

## Impact of gelling agents on the texture and stability of herbal gummy candies

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### Abstract

Research on gummy products has gained increasing attention in recent years due to their versatility, consumer appeal, and potential as carriers for functional ingredients. This systematic review critically examines the impact of various gelling agents, including pectin, xanthan gum, gelatin, carrageenan, guar gum, and starch, on the texture and stability of herbal gummy candies, a growing sector in the confectionery industry. The review evaluated the physicochemical properties of these gelling agents, focusing on their influence on key parameters such as pH, moisture content, rheological behaviour, and structural integrity. The findings underscore the significant role of gelling agents in modulating textural attributes, with pectin imparting a softer consistency compared to gelatin, while carrageenan and xanthan gum contribute to enhanced structural stability. Texture and stability are critical factors, as they play a significant role in consumer acceptance and product longevity. Additionally, the use of natural extracts enhances both the flavour and nutritional value of the gummies. This review served as a comprehensive reference for researchers and food manufacturers aiming to develop high-quality, stable, and consumer-preferred herbal gummy formulations, while highlighting the need for further investigations into gelling agent interactions and their long-term effects on product performance.

## 1. Introduction

Gelatinised candies, particularly soft ones like jelly and gummy candies, are experiencing rapid growth in the confectionery industry due to their popularity among consumers, especially children (Székelyhidi *et al.*, 2024). Gummy candies are conventionally produced using sugar, water, and gelatin. Many strategies are commonly applied to enhance candy formulations, including replacing gelatin with alternative gelling agents, using natural colourants, vitamins, or fruit derivatives, and substituting sugar with alternative sweeteners (Roudbari *et al.*, 2024). Recently, there has been a notable trend in utilising plant extracts to add unique flavours and aromas in candies (Latif *et al.*, 2022). By integrating these natural ingredients, manufacturers can offer consumers a tasty snack that satisfies their sweet cravings and provides added health benefits.

The global gummy market size was valued at USD 23.93 billion in 2023 and is expected to grow at a

compound annual growth rate (CAGR) of 11.8% from 2024 to 2030, driven by increasing consumer demand for functional and fortified gummies as well as a growing interest in plant-based products (Grand View Research, 2023). Gelling agents are essential for creating the desired chewy texture that characterises gummy candies. The choice of gelling agent significantly affects gummy products' stability and shelf life (Tarahi *et al.*, 2023). Incorporating multiple gelling agents can lead to synergistic effects that improve texture and stability, allowing manufacturers to create products that remain appealing throughout their shelf life (Ge *et al.*, 2020). Some studies suggest that gelatine, carrageenan, pectin, guar and xanthan gums, starch, and their derivatives are all commonly used as gelling agents in making jelly candies (Stępień *et al.*, 2023). These agents can impart different textures; for instance, pectin creates a softer, gummier texture than gelatin, while carrageenan can provide a more elastic and resilient texture. Guar and xanthan gums can increase viscosity and create a

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smoother mouthfeel.

This review examines the diverse gelling agents utilised in the production of herbal gummy candies, highlighting their potential health benefits, such as antioxidant and anti-inflammatory properties, and their impact on product stability. The discussion focuses on critical factors, including pH levels, moisture content, and texture analysis, which are essential for evaluating the performance of gelling agents. These parameters play a significant role in the gelation process, influencing the texture and long-term stability of the final product (Tarahi *et al.*, 2023). By analysing these aspects, this review aims to provide a deeper understanding of how various gelling agents can be effectively employed to enhance the quality and consumer appeal of herbal gummy formulations.

## 2. Type of gelling agent in gummy production

### 2.1 Gelatin

Gelatin, extracted from animal collagen, is commonly employed as a thickener, gelling agent, or stabiliser, imparting texture and moisture retention qualities to food products (Wang and Hartel, 2021). However, pigskin being the primary source of gelatin in the global market, it can create controversy among religious followers (Zin *et al.*, 2021). To address this concern, alternatives such as fish or bovine gelatin or plant-based substitutes can be used to cater to various religious and dietary needs. Gel strength and viscosity determine the type of gelatin. The greater the viscosity level, the greater the gel strength in jelly candy (Cahyaningrum *et al.*, 2021). This increased gel strength contributes to a firmer texture, which can enhance the chewy experience that consumers often associate with gummy candies. Studies have demonstrated the effectiveness of gelatin in enhancing the texture and consistency of gummy candies. For example, Renaldi *et al.* (2022) optimised the composition of pectin and gelatin in a gummy jelly formulation, resulting in a product that balanced consumer preferences for taste and texture. Their study found that a higher proportion of gelatin (8.58%) contributed to a firmer and more elastic texture in the final gummy product. In another study, panellists favoured jelly candy made with 7% pangasius skin gelatin due to its delightful sweetness and satisfying chewy texture (Handayani *et al.*, 2024). Overall, these findings highlight the pivotal role of gelatin in shaping the sensory attributes of gummy candies while addressing consumer needs for quality and taste.

### 2.2 Pectin

Pectin, an intricate polysaccharide, is found in the primary cell walls and middle lamella of land plants,

particularly in citrus fruits and apples (Roman-Benn *et al.*, 2023). Pectin, a sugar acid obtained from galactose, is a commonly used substitute thickening agent in making gummy candies. In contrast to gelatin, pectin has a unique gelling profile, resulting in a softer and more delicate texture. However, to achieve the desired sweetness and flavour profile, pectin often requires higher sugar levels than gelatin (Tarahi *et al.*, 2023). Research has focused on the composition of pectin (1.42%) and gelatin (8.58%) in the *G. atroviridis* gummy jelly (GAGJ), where the optimized formula had a moderate sensory rating score (6.9–7.5) in terms of consumer acceptance; in this context, a score closer to 7.5 indicates a more favorable consumer acceptance compared to a score closer to 6.9, indicating that while the product was somewhat accepted by consumers, there may be room for improvement (Renaldi *et al.*, 2022). Additionally, research on the impact of hydrocolloids (gelatin, pectin, and starch), sugar, and citric acid on the volatiles in strawberry gummy candy found that gelatin resulted in lower volatile levels compared to pectin and starch, which had similar levels, and higher levels of pectin led to lower concentrations of volatiles (Zhang and Barringer, 2017). Furthermore, a study on jelly candy produced with red dragon fruit peel pectin mixed with carrageenan indicates that a 2:1 ratio at 4.5% of red dragon fruit peel pectin and carrageenan was identified as the optimal combination for producing jelly candy (Soedirga and Marchellin, 2021). These findings underscore pectin's suitability for creating versatile, plant-based gummy candies with desirable textures.

### 2.3 Carrageenan

Carrageenan is a popular gelling agent in gummy candy production. It is derived from red seaweed and is classified into three main types: kappa, iota, and lambda, each offering distinct applications that enhance the quality of confectionery products. Kappa carrageenan, for example, forms firm gels in the presence of potassium ions, making it ideal for creating a chewy texture in gummies; iota carrageenan produces softer, more elastic gels when combined with calcium ions, which can improve the mouthfeel of gummy candies; lambda carrageenan does not gel but is useful as a thickener and stabilizer in various formulations (Gino Biotech, 2024). This versatility makes carrageenan an excellent choice for creating plant-based gummy candies that mimic the texture of traditional gelatin-based products. Research cited by Tarahi *et al.* (2023) found that dragon fruit gummies with varying concentrations of carrageenan met water and ash content standards, with panellists showing a preference for those made with 3% carrageenan. These studies highlight carrageenan's effectiveness as a plant-based alternative to gelatin,

offering a range of textures in gummy candies while maintaining structural integrity and consumer appeal.

#### 2.4 Guar gum

Guar gum, also known as guaran, is a polysaccharide extracted from guar beans, derived from the endosperm of *Cyamopsis tetragonolobus* or *Cyamopsis psoralioides*, both members of the leguminosae family (Sharma *et al.*, 2018). This low-cost source of galactomannan is renowned for its thickening and stabilising properties, making it invaluable in various applications across food, feed, and industrial sectors (Thombare *et al.*, 2016). Commercial food-grade guar gum typically comprises approximately 80% guaran, alongside 5-6% crude protein, 8-15% moisture, 2.5% crude fibre, and 0.5-0.8% ash, with minor levels of lipids mainly consisting of free and esterified plant fatty acids (Mortensen *et al.*, 2017). A study on jaggery-based hard-boiled candy consistency using thickening and gelling agents showed that adding guar gum during gummy candy making led to innovative products with enhanced texture and vibrant colour, preferred by testers (Kumar *et al.*, 2021). Furthermore, other research has shown that guar gum might offer advantages for gluten-free products, as it provides a stronger retrogradation inhibition effect, better freeze-thaw stability, and minimal texture alterations in gels (Xu *et al.*, 2022). Hence, guar gum could be utilised as a substitute thickening agent to attain the preferred visual appeal, consistency, and sensation in the mouth.

#### 2.5 Xanthan gum

Xanthan gum is a versatile gelling agent renowned for its unique properties that enhance texture and stability in gummy candies, as well as in various food and non-food applications. Its effectiveness as a hydrocolloid stems from its ability to improve viscosity, stabilise emulsions, maintain temperature stability, and enhance pouring characteristics (Sepulveda *et al.*, 2021). Moreover, xanthan gum is a polysaccharide produced through the fermentation of glucose or sucrose by the bacterium *Xanthomonas campestris* (Kumar *et al.*, 2017). Furthermore, xanthan gum exhibits excellent shear-thinning properties, allowing gummies to maintain a desirable consistency while being processed and consumed (Sepulveda *et al.*, 2021). Overall, xanthan gum's unique properties make it an essential ingredient in gummy candy production, enhancing texture, stability, and overall product quality.

#### 2.6 Starch

Starch is a vital gelling agent that significantly enhances the texture and stability of the final product. Starch, composed of amylose and amylopectin, serves as a versatile gelling agent that can significantly enhance

the texture and stability of gummies. High-amylose starches, known for their capacity to form stronger gels, contribute to a firmer, chewy texture in gummy formulations due to retrogradation and firm structure formation (Pulgarín *et al.*, 2023). Notably, once gelation occurs, the starch gel does not remain static; it begins to retrograde during storage at room temperature, altering its texture over time (Tireki *et al.*, 2021). Retrogradation in starch can lead to the formation of a firmer, sometimes more crystalline texture, which can cause gummies to become less elastic and more brittle with prolonged storage. This change in texture may affect the consumer experience, especially if gummies become too firm or lose their desired chewiness over time. The water-binding capacity of starch enhances moisture retention, which is essential for achieving the desired chewiness in gummies (Tarahi *et al.*, 2023). For example, a study demonstrated that incorporating corn starch in varying ratios with gelatin resulted in gummies exhibiting increased adhesiveness and stringiness, which are favourable traits for consumer acceptance (Marfil *et al.*, 2012). Additionally, research has shown that acid-thinned starch can be effectively used in gummy formulations to improve texture and reduce stickiness (Habilla *et al.*, 2011). Overall, the choice of starch type and its concentration are pivotal in determining the sensory attributes and shelf stability of gummy candies, making it a versatile ingredient in confectionery applications.

### 3. The role of pH in herbal gummy candy production

The significance of pH in gummy candy production is paramount, as it directly influences the gelation process, texture, and stability of the final product. A carefully controlled pH level is essential for achieving optimal gel formation; for instance, pectin requires an acidic environment to activate its gelling properties effectively (Tarahi *et al.*, 2023). Moreover, the pH can affect the solubility and interaction of gelling agents with other ingredients, impacting the texture and sensory attributes of gummy candies. Maintaining an appropriate pH range ensures that the desired texture is achieved and enhances the shelf life and overall quality of the gummies by preventing microbial growth and degradation (Food Science Toolbox, 2024). Thus, understanding and controlling pH is crucial for manufacturers aiming to produce high-quality gummy candies that meet consumer expectations.

Based on Table 1, the analysis of pH levels across various herbal gummy formulations reveals a range from 3.02 to 7.0, with differences primarily influenced by the nature of the ingredients and the presence of added acids

Table 1. pH analysis of herbal gummy formulations.

Study	pH range	Reference
Functional gummies with antioxidants and stevia	3.5 - 6.5	Roudbari <i>et al.</i> (2024)
Anthocyanin co-pigmentation from Butterfly Pea	3.81±0.01	Wagiman <i>et al.</i> (2024)
Herbal medicated gummies for nicotine cessation	4 - 5	Khune <i>et al.</i> (2024)
Vegan gummies with turmeric and black pepper	3.5±0.24	Rawat <i>et al.</i> (2024)
Gummies containing ginger and vitamins	3.02	Vaibhav <i>et al.</i> (2023)
Antioxidant-rich onion gummies	5.53±0.01	Abinaya <i>et al.</i> (2023)
Gummy jelly candy from natural sources	5 - 7	Latif <i>et al.</i> (2022)

or extracts. Formulations such as those with natural antioxidants and stevia maintain a pH of 3.5 to 4.6, highlighting the role of extracts like pistachio green hull extract (PGHE) in stabilising the pH (Roudbari *et al.*, 2024). Incorporating anthocyanins from Butterfly Pea (*Clitoria ternatea*) in gummy formulations presents a pH-sensitive application. Anthocyanin extracts are known for their colour variability with pH changes: the extract turns red at pH values below 3.2, shifts to violet or blue between pH 3.2 and 5.2, and transitions to greenish tones at higher pH values (Sutakwa *et al.*, 2021). In the context of gummy production, a pH of 3.81 has been identified as ideal for stabilising anthocyanin co-pigmentation, offering a balance between vibrant colour retention and the protection of the anthocyanins' structural integrity (Wagiman *et al.*, 2024).

In contrast, gummies incorporating plant-based hydrocolloids, like turmeric and black pepper, have a slightly lower pH of 3.5±0.24 (Rawat *et al.*, 2024), while those containing ginger and vitamins reach a more acidic pH of 3.02 (Vaibhav *et al.*, 2023). However, formulations like antioxidant-rich onion-based gummies exhibit higher pH values (5.53), due to the presence of ascorbic acid, pantothenic acid, and sulfur compounds (Monte-Filho *et al.*, 2019; Abinaya *et al.*, 2023). These pH levels are advantageous for maintaining the antioxidant properties of the onion extract, providing a formulation that offers both nutritional benefits and a balanced flavour profile.

General observations suggest that a very low pH (<3.0) could negatively impact product stability (Romo-Zamarrón *et al.*, 2019). Therefore, considering the varying needs for texture, stability, and active ingredient preservation, the optimal pH range for herbal gummy formulations is between 3.5 and 5.5. This range provides a balance between acidity that aids in gelation and texture development, while not being so low as to compromise the stability of the gummy matrix. Ultimately, selecting the appropriate pH within this range depends on the specific functional ingredients being used and the desired attributes of the final gummy product.

#### 4. The importance of moisture content in herbal gummy candy production

Moisture content is a critical factor in producing gummy candies, as it significantly influences the texture, shelf-life, and overall quality of the product. The moisture content of gummies must be carefully controlled to ensure an ideal balance between softness and chewiness while preventing microbial growth. Higher moisture content can lead to a softer texture but may reduce the shelf-life due to the increased risk of microbial spoilage. In contrast, lower moisture levels can result in a firmer product with better preservation characteristics (Roudbari *et al.*, 2024). Additionally, the type of hydrocolloids used plays a role in determining the water-binding capacity and moisture retention properties of the gummies, which directly affects their texture and structural integrity (Kurbanova *et al.*, 2023). Therefore, optimising moisture content is essential for achieving the desired product attributes and ensuring the stability and quality of gummy candies throughout their shelf life.

The analysis of moisture content in herbal gummy formulations reveals the pivotal role that moisture plays in determining the texture, stability, and quality of gummy products. Based on Table 2, the analysis of moisture content in various studies of herbal gummy formulations indicates a broad range, from as low as 11.21% to as high as 60.0%. The moisture content can vary significantly depending on the formulation components, particularly the types and concentrations of extracts, sweeteners, and hydrocolloids used. For example, the study on functional gummy candies containing natural antioxidants and stevia found a moisture content range of 13% to 17.95%. Higher moisture content (17.95%) was observed in formulations with a greater concentration of extract, starch, and stevia, which contributes to the retention of moisture due to the hydrophilic nature of these ingredients (Roudbari *et al.*, 2024). Starch, rich in water-soluble hydroxyl groups, effectively binds water, leading to a softer and more elastic texture in the gummies (Pereira *et al.*, 2022).

In another study involving the co-pigmentation of anthocyanins from Butterfly Pea flower extract, the moisture content of 17.11% was determined to be ideal

Table 2. Moisture content analysis of herbal gummy formulations.

Study	Moisture content	Reference
Functional gummies with antioxidants and stevia	13 - 17.95%	Roudbari <i>et al.</i> (2024)
Anthocyanin co-pigmentation from Butterfly Pea	17.11±0.04	Wagiman <i>et al.</i> (2024)
Vegan gummies with turmeric and black pepper	11.21±0.46	Rawat <i>et al.</i> (2024)
Gummies containing ginger and vitamins	11.65%	Vaibhav <i>et al.</i> (2023)
Antioxidant-rich onion gummies	60.0±1.2	Abinaya <i>et al.</i> (2023)
Gummy jelly candy from natural sources	15 – 20%	Latif <i>et al.</i> (2022)

for balancing the anthocyanin stability with the desired gummy texture (Wagiman *et al.*, 2024). Next, higher moisture contents, such as those observed in antioxidant-rich gummies using surplus onion extracts, reach up to 60%, contributing to a softer and more jelly-like consistency but requiring careful handling for stability and shelf life (Abinaya *et al.*, 2023). Studies suggest that higher moisture content may enhance texture but can pose risks to shelf stability and microbial safety (Yan *et al.*, 2021).

Based on these findings, the optimal moisture content for herbal gummies lies between 13% and 20%, a range that supports key sensory properties like chewiness by maintaining an ideal balance of softness and firmness while safeguarding against spoilage risks. This range allows for flexibility in ingredient use while ensuring the structural integrity and quality of the final gummy product. Ultimately, the moisture content should align with the desired textural attributes and stability requirements of the final gummy product, taking into account the specific extracts and hydrocolloids used in the formulation. Furthermore, factors like moisture retention and pH interact with gelling agents to influence shelf life. For instance, gelatin and pectin are known to help retain product stability in warm or humid climates due to their excellent water-binding properties and ability to form stable gels at low pH levels (Jiamjariyatam, 2018; Said *et al.*, 2023). This is particularly relevant for consumer products that need to maintain quality under varying environmental conditions.

### 5. Impact of gelling agents on herbal gummy candy texture

The introduction of gelling agents in herbal gummy candies has significantly transformed their texture and appeal. Traditionally, gelatin was the primary gelling agent, providing a chewy and elastic consistency. However, with the rise of vegan and health-conscious consumers, alternative gelling agents such as pectin, agar, and various gums have gained prominence. These alternatives not only cater to dietary preferences but also influence the texture profile of the gummies. For instance, pectin can create a softer texture than gelatin, while agar offers a firmer bite (Tarahi *et al.*, 2023). The

selection and combination of these gelling agents require careful formulation to optimise overall product stability.

The studies in Table 3 illustrate the significant influence of various gelling agents and ingredient combinations on the textural properties of gummy candies, focusing on hardness, cohesiveness, springiness, chewiness, gumminess, and adhesiveness.

Hardness values exhibited considerable variation, with the highest measurement reaching 7507.48 g in anthocyanin co-pigmented gummies produced with a gelatin and agar combination (Wagiman *et al.*, 2024). Conversely, formulations incorporating 7% gelatin from Patin fish skin resulted in lower hardness levels of 0.62 k.gf (Handayani *et al.*, 2024). A consistent trend observed across multiple studies is that increasing gelatin concentrations typically enhances hardness; for instance, gummies containing 9% gelatin, 1% extract, and 0.013% stevia exhibited the highest hardness (Roudbari *et al.*, 2024). In addition, pectin-based jelly gums incorporating berries and aromatic plants demonstrated a moderate hardness of 25.6 N, suitable for chewable applications (Guiné *et al.*, 2020). In contrast, adding starch to gummy formulations has been shown to decrease hardness, likely due to its interaction with water and sugars, creating a softer texture. Research on jelly candy made with k-carrageenan and konjac at a 40:25 ratio found hardness values of 470.7 g, with significant variation depending on the formulation (Utomo *et al.*, 2014). For gummies without xanthan gum, the lowest recorded hardness was 41.28 N, whereas adding 4 g of xanthan gum increased hardness to 182.18 N. The more xanthan gum was added, the higher the hardness. The average hardness values across the studies ranged from approximately 0.62 k.gf to 7507.48 g, indicating the substantial impact of formulation on textural outcomes.

Cohesiveness, indicative of the internal structural resistance, was influenced by gelatin concentration and other ingredients. The highest cohesiveness recorded was 0.90±0.1 in gummies made with 8% gelatin and *Psidium guajava* leaf extract (Charoen *et al.*, 2015). Natural plant-based gummy formulations achieved cohesiveness values ranging from 0.739 to 0.925, with the highest value noted in gummies containing date fruit juice and chocolate (Latif *et al.*, 2022). The average cohesiveness across studies ranged from 0.739 to 0.90, indicating that

Table 3. Textural properties of herbal gummy candies influenced by gelling agents.

Study	Gelling agent	Textural properties		Reference
Functional gummies with antioxidants and stevia	Gelatin:Starch 9:1	Hardness	1967 - 3572 g	Roudbari <i>et al.</i> (2024)
		Cohesiveness	0.75 - 1.02	
		Springiness	2.0 - 3.4 mm	
Anthocyanin co-pigmentation from Butterfly Pea	Gelatin + Agar	Hardness	7507.48±178.97	Wagiman <i>et al.</i> (2024)
		Adhesiveness	-18.78±0.20	
		Springiness	0.99±0.01	
		Cohesiveness	0.87±0.01	
		Gumminess	5584.02±253.20	
Vegan gummies with turmeric and black pepper	1% Agar-agar + 5.5% Guar gum	Chewiness	4326.60±132.14	Rawat <i>et al.</i> (2024)
		Gumminess	4023.16±15.38	
		Springiness	1455.12±1.75 N	
Jelly Candy Characterization with Patin Fish Skin Gelatin	7% concentration Gelatin from Patin fish skin	Gumminess	2251.11±2.14 N	Handayani <i>et al.</i> (2024)
		Hardness	0.62±0.05	
		Chewiness	8.46±0.52	
Antioxidant-rich onion gummies	10 g Gelatin + 5 g Agar	Gumminess	3.13±0.25	Abinaya <i>et al.</i> (2023)
		Hardness	378.26±0.9	
		Chewiness	1390.9±56.7	
Antioxidant Gummy Candy with <i>Psidium guajava</i> extract	8 g Gelatin	Adhesiveness	59.8±1.44	Charoen <i>et al.</i> (2015)
		Springiness	40.73±0.4	
		Gumminess	1,273±340	
Gummy jelly candy from natural sources	Gelatin	Chewiness	1,226±341	Latif <i>et al.</i> (2022)
		Cohesiveness	0.90±0.1	
Jelly gums incorporating berries and aromatic plants	Pectin	Springiness	0.97±0.0	Guiné <i>et al.</i> (2020)
		Hardness	25.6 N	
		Adhesiveness	-0.5 N·s to -2.0 N·s	
Jelly candy made from a different ratio of κ-carrageenan and konjac	κ-carrageenan: konjac 40:25	Hardness	470.7 g	Utomo <i>et al.</i> (2014)

a careful balance of gelatin and natural extracts is crucial for maintaining structural integrity and enhancing the overall texture.

Springiness, which measures the ability of gummies to return to their original shape after deformation, showed considerable variation based on formulation. Gummies with higher gelatin-to-starch ratios exhibited springiness values of up to 3.4 mm (Roudbari *et al.*, 2024). However, increasing the concentration of herbal extracts, such as 5% *Psidium guajava* extract, decreased springiness, indicating that these extracts disrupt the gel matrix (Charoen *et al.*, 2015). The average springiness observed across the studies ranged from 0.62 mm to 3.4 mm, reflecting the influence of gelling agents.

Chewiness and gumminess also varied significantly according to the gelling agents used. The highest recorded gumminess score was 5584.02 N in anthocyanin co-pigmented gummies (Wagiman *et al.*,

2024), while gummies with 5.5% guar gum and 1% agar-agar exhibited a gumminess of 2251.11 N (Rawat *et al.*, 2024). Chewiness scores showed a similar trend; the onion-based gummies demonstrated a decline in chewiness from 1819.1 to 1390.9 as the concentration of onion extract increased (Abinaya *et al.*, 2023). For pectin-based jelly gums incorporating berries and aromatic plants, chewiness was recorded at 16.9 N, which is lower compared to other formulations (Guiné *et al.*, 2020). The gumminess of the same formulation was measured at 69.55 N, indicating that the addition of xanthan gum increases gumminess. The average chewiness across the studies ranged from 16.9 N to 1819.1 N, while the average gumminess ranged from 69.55 N to 5584.02 N.

Adhesiveness is a crucial quality attribute for consumer preference, with a lower adhesiveness desirable to minimise stickiness. The anthocyanin co-pigmented gummies achieved an adhesiveness of -18.78,

indicating effective formulation (Wagiman *et al.*, 2024). Meanwhile, the onion extract gummies exhibited slightly higher adhesiveness values ranging from 57.4 to 59.8, suggesting that while some stickiness may occur, it is within acceptable limits (Abinaya *et al.*, 2023). For pectin-based jelly gums incorporating berries and aromatic plants, adhesiveness was recorded between -0.5 N·s and -2.0 N·s, showing a wide range of formulation effectiveness in reducing stickiness (Guiné *et al.*, 2020). The average adhesiveness across formulations varied, but maintaining low values is essential for product acceptability.

In summary, the findings emphasise the importance of balancing gelatin concentration with the incorporation of other gelling agents or natural extracts to achieve desirable textural properties in gummy candies. Increased gelatin levels generally enhance attributes such as hardness, chewiness, and cohesiveness, while the inclusion of additional hydrocolloids or extracts often modifies these properties, potentially reducing hardness and influencing springiness and gumminess (Roudbari *et al.*, 2024; Rawat *et al.*, 2024; Handayani *et al.*, 2024). Strategic adjustments to these parameters allow manufacturers to customise gummy candy textures to align with consumer preferences and specific product requirements.

## 6. Impact of gelling agents on stability and shelf-life of gummy candy

The stability and shelf-life of gummy candies are significantly influenced by the properties of the gelling agents used, particularly under varying storage conditions. Gelatin, a widely used gelling agent, provides a desirable texture but is sensitive to moisture and temperature fluctuations. Its effectiveness in preserving gummies is closely tied to water activity (*aw*); maintaining *aw* below 0.85 is essential to inhibit microbial growth and extend shelf-life. Studies have shown that formulations with lower initial moisture content and effective drying methods, such as freeze-drying, can achieve optimal *aw* levels, thereby enhancing the stability of gelatin-based gummies (Ranalli *et al.*, 2020).

In contrast, pectin offers a plant-based alternative that requires an acidic environment to gel effectively. This agent's gelling properties are influenced by sugar concentration and pH, which can be tailored to create gummies with varying textures and flavours. Pectin's ability to form stable gels at lower temperatures also aids in preserving heat-sensitive ingredients, contributing to the overall shelf-life of the product (Tarahi *et al.*, 2023; Nutreebio, 2024). Other gelling agents like carrageenan,

xanthan gum, and guar gum present unique advantages as well. For instance, carrageenan forms strong gels that maintain their structure even under higher temperatures, while xanthan gum improves viscosity and mouthfeel without compromising stability. Guar gum enhances texture and colour, making it a valuable addition for aesthetic appeal in gummy formulations (Tarahi *et al.*, 2023).

Ultimately, selecting the appropriate gelling agent and optimising formulation parameters such as moisture content and storage conditions are crucial for maximising the preservation of gummies. By understanding how each gelling agent interacts with environmental factors, manufacturers can produce gummies that not only meet consumer preferences but also have enhanced stability and extended shelf-life.

## 7. Nutritional and functional benefits of gelling agents

Gelatin, a protein derived from collagen, offers numerous nutritional benefits, making it a valuable ingredient in various food products, including gummies. Gelatin is rich in essential amino acids, particularly glycine and proline, which are crucial for maintaining healthy skin, joints, and connective tissues. These amino acids support collagen synthesis, enhancing skin elasticity and reducing wrinkles, as well as improving joint health by strengthening cartilage and reducing pain. Additionally, gelatin's high protein content makes it a beneficial supplement for muscle repair and growth, contributing to overall physical health (Ambli *et al.*, 2023).

In the context of gummy production, gelatin's unique gelling properties are essential for creating the desired texture and consistency. Gelatin-based gummies not only provide a tasty treat but also offer health benefits. For instance, gelatin can aid in digestion by promoting the production of gastric juices and improving gut health (WebMD, 2023). Furthermore, gelatin contains no fat and minimal carbohydrates, making it a low-calorie option that can help with weight management (Verywell Health, 2024). Its ability to support bone health by enhancing calcium absorption and reducing the risk of osteoporosis is another significant advantage (WebMD, 2023). Thus, incorporating gelatin into gummies not only enhances their nutritional profile but also provides a functional benefit to consumers.

Pectin, a complex polysaccharide found in various fruits and vegetables, offers numerous nutritional benefits. Pectin is recognised for its ability to regulate post-prandial blood glucose levels and reduce total and low-density lipoprotein (LDL) cholesterol levels. This

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dietary fibre is not digested in the small intestine but is fermented in the large intestine, contributing to gut health by promoting the growth of beneficial bacteria. Additionally, pectin has been associated with improved glycemic response and appetite regulation, making it a valuable component in managing diabetes and obesity.

In the context of gummy production, pectin's gelling properties are particularly beneficial. It is often used as a gelling agent in gummy candies, providing a plant-based alternative to gelatin. This not only caters to vegetarian and vegan consumers but also enhances the nutritional profile of the gummies. Pectin-based gummies can deliver the health benefits of pectin, such as improved blood sugar control and cholesterol management, in a convenient and enjoyable form. Furthermore, pectin's ability to modulate the gut microbiome and its anti-inflammatory properties add to its appeal as a functional ingredient in health-focused confectionery products (Soomro *et al.*, 2024).

Carrageenan, a polysaccharide derived from red seaweed, is widely used in the food industry for its gelling, thickening, and stabilising properties. Recent studies have highlighted its potential health benefits, particularly in the context of gut health. According to Wagner *et al.* (2024), carrageenan may influence insulin resistance and gut inflammation. Their study found that carrageenan consumption could lead to lower insulin sensitivity and increased markers of inflammation in overweight individuals, suggesting a complex interaction with metabolic health. Despite these findings, carrageenan's role in promoting gut health through its prebiotic effects, which support the growth of beneficial gut bacteria, remains a significant area of interest (Wagner *et al.*, 2024).

In gummy production, carrageenan serves as an excellent alternative to gelatin, providing a plant-based option that appeals to vegetarians and vegans. Its ability to form strong gels at room temperature makes it ideal for creating stable, chewy textures in gummies. Additionally, carrageenan's potential to modulate gut microbiota and its anti-inflammatory properties can enhance the nutritional profile of gummy products, making them not only enjoyable but also beneficial for digestive health (Borsani *et al.*, 2021). This dual functionality of carrageenan in both food texture and health benefits underscores its value in the food industry.

Guar gum, a soluble fibre derived from the seeds of the *Cyamopsis tetragonoloba* plant, offers several nutritional benefits, particularly in the context of lipid metabolism and digestive health. A systematic review and meta-analysis by Setayesh *et al.* (2022) found that guar gum supplementation significantly reduces total

cholesterol (TC) and low-density lipoprotein (LDL) levels in adults, which can help lower the risk of cardiovascular diseases. The study highlighted that while guar gum effectively lowers TC and LDL, it does not significantly impact triglycerides (TAG) and high-density lipoprotein (HDL) levels (Setayesh *et al.*, 2022). Additionally, guar gum's high viscosity can slow down the absorption of carbohydrates, leading to improved glycemic control, which is beneficial for individuals with diabetes (Barber *et al.*, 2023).

In gummy production, guar gum is valued for its thickening and stabilising properties, making it an excellent alternative to gelatin for creating plant-based gummies. These gummies not only cater to vegetarian and vegan consumers but also incorporate the health benefits of guar gum. The prebiotic effects of guar gum, which promote the growth of beneficial gut bacteria, can enhance digestive health and overall well-being. Furthermore, its ability to modulate gut microbiota and improve cholesterol metabolism makes guar gum a functional ingredient in health-focused confectionery products (Barber *et al.*, 2023). This dual role in both food texture and nutritional enhancement underscores the versatility and health benefits of guar gum in the food industry.

Xanthan gum, a polysaccharide produced by the bacterium *Xanthomonas campestris*, is widely recognised for its thickening and stabilising properties in the food industry. Recent studies have highlighted its potential health benefits, particularly in the context of gut health. According to a study by Alsaleem and Hamouda (2024), xanthan gum can enhance the microbiological quality and functionality of low-fat probiotic yoghurt by increasing the counts of beneficial bacteria such as *Streptococcus thermophilus*, *Lactobacillus bulgaricus*, and *Bifidobacterium bifidum*. This suggests that xanthan gum may act as a prebiotic, promoting the growth of beneficial gut microbiota. Additionally, xanthan gum has been shown to improve the texture and water-holding capacity of food products, which can contribute to better digestive health by increasing stool bulk and reducing constipation (Alsaleem and Hamouda, 2024).

In gummy production, xanthan gum is an excellent alternative to gelatin, providing a plant-based option that appeals to vegetarians and vegans. Its ability to form stable gels at various pH levels and temperatures makes it ideal for creating chewy textures in gummies. Moreover, xanthan gum's potential to lower cholesterol levels and improve blood sugar control adds to its appeal as a functional ingredient in health-focused confectionery products (Forbes Health, 2024). The

incorporation of xanthan gum in gummies not only enhances their texture but also delivers nutritional benefits, making them a convenient and enjoyable way to support digestive health and overall well-being.

Starch, a primary carbohydrate source in the human diet, offers numerous nutritional benefits, particularly in terms of energy provision and digestive health. According to Han *et al.* (2023), resistant starch (RS), a type of starch that resists digestion in the small intestine, plays a crucial role in maintaining glucose homeostasis, lipid metabolism, and gut health. RS ferments in the large intestine, producing short-chain fatty acids that nourish beneficial gut bacteria, thereby enhancing gut microbiota composition and function. This fermentation process also contributes to improved insulin sensitivity and reduced systemic inflammation, which are beneficial for managing metabolic disorders such as diabetes and obesity (Han *et al.*, 2023).

In the context of gummy production, starch, particularly modified starches like RS, is highly valued for its functional properties. It can be used to create gummies with desirable textures and stability, while also delivering health benefits. For instance, incorporating RS into gummy formulations can enhance their nutritional profile by promoting satiety, supporting digestive health, and aiding in blood sugar control (National Geographic Science, 2024). This makes starch-based gummies not only a tasty treat but also a functional food that supports overall well-being.

## 8. Limitations of gelling agents in gummy production

Gelatin, derived from animal collagen, is widely used in gummy production due to its excellent gelling properties and ability to form clear, elastic gels. However, its animal origin raises issues for vegetarians, vegans, and certain religious groups, and its gelling properties can be affected by temperature and pH, making it less stable in varying conditions (Park *et al.*, 2021; Avallone *et al.*, 2022). In contrast, pectin, a plant-based polysaccharide, is ideal for fruit-based gummies but requires precise conditions to gel properly, including specific pH and sugar concentrations, which can limit its versatility. Furthermore, pectin may not provide the same texture as gelatin, with its availability affected by the seasonal nature of fruit crops (Gawkowska *et al.*, 2018; Said *et al.*, 2023). Similarly, carrageenan, extracted from red seaweed, is known for its strong gelling properties but has been associated with gastrointestinal issues in some consumers, leading to controversy and regulatory scrutiny. Moreover, its gelling properties can be influenced by the presence of

certain ions, requiring careful formulation (Park *et al.*, 2021).

On the other hand, guar gum, derived from guar beans, is a cost-effective thickening agent with good water-binding properties. However, it can produce highly viscous solutions that may be difficult to handle in gummy production. Additionally, guar gum can be less clear than other gelling agents, affecting the appearance of the final product, and its stability can be compromised in acidic conditions, potentially leading to inconsistent textures (Kant *et al.*, 2018; Sujatha *et al.*, 2020). Conversely, xanthan gum, produced by bacterial fermentation, is highly effective at low concentrations and stable across a wide range of temperatures and pH levels. Nevertheless, it can be susceptible to microbial contamination, requiring careful handling and storage, and can produce a slimy texture if used in excess, which may not be desirable in gummy products (Patel *et al.*, 2020). Finally, starch is a versatile and widely available gelling agent used in many food products. However, native starches can have low thermal and shear resistance, leading to breakdown during processing. Although modified starches can address some of these issues, they may introduce concerns about chemical additives and consumer acceptance. Moreover, starch-based gels can exhibit syneresis (water release) over time, affecting the texture and shelf life of gummies (Chakraborty *et al.*, 2022; Li *et al.*, 2023).

In summary, these limitations highlight the importance of selecting the appropriate gelling agent based on the specific requirements of the gummy product, including desired texture, stability, and consumer preferences.

## 9. Conclusion

In conclusion, selecting gelling agents is vital for the texture, stability, and consumer acceptance of herbal gummy candies. Different gelling agents offer unique functionalities that enable tailored product development; for instance, pectin is ideal for creating softer textures, while carrageenan is preferred for achieving firmer gels that maintain their structure under various conditions. Traditional gelling agents like gelatin have been complemented by plant-based alternatives such as pectin, carrageenan, guar gum, xanthan gum, and starch to meet the diverse dietary preferences of consumers. Precise control over pH and moisture levels is critical for achieving desired gel strength and prolonging shelf stability, ensuring that products retain their texture and appeal over time. As the demand for healthier and more natural candy options continues to rise, ongoing research into optimising gelling agents and formulation strategies

will be essential for developing appealing and nutritionally beneficial herbal gummy candies. By focusing on texture, stability, and consumer satisfaction, manufacturers can innovate in this dynamic sector of the confectionery market, ensuring that herbal gummy candies remain a popular choice for consumers of all ages.

### Conflict of interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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