloids play a pivotal role in rice noodle production by significantly enhancing the textural properties, cooking quality, and overall sensory attributes of the final product (Kraithong et al., 2023). These hydrocolloids—such as guar gum, xanthan gum, carboxymethyl cellulose (CMC), agar-agar, carrageenan, modified starch, and sodium alginate—are utilized for their ability to stabilize, thicken, and improve water retention in rice noodles, addressing common challenges associated with gluten-free products made from rice flour (Kraithong et al., 2023; Liao et al., 2021; Pegg, 2012).

Carrageenan, serves as a multifunctional ingredient in rice noodle production, improving texture, reducing cooking loss, and enhancing overall quality. Its unique gelling and stabilizing properties make it an essential component in developing gluten-free noodle products that meet consumer expectations. Carrageenan is a natural polysaccharide derived from red seaweeds, particularly from species such as *Chondrus crispus*, and *Kappaphycus alvarezii*. It is primarily composed of linear sulfated galactans, which can be categorized into three main types: kappa (κ), iota (ι), and lambda (λ) carrageenan, each differing in their degree of sulfonation and gelling properties (Nečas & Bartošíková, 2013; Weiner, 2014). Carrageenan is widely utilized in the food industry as a thickening, gelling, and stabilizing agent due to its unique ability to form gels in the presence of potassium ions and its compatibility with various food matrices (Cheng et al., 2022; Amruth et al., 2023).

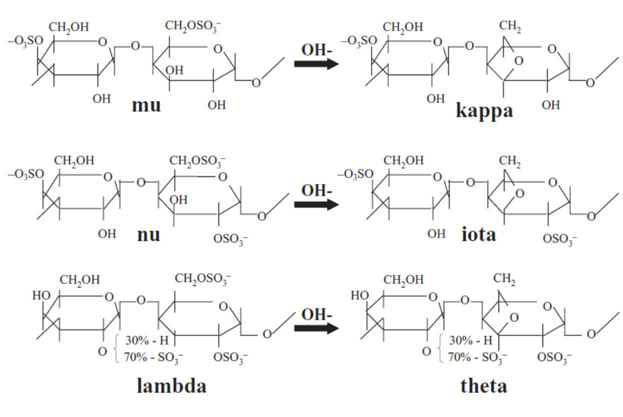

Fig. 3: Structures of primary carrageenans. (Source: William et al., 2009).

In rice noodle production, carrageenan plays a crucial role in enhancing the texture and quality of the final product. The incorporation of carrageenan into rice noodle formulations improves the noodles' water retention capacity, which is essential for maintaining moisture during cooking and storage (Weiner, 2014). This property helps reduce cooking loss, which is a common issue in rice noodles that can lead to undesirable texture and quality (Cheng et al., 2022). The gelling properties of carrageenan contribute to the formation of a stable matrix that supports the starch structure in the noodles, thereby enhancing their firmness and elasticity (Nečas & Bartošíková, 2013; Weiner, 2014).

Moreover, carrageenan can interact with other components in the noodle formulation, such as proteins and starches, to create a cohesive and resilient structure. This interaction is particularly beneficial in gluten-free products like rice noodles, where the absence of gluten necessitates the use of hydrocolloids to achieve desirable textural characteristics (Weiner, 2014). Studies have shown that the addition of carrageenan can significantly improve the sensory attributes of rice noodles, including chewiness and overall mouthfeel, making them more appealing to consumers (Cheng et al., 2022). Additionally, carrageenan's ability to form gels can help control retrogradation in starch, which is critical for maintaining the quality of noodles during storage and reheating (Weiner, 2014). This property is particularly important for instant noodles, where the quality must be preserved over time and through various cooking methods. The use of carrageenan in rice noodle production not only enhances the physical characteristics of the noodles but also contributes to their stability and shelf life, making it a valuable ingredient in the formulation of high-quality rice noodles.

Carboxymethyl Cellulose (CMC), serves as a vital ingredient in rice noodle production, enhancing texture, reducing cooking loss, and improving the overall quality of the final product. Its ability to modify the rheological properties of the noodle dough makes it an essential component in developing high-quality rice noodles that meet consumer expectations for texture and mouthfeel. Carboxymethyl cellulose (CMC) is a cellulose derivative that is widely used in food production, particularly in the manufacture of rice noodles. CMC is synthesized by the carboxymethylation of cellulose, which introduces carboxymethyl groups into the cellulose structure, enhancing its solubility and functional properties in aqueous solutions (Pongpichaiudom & Songsermpong, 2018). This modification allows CMC to act as a thickening agent, stabilizer, and emulsifier, which are crucial in improving the texture and quality of noodle products. In rice noodle production, CMC plays a significant role in enhancing the textural properties and cooking characteristics of the noodles. The incorporation of CMC into noodle formulations can improve the water-holding capacity, thereby reducing cooking loss and maintaining the desired firmness and elasticity of the noodles during cooking (Pongpichaiudom & Songsermpong, 2018; Rękas & Marciniak-Łukasiak, 2015). The hydrocolloid nature of CMC allows it to form a gel-like structure when hydrated, which contributes to the overall mouthfeel and sensory attributes of the noodles (Nasruddin et al., 2018; Shere et al., 2020). This is particularly important in rice noodles, which are gluten-free and rely heavily on the starch matrix for structural integrity. The addition of CMC helps to compensate for the lack of gluten, providing a more cohesive and resilient noodle structure (Sandhu et al., 2010). Moreover, studies have shown that the optimal concentration of CMC can significantly influence the physicochemical properties of rice noodles. For instance, the addition of CMC in varying percentages has been found to enhance the tensile strength and reduce the cooking loss of the noodles, leading to improved overall quality (Nasruddin et al., 2018; Choi & Koh, 2017). The interaction between CMC and starch molecules in the noodle dough can also help control retrogradation, which is essential for maintaining the quality of noodles during storage and after cooking (Pongpichaiudom & Songsermpong, 2018; Sandhu et al., 2010).

Guar Gum, is a galactomannan derived from the seeds of the guar plant (*Cyamopsis tetragonoloba*). This hydrocolloid has exceptional water-absorbing capacity and forms a viscous solution at low concentrations, making it highly effective as a thickener and stabilizer (Tahmouzi et al., 2023). In rice noodle production, guar gum enhances water retention, which helps prevent the noodles from drying out and improves their cohesiveness during cooking. The ability of guar gum to form hydrogen bonds with water molecules also increases the dough's elasticity and chewiness, resulting in noodles with a smooth texture and improved mouthfeel (Singh, Viswakarma, & Kumar, 2021)). Research shows that guar gum can improve the freeze-thaw stability of rice starch gells, reduce syneresis, and prolong shelf life, making it a popular choice in large-scale production (Xu, Ye, Zuo, & Fang, 2022).

Xanthan Gum, produced by the fermentation of sugars by *Xanthomonas campestris*, is a high-molecular-weight polysaccharide known for its excellent stability across a broad range of temperatures and pH levels (Chaturvedi et al., 2021; García-Ochoa et al., 2000). In rice noodle production, xanthan gum acts as a thickener, stabilizer, and emulsifier, forming a highly viscous solution even at low concentrations. It enhances the noodle dough's structural integrity, improves the noodles' elasticity and chewiness, and ensures consistency in texture and quality across various storage and cooking conditions (Raungrusmee, Shrestha, Sadiq, & Anal, 2020). Studies have shown that xanthan gum's ability to interact with starch molecules can help control retrogradation and amylose-amylose interactions, which leads to better freeze-thaw stability and reduced cooking loss

Agar-Agar, commonly referred to simply as agar, is a gelatinous substance derived from the cell walls of certain red algae, particularly from the genera *Gelidium* and *Gracilaria*. It is primarily composed of two polysaccharides: agarose and agaropectin, which contribute to its gelling properties. Agar is widely used in various food applications, as well as in microbiological media due to its ability to form a stable gel at room temperature and its resistance to degradation by most microorganisms (Fu et al., 2021; Ramos, 2018). In the context of rice noodle production, agar serves several important roles. First and foremost, it acts as a gelling agent that can enhance the texture and mouthfeel of the noodles. The incorporation of agar into rice noodle formulations can improve the overall firmness and elasticity, which are crucial characteristics for consumer acceptance (Chen et al., 2017). This is particularly significant for rice noodles, which are naturally gluten-free and rely on hydrocolloids like agar to mimic the structural properties typically provided by gluten in wheat-based noodles (Chen et al., 2017; Ramos, 2018). Agar's ability to retain water is another critical factor in rice noodle production. By improving the water-holding capacity of the noodle matrix, agar helps to minimize cooking loss, thereby maintaining the integrity and quality of the noodles during cooking (Chen et al., 2017). This property is essential for achieving the desired texture and preventing the noodles from becoming overly soft or mushy, which can occur when they are cooked in water (Chen et al., 2017; Ramos, 2018). Moreover, agar can also play a role in controlling retrogradation in starches, which is a common issue in noodle products. Retrogradation occurs when gelatinized starch molecules reassociate upon cooling, leading to a firm and undesirable texture. The presence of agar can help stabilize the starch matrix, thereby reducing the extent of retrogradation and enhancing the shelf life of the noodles (Chen et al., 2017; Ramos, 2018). This stabilization is particularly beneficial for instant rice noodles, which need to retain quality over time and through various cooking methods. Therefore, agar-agar is a valuable ingredient in rice noodle production, contributing to improved texture, reduced cooking loss, and enhanced stability against retrogradation. Its unique properties make it an essential component for formulating high-quality rice noodles that meet consumer expectations for texture and overall quality.

Sodium Alginate, a biopolymer derived from brown seaweed, is a linear polysaccharide composed of mannuronic (M) and guluronic (G) acid units (Smith & Miri, 2011). It is widely used in various industries, including food production, due to its multifunctional properties such as thickening, gelling, and stabilizing. In rice noodle production, sodium alginate plays a critical role in improving the structural integrity, texture, and overall quality of the noodles. The gelling mechanism of sodium alginate involves the interaction of G-blocks with divalent cations, such as calcium ions, to form a stable gel network. This gel network enhances the noodles' resistance to mechanical stress during cooking and handling, resulting in improved elasticity and chewiness, which are essential for consumer acceptance (Lubowa et al., 2019). Sodium alginate is particularly beneficial for rice noodle production because it increases water absorption and swelling power in the noodle dough, improving its hydration properties (Lee et al., 2008). This property is critical for maintaining moisture in the noodles, preventing them from drying out during storage, and ensuring a desirable texture.

Additionally, sodium alginate enhances the tensile strength and cutting forces of rice noodles, giving them a firmer texture. In a study conducted by Lubowa et al. (2019), the combination of pre-gelatinized high amylose corn starch with calcium-induced sodium alginate resulted in noodles with improved tensile strength and increased density. This ability to form a strong gel network contributes to the overall structural integrity of the noodles, making them more durable during handling and cooking.

The addition of sodium alginate in rice noodles also leads to improved cooking quality. It has been shown to reduce cooking loss and increase the cooked weight of noodles, which enhances their overall quality (Lee et al., 2008). Furthermore, sodium alginate helps minimize stickiness between noodle ribbons, improving mouthfeel and palatability (Hashimoto et al., 2003). These improvements in texture and sensory attributes make sodium alginate an ideal ingredient for both fresh and frozen rice noodle products. Additionally, when used in combination with other hydrocolloids, such as xanthan gum, sodium alginate further enhances the freeze-thaw stability of noodles, which is especially valuable in frozen food applications (Lubowa et al., 2020). Beyond its impact on texture and cooking properties, sodium alginate has demonstrated the ability to reduce the glycemic index (GI) of rice noodles, offering potential health benefits for consumers. By forming a gel network around starch granules, sodium alginate slows down the digestion and absorption of carbohydrates, reducing postprandial blood glucose levels (Koh et al., 2009; El Khoury, Goff, & Anderson, 2015). This mechanism occurs through hydrogen bonding between sodium alginate and starch, which decreases starch crystallinity and increases thermal stability (Xu et al., 2023). In a study by Xu et al. (2023), the addition of 1% sodium alginate to rice noodles reduced the predicted glycemic index from 84.76 to 78.92. In vitro digestion simulations also showed that sodium alginate significantly slowed glucose release, further confirming its role in managing postprandial blood glucose levels (Wang et al., 2023).

Sodium alginate's effectiveness in rice noodle production extends beyond its ability to improve quality and health outcomes. It is a versatile ingredient with applications across various food products due to its thickening, gelling, and stabilizing properties (Smith & Miri, 2011). While sodium alginate has already proven beneficial in rice noodle production, further research is needed to optimize its use in different formulations and processing conditions. Its interaction with other ingredients, such as modified starches or alternative hydrocolloids, could potentially unlock new opportunities to enhance the nutritional profile and texture of rice noodles.

Konjac glucomannan (KGM)

Konjac glucomannan (KGM) is a water-soluble polysaccharide derived from the tuber of the konjac plant (Amorphophallus konjac). It is composed of a linear chain of β-1,4-linked D-mannose and D-glucose residues, typically in a molar ratio of approximately 1.6:1 (Figure 3) (Tan et al., 2016). KGM is known for its exceptional thickening, gelling, and emulsifying properties, making it a valuable ingredient in various food applications, including rice noodle production.

One of the primary roles of KGM in rice noodle production is its ability to enhance the textural properties of the noodles. The addition of KGM improves the elasticity and chewiness of the noodles, which are critical sensory attributes for consumer acceptance (Thuy et al., 2023). Research by Zhang et al. indicated that KGM can significantly affect the long-term retrogradation of starch in noodles, thereby influencing their texture and shelf life (Zhang et al., 2021). By stabilizing the noodle structure, KGM helps to maintain a desirable mouthfeel and prevent the noodles from becoming overly stiff or gummy during storage (Zhang et al., 2021; Halim et al., 2023). Moreover, KGM contributes to the water retention capacity of rice noodles. Its high water-binding ability allows for better moisture retention during cooking, which is essential for achieving the desired noodle texture (EFSA Panel on Dietetic Products, Nutrition and Allergies [NDA], 2010). This property is particularly beneficial in gluten-free formulations, where traditional binding agents are absent. The incorporation of KGM can lead to improved cooking quality, as it helps to reduce cooking loss and enhances the overall hydration of the noodle matrix (Li, 2024). In addition to its functional properties, KGM also plays a role in the nutritional profile of rice noodles. As a soluble dietary fiber, KGM has been associated with various health benefits, including the regulation of blood glucose levels and the promotion of satiety (EFSA Panel on Dietetic Products, Nutrition and Allergies [NDA], 2010; Jin, 2024). This makes KGM-enriched rice noodles an appealing option for health-conscious consumers looking for low-calorie and high-fiber food alternatives (Tan et al., 2016; Cheang et al., 2017). The incorporation of KGM can also enhance the nutritional value of rice noodles by increasing their fiber content without significantly altering their taste or texture (Thuy et al., 2023). Furthermore, KGM's gelling properties can be utilized to create unique noodle textures that mimic those of traditional wheat noodles, thereby expanding the market for gluten-free products (Yu et al., 2020). The ability of KGM to form a gel-like structure when hydrated allows for the development of noodles that are both stable and enjoyable to eat, making it a versatile ingredient in noodle production.

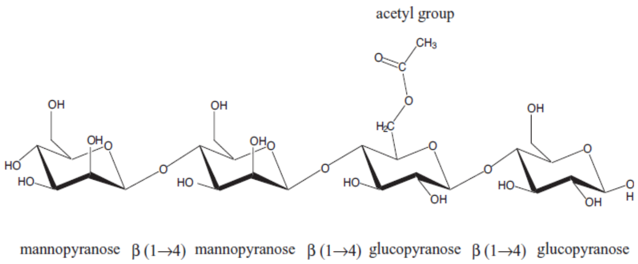

Fig. 4: Chemical structure of konjac glucomannan (Source; Parry, 2009).

Modified Starch, refers to starch that has been chemically, physically, or enzymatically altered to enhance its functional properties for specific applications in food production. In the context of rice noodle production, modified starch plays a multifaceted role by enhancing gelatinization, controlling retrogradation, improving nutritional profiles, and optimizing cooking quality. Its incorporation into rice noodle formulations is essential for achieving the desired textural and functional properties that meet consumer expectations (Lubowa, Yeoh, & Easa, 2018). One of the primary functions of modified starch in rice noodle production is to enhance the gelatinization process. Gelatinization is the process where starch granules absorb water and swell upon heating, leading to the formation of a viscous gel. The use of modified starch can lower the pasting temperature and increase the peak viscosity of the noodle dough, which is essential for creating a stable structure during cooking (Malahayati et al., 2014; Hormdok & Noomhorm, 2007). For instance, finer flour particle sizes have been shown to yield higher paste viscosities, indicating a greater proportion of gelatinized starch, which acts as a binder during the extrusion process (Malahayati et al., 2014). This binding capability is crucial for maintaining the integrity of the noodles during cooking and storage. Moreover, modified starch can significantly affect the retrogradation of starch in rice noodles. Retrogradation occurs when gelatinized starch molecules reassociate upon cooling, which can lead to changes in texture and firmness over time. A high amylose content in modified starch promotes retrogradation, resulting in a firmer noodle structure that is often preferred by consumers (Pinyo, 2024; Denchai et al., 2019). However, excessive retrogradation can lead to undesirable textural changes, so the degree of modification is critical to balance these effects (Pinyo, 2024; Denchai et al., 2019). Studies have shown that the incorporation of modified starch can help control the retrogradation process, thereby improving the shelf life and cooking quality of rice noodles (Denchai et al., 2019).

In addition to textural improvements, modified starch can also enhance the nutritional profile of rice noodles. By incorporating resistant starch, which is less digestible than regular starch, modified starch can contribute to lower glycemic index (GI) values in noodles, making them more suitable for health-conscious consumers (Srikaeo et al., 2011). This is particularly important as the demand for healthier food options continues to rise. The presence of resistant starch can also provide dietary fiber benefits, promoting digestive health (Sangpring et al., 2015). Furthermore, modified starch can improve the cooking quality of rice noodles by reducing cooking loss and enhancing water retention. The modified starch can create a more stable matrix that encapsulates starch granules, minimizing the leaching of solids during cooking (Pongpichaiudom & Songsermpong, 2018). This leads to noodles that are less sticky and have a more desirable texture after cooking (Pongpichaiudom & Songsermpong, 2018; González et al., 2022). The ability to retain moisture is particularly beneficial in gluten-free formulations, where achieving the right texture can be challenging due to the absence of gluten (González et al., 2022; Leakhena et al., 2021).

4. Impact of Hydrocolloids on Rice Noodle properties

Hydrocolloids play a pivotal role in shaping the quality of rice noodles by influencing various properties, including texture, cooking behavior, shelf life, and nutritional profile. The incorporation of hydrocolloids such as guar gum, xanthan gum, and carboxymethyl cellulose (CMC) has been shown to significantly enhance these key attributes, ultimately improving the overall consumer experience.

Enhancing Texture and Mouthfeel: The texture and mouthfeel of rice noodles are critical factors in determining consumer acceptance, and hydrocolloids contribute significantly to improving these qualities. By modifying the structural integrity and elasticity of the noodles, hydrocolloids create a desirable texture that is both firm and tender. Guar gum, known for its high water-binding capacity, plays a crucial role in maintaining moisture within the noodles, preventing them from becoming dry and brittle during storage and cooking. This results in a softer, more pliable texture, which is essential for enhancing mouthfeel. Xanthan gum, on the other hand, increases the elasticity of the noodles, making them more resistant to deformation during cooking and providing a pleasant chewiness. Additionally, CMC forms a gel-like network that contributes to a smooth, cohesive structure, further improving the overall texture of the noodles (Wu et al., 2018).

Improving Cooking Quality: Hydrocolloids also enhance the cooking quality of rice noodles, ensuring they withstand rigorous cooking processes such as boiling and stir-frying without disintegrating or becoming excessively sticky. This is particularly important for consumers who prefer noodles that maintain their shape, firmness, and texture during preparation (Hu et al., 2021). Hydrocolloids like agar-agar and carrageenan have been shown to enhance the thermal stability of rice noodles by forming a gel matrix that traps water. This gel network prevents overcooking, allowing the noodles to retain their structure and firmness even after prolonged cooking. Moreover, hydrocolloids reduce cooking loss, ensuring that the noodles remain intact and exhibit desirable eating qualities (Kraithong & Rawdkuen, 2020).

Extending Shelf Life and Storage Stability: One of the significant advantages of using hydrocolloids in rice noodles is the improvement in shelf life and storage stability. Hydrocolloids help prevent syneresis, the expulsion of water from the noodle matrix, which can lead to textural degradation and spoilage. By retaining moisture, hydrocolloids such as guar gum and xanthan gum extend the freshness and quality of the noodles during storage. This moisture retention also helps prevent the noodles from becoming too dry or brittle over time. Furthermore, the stabilizing properties of hydrocolloids reduce the likelihood of microbial growth, contributing to an extended shelf life, which is crucial for commercially produced noodles that need to remain viable during long distribution and retail periods (Kraithong & Rawdkuen, 2020).

Enhancing Nutritional Profile: In addition to their primary role of improving texture, cooking quality, and shelf life, some hydrocolloids can positively impact the nutritional profile of rice noodles. For example, guar gum is a source of soluble dietary fiber, which can enhance the fiber content of the noodles. This offers potential health benefits, such as improved digestive health, making the noodles more appealing to health-conscious consumers (Qazi et al., 2011). While the primary function of hydrocolloids is to improve the physical properties of the noodles, their contribution to the nutritional value adds an additional layer of consumer appeal, especially as demand for healthier food options grows.

Influence on Sensory Attributes: The sensory attributes of rice noodles, including taste, color, and appearance, are essential in influencing consumer preference. Hydrocolloids indirectly impact these sensory qualities by modifying the texture and interaction of the noodles with other ingredients. For instance, agar-agar can produce clear, translucent noodles that are visually appealing, adding to the overall attractiveness of the product. Additionally, the choice and concentration of hydrocolloids can influence the taste perception of the noodles by altering their texture and mouthfeel, which, in turn, affects flavor perception (Lubowa et al., 2019). Thus, the careful selection of hydrocolloids plays a significant role in not only enhancing texture but also in optimizing sensory characteristics that appeal to consumers.

5. Mechanisms by Which Hydrocolloids Improve Noodle Quality

Hydrocolloids play a crucial role in enhancing the quality of rice noodles through various mechanisms, primarily by improving texture, water retention, and cooking properties. The incorporation of hydrocolloids such as xanthan gum (XG), guar gum (GG), and carboxymethyl cellulose (CMC) has been shown to significantly influence the physical properties of rice noodles, leading to improved sensory attributes and overall quality.

Water Binding: Hydrocolloids have a high affinity for water and can bind large amounts of it, which helps maintain moisture within the noodle structure. This results in a softer and more pliable texture. For instance, guar gum and xanthan gum are particularly effective at retaining water, preventing the noodles from becoming too dry or brittle. Kraithong et al. (2018) demonstrated that the addition of GG, CMC, and XG improved the rehydration capacity of rice noodles by 25%, 26%, and 33%, respectively. This increased water retention contributes to a softer texture, reduced stickiness, and improved mouthfeel during consumption (Kraithong & Rawdkuen, 2020). The presence of hydrocolloids also reduces cooking loss, maintaining the noodles' integrity and texture during preparation (Ojukwu et al., 2020).

Gel Formation: Hydrocolloids such as agar-agar and carrageenan form gels when dissolved in water, creating a three-dimensional network that provides structure and stability to the noodles. This gel network helps to distribute water evenly throughout the noodle, preventing localized drying and improving the overall texture. The formation of this gel network is critical for maintaining noodle shape and structure during cooking. This also helps improve freeze-thaw stability in certain formulations, making hydrocolloids beneficial for both fresh and frozen noodle products (Tan et al., 2018).

Interaction with Starch and Protein: Hydrocolloids interact with starch and protein molecules in rice flour, modifying their functionality. This interaction inhibits retrogradation, the recrystallization of starch molecules responsible for undesirable hard textures (Gasparre & Rosell, 2019). In addition, hydrocolloids enhance the elasticity and chewiness of the noodles by forming cross-links with protein molecules, contributing to a more stable noodle structure. This is particularly important in gluten-free formulations, where traditional gluten networks are absent. Hydrocolloids compensate for this absence by strengthening the starch-protein matrix, leading to improved texture and cooking performance (Dahal et al., 2020).

Rheological Properties: The rheological properties of noodle dough are significantly affected by the addition of hydrocolloids. Negatively charged hydrocolloids, such as CMC and xanthan gum, interact electrostatically with the functional groups of proteins and starches, enhancing the viscosity and extensibility of the dough (Pongpichaiudom & Songsermpong, 2018). This improved machinability facilitates better processing and handling during noodle production. As a result, the dough becomes easier to shape and process, ultimately leading to a higher quality end product (Ojukwu et al., 2020). Moreover, hydrocolloids exhibit synergistic effects when combined with other ingredients like proteins and salts, further optimizing the textural attributes of rice noodles (Parvathy et al., 2016).

6. Technological Innovations in Hydrocolloid Applications for Rice Noodle Production

Hydrocolloids, which are water-soluble polysaccharides, have significantly transformed rice noodle production, enhancing their quality, texture, and overall consumer appeal. This writeup explores the role of hydrocolloids in gluten-free formulations, technological advancements in noodle production, sustainability trends, and the integration of alternative ingredients for improved nutritional value.

Overcoming the Challenges of Gluten-Free Noodle Production: One of the primary challenges in rice noodle production is the absence of gluten, which contributes to the cohesiveness and elasticity of traditional noodles. Hydrocolloids such as xanthan gum, carrageenan, and konjac glucomannan have been identified as effective substitutes to improve the textural properties of rice noodles. Xanthan gum significantly enhances cooking quality, giving the noodles a desirable chewy texture (Tan et al., 2018; Ojukwu et al., 2020). Konjac glucomannan mimics gluten's viscoelastic properties, improving the mouthfeel and elasticity of noodles (Halim et al., 2023; Zoghi et al., 2020). These hydrocolloids also improve the water retention capacity of noodles, which enhances rehydration properties during cooking (Kraithong et al., 2018; Qazi et al., 2011).

Optimizing Hydrocolloid Combinations: Recent studies focus on fine-tuning hydrocolloid combinations to enhance specific textural and functional properties. Blending konjac glucomannan with xanthan gum or guar gum has shown promising results in optimizing the texture, elasticity, and cohesiveness of rice noodles (Li et al., 2021; Zhang et al., 2021). Synergistic effects have also been observed when hydrocolloids are combined with additives like microbial transglutaminase and glucono-δ-lactone, which further improve the texture and mechanical properties of noodles. This innovative approach also reduces cooking loss, a critical factor in consumer satisfaction (Ojukwu et al., 2020; Dahal et al., 2020; Lubowa, Yeoh, & Easa, 2018).

Technological Advancements in Hydrocolloid Application: Modern advancements in processing technologies have revolutionized the application of hydrocolloids in rice noodle production. Equipment like high-shear mixers and extrusion technology ensure the precise and uniform distribution of hydrocolloids throughout the dough, resulting in consistent noodle quality (Milani & Maleki, 2012). Furthermore, innovative drying techniques such as vacuum drying and freeze-drying have been explored to retain the functional properties of hydrocolloids, ensuring that the noodles maintain their texture and moisture levels during storage. Packaging innovations like modified atmosphere packaging (MAP) further enhance shelf life by minimizing oxidation and microbial growth (Obadi, Li, & Xu, 2023).

Enhancing Nutritional Profile and Health Benefits: Consumer demand for gluten-free and health-conscious products is driving the use of hydrocolloids in rice noodle formulations. Hydrocolloids not only improve the texture but also contribute to the noodles' nutritional profile by enhancing antioxidant activity (Kraithong & Rawdkuen, 2020). Manufacturers are increasingly incorporating ingredients like vegetable powders, protein isolates, and dietary fibers to further boost the nutritional value of noodles. For example, pea protein isolate enhances both the protein content and the chewiness of noodles when combined with hydrocolloids (Lee et al., 2020). Additionally, natural colorants and flavors from fruits and vegetables are being used to create more visually appealing and flavorful noodle products (Li et al., 2014).

Sustainability Trends in Rice Noodle Production: Sustainability is becoming a critical focus in food production, including rice noodles. Researchers are investigating the use of hydrocolloids derived from renewable, environmentally friendly sources to address sustainability concerns. For instance, the development of biodegradable packaging materials containing hydrocolloids offers a potential solution to reducing plastic waste. Efforts are also being made to minimize water and energy consumption during the noodle production process. Technological innovations, such as energy-efficient drying methods and hydrocolloid formulations, are helping manufacturers optimize resource usage and reduce the environmental footprint of rice noodle production (Zhili et al., 2016).

Future Prospects for Hydrocolloids in Rice Noodle Production: The ongoing research on hydrocolloids continues to shape the future of rice noodle production. Hydrocolloids are expected to play an even greater role in gluten-free and health-oriented product formulations, catering to the growing market for high-quality, health-conscious, and sustainable food products. As advancements in hydrocolloid applications and noodle processing technologies continue, the potential for further innovations remains promising (Lubowa et al., 2021).

7. Challenges and Limitations in Using Hydrocolloids for Rice Noodle Production

The incorporation of hydrocolloids in rice noodle production presents various advantages, particularly in enhancing texture, cooking quality, and shelf life. However, several challenges and limitations hinder their optimal utilization. These challenges encompass technical difficulties, economic considerations, consumer acceptance, and regulatory issues.

Technical Challenges in Hydrocolloid Use: A primary technical challenge in utilizing hydrocolloids is achieving the appropriate concentration balance. While hydrocolloids can enhance noodle texture, incorrect dosages may lead to undesirable outcomes. Excessive use can result in overly gummy or sticky textures, whereas insufficient amounts may fail to yield the desired improvements (Kraithong et al., 2018; Imeson, 2010). For instance, research has shown that the addition of hydrocolloids like xanthan gum (XG) and guar gum (GG) can significantly enhance sensory attributes such as taste and elasticity, but only when used in optimal concentrations (Kraithong et al., 2018). Achieving this balance necessitates precise formulation and rigorous testing to ensure that the texture remains acceptable and does not compromise other noodle properties. Another technical hurdle involves the uniform dispersion of hydrocolloids within the noodle dough. Inconsistent mixing can lead to uneven texture, where certain sections of the noodles may exhibit firmer or more elastic characteristics than others (Mikuš, Valík, & Dodok, 2011). Advanced mixing techniques and meticulous control of processing parameters are essential to ensure that hydrocolloids are evenly distributed, resulting in consistent product quality (Mikuš, Valík, & Dodok, 2011). Furthermore, hydrocolloids interact with other ingredients, such as starches and proteins, in complex ways that can affect the final texture, cooking behavior, and shelf life of the noodles (Qazi et al., 2011). This necessitates extensive research and experimentation to optimize ingredient combinations, requiring producers to possess a comprehensive understanding of the behavior of each hydrocolloid in various formulations (Yemenicioğlu et al., 2019).

Economic Considerations: The cost of hydrocolloids can be a significant barrier, particularly for small-scale noodle producers. High-quality hydrocolloids often come with a substantial price tag, which can elevate production costs. For producers operating in regions with narrow profit margins or low consumer purchasing power, this expense may restrict the widespread adoption of hydrocolloids (Mikuš, Valík, & Dodok, 2011). Producers must carefully evaluate the benefits of hydrocolloid use against the increased costs to determine their economic viability. Moreover, the stability of hydrocolloid supply is another critical economic factor. Fluctuations in supply chains due to raw material shortages, geopolitical issues, or market disruptions can affect the availability and pricing of hydrocolloids (Yemenicioğlu et al., 2019). Producers need to be cognizant of these risks and develop strategies to mitigate potential supply issues, ensuring a consistent production process (Mikuš, Valík, & Dodok, 2011).

Consumer Acceptance and Market Trends: Consumer acceptance is crucial for the successful integration of hydrocolloids in rice noodle production. Despite the functional advantages, some consumers may view hydrocolloids as artificial or undesirable additives in their food (Yemenicioğlu et al., 2019). Educating consumers about the safety and benefits of hydrocolloids is vital to overcoming this perception and fostering trust. Transparent labeling and communication regarding the natural origins and safety of hydrocolloids can help alleviate concerns (Yemenicioğlu et al., 2019). Additionally, evolving market trends favoring natural and minimally processed foods pose challenges. Many consumers are increasingly wary of synthetic or processed additives, leading to a preference for "clean-label" products (Yemenicioğlu et al., 2019). To align with these consumer preferences, manufacturers may need to explore natural hydrocolloids or alternative ingredients to meet the demand for less processed options (Yemenicioğlu et al., 2019).

Regulatory Aspects and Safety Concerns: The use of hydrocolloids in food production is subject to stringent regulations, with varying restrictions on the types and permissible concentrations of these additives across different countries. For producers aiming to market their products in multiple regions, navigating these regulations can be complex (Yemenicioğlu et al., 2019). Compliance with local and international food standards is essential to avoid legal or regulatory complications (Kraithong et al., 2018; Imeson, 2010). Safety concerns regarding hydrocolloids, although infrequent, also warrant attention. Potential allergic reactions or other health risks must be considered, even though most hydrocolloids are generally recognized as safe (GRAS) by food safety authorities (Yemenicioğlu et al., 2019). Continuous monitoring and adherence to safety standards are crucial to ensure that hydrocolloids do not pose health risks to consumers (Kraithong et al., 2018; Williams & Phillips, 2004). Producers must remain vigilant in keeping abreast of regulatory changes and addressing any emerging safety concerns to maintain product integrity.

Conclusion

Hydrocolloids have proven to be indispensable in rice noodle production, significantly enhancing the textural, sensory, and nutritional properties of the noodles. Their ability to improve water retention, reduce cooking loss, and create a stable gel network enables manufacturers to produce noodles with improved elasticity, firmness, and overall quality, which are critical to consumer satisfaction. As gluten-free products grow in demand, hydrocolloids play a key role in developing noodles that can mimic the structural properties traditionally provided by gluten. Furthermore, modern technological advancements, such as the precise control of hydrocolloid dispersion and the use of sustainable ingredients, have pushed rice noodle production into a new era of innovation. However, challenges such as optimal dosage, cost, and consumer acceptance of hydrocolloids remain barriers to their widespread adoption. By overcoming these limitations through continued research and development, hydrocolloids hold great potential to transform the global rice noodle industry, providing healthier, higher-quality, and more sustainable food products that cater to evolving consumer preferences. The continued exploration of new hydrocolloid combinations and alternative ingredients will be pivotal to meeting future market demands for gluten-free, nutritious, and environmentally friendly noodles.

Conflict of interest

The authors declare that there is no conflict of interest concerning the publication of this paper

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