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The Effect of Adding Alginate and Konjac Hydrocolloid Gels as Fat Replacements on the Physicochemical Properties of Low-Fat Burgers

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ABSTRACT: In recent years, there has been a significant rise in the demand for low-fat meat products, which can be attributed to a growing awareness of health and nutritional issues among consumers. Burgers, recognized as one of the most widely consumed meat products, require enhancements in quality alongside the preservation of their sensory attributes, all while striving to reduce fat content. In this context, the incorporation of hydrocolloids, such as alginate and konjac, as fat substitutes in the formulation of low-fat burgers has been explored. The current study examines the impact of alginate and konjac hydrocolloids as fat replacers in the formulation of low-fat burgers. The primary aim of this study was to assess the physicochemical, sensory, and final quality attributes of burgers incorporating varying concentrations of the aforementioned gums. The findings indicated that there was no statistically significant difference in protein content, as well as in sensory evaluations of odor, color, and overall acceptability, between the samples on days 0 and 5 ($p \geq 0.05$). However, by day 10, the sample devoid of both alginate and konjac (Sample 1) exhibited the lowest scores across all assessed criteria. The findings demonstrate a significant decline in sensory scores, encompassing attributes such as odor, color, and texture, over the observed time period. The samples containing alginate and konjac demonstrated superior moisture retention capabilities, thereby mitigating the risk of quality degradation. The sample devoid of hydrocolloids exhibited the highest cooking loss rate, thereby highlighting the beneficial influence of hydrocolloids on moisture retention and the overall quality of burgers. The formulation comprising 0. 5% alginate and 0. 5% konjac was identified as the optimal sample, attributable to its elevated sensory evaluation scores, superior moisture retention properties, and reduced cooking loss. The findings of this study underscore the significance of incorporating hydrocolloids in the formulation of low-fat burgers, demonstrating that these additives can enhance both sensory attributes and physicochemical characteristics.

Keywords: Alginate, Burger, Hydrocolloids, Konjac, Low-Fat.

Introduction

In contemporary society, the challenges associated with industrialized communities, coupled with a growing inclination towards the consumption of convenience foods, have led to a notable increase in the intake of meat products, including burgers, sausages, and hot dogs. Data from 2024 indicate that over 40% of consumers worldwide are actively

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pursuing food options that are low in fat and low in calories. This phenomenon is especially pronounced within the meat industry. The reduction of fat content in meat products presents considerable challenges, as fat is a fundamental component that significantly influences the physicochemical and sensory characteristics of food. These characteristics encompass texture, juiciness, flavor, and overall acceptability. Consequently, it is imperative to identify effective alternatives to fats that can replicate their functional properties while preserving or enhancing the quality of low-fat meat products. This consideration is particularly significant in light of the established correlation between high-fat diets and various health issues, including obesity and cardiovascular disease, both of which are among the leading causes of mortality globally (World Health Organization, 2021). The process of removing fat from meat products frequently results in unfavorable alterations to their physicochemical properties. These modifications may manifest as increased hardness, decreased juiciness, and variations in flavor profiles, all of which can contribute to a decline in consumer acceptance of the modified product consequently, it is imperative to identify effective alternatives to fat that can preserve its functional properties in order to ensure the success of low-fat formulations (Lu *et al*., 2021). The burger is a type of meat product composed of ground beef, and it retains the same nomenclature across nearly all countries (Lu *et al*., 2021). In accordance with Iranian National Standard No. 2304, the industrial burger sector within the country is categorized into three distinct classifications: regular burgers, which contain 30% meat; premium burgers, characterized by their composition of 60% meat; and a third category comprising burgers that contain more than 60% meat. Fat, being a predominant constituent of meat and meat products, is often perceived as an undesirable element among a significant proportion of consumers (Domínguez *et al*., 2024). Recent research has increasingly established a correlation between dietary fat consumption and the prevalence of various health conditions, including obesity and certain forms of cancer. Consequently, the reduction of fat intake emerges as a fundamental approach for mitigating associated health risks (Choe *et al*., 2013). Moreover, the reduction of fat content in meat products may lead to the development of textures that are perceived as tough and rubbery, accompanied by a darker coloration and increased production costs (Zaki, 2018). Currently, the application of hydrocolloids as substitutes for fats in the manufacturing of low-fat foods has attracted significant scholarly interest (Murtaza *et al*., 2024).

Hydrocolloids, including alginate and konjac, possess distinctive characteristics that can efficiently preserve the sensory and physicochemical qualities of meat products. Alginates are linear heteropolysaccharides composed of β-D-mannuronic acid and L-glucuronic acid. Their unique functional properties, which include enhanced viscosity, gelation capabilities, and stability in aqueous solutions, render them valuable in both the food and pharmaceutical industries (Kim *et al*., 2018). These compounds exhibit a high solubility in both hot and cold water, and they form a gel at ambient temperatures in the presence of calcium ions. Konjac, derived from the plant Amorphophallus konjac, is classified as a non-cellulosic polysaccharide characterized by its gelling and stabilizing properties (Sun *et al*., 2023). Research has demonstrated that konjac possesses the potential to reduce blood cholesterol levels and enhance carbohydrate metabolism. Furthermore, this gum enhances the rate of gelatinization in association with elevated temperature and concentration levels. It also exhibits synergistic interactions with other hydrocolloids, including xanthan gum. These attributes render alginate and konjac advantageous alternatives for the fat replacement in low-fat meat products. In recent years, a substantial body of research has been dedicated to the exploration of various fat replacers utilized in low-fat meat products. A recent study demonstrated that the incorporation of guar and xanthan gums significantly enhanced cooking efficiency and resulted in a reduction in the diameter of meatballs. Conversely, the addition of gum Arabic was found to increase the brightness and yellowness of the final product (Kilincceker & Yilmaz, 2016). Furthermore, an additional investigation was conducted to examine the impact of guar gum on the physicochemical properties of low-fat meat emulsions. The findings indicated that the incorporation of this gum enhanced emulsion stability and mitigated the loss of moisture and fat (Rather et al., 2017). Furthermore, another study examined the impact of hydrocolloids such as alginate, konjac, and carrageenan on the quality of duck burgers. The findings indicated that these compounds contributed to an increase in moisture content and a reduction in cooking loss. Overall, the findings from these studies suggest that the incorporation of gums and hydrocolloids can enhance the physicochemical and sensory characteristics of low-fat meat products. However, additional research is necessary to optimize the formulations and to explore the effects of various compounds on the final quality of these products. In light of the aforementioned factors, the objective of this study was to optimize the influence of incorporating alginate and konjac hydrocolloid gels on the physicochemical properties of low-fat burgers (Kim et al., 2018).

Materials and Methods

- ***Materials***

The compilation of raw materials and chemicals utilized in this study is presented in Table 1.

Table 1. List of raw materials and chemicals

Material	Chemical Manufacturer/Supplier	Country
Beef tripe	Local Market	Tehran
Soy protein	Local Market	Tehran
Wheat flour	Local Market	Tehran
Gluten	Local Market	Tehran
Sunflower oil	Local Market	Tehran
Spices	Local Market	Tehran
Konjac gum (E425)	Konjac Foods	China
Alginate	Kimica alginate	Japan
Concentrated Sulfuric Acid	Merck	Germany
NaOH 50%	Sigma Aldrich	USA
Boric Acid	Fluka	Switzerland
Sulfuric Acid	Merck	Germany
Etherdopetrol (Solvent)	Carlo Erba	Italy
Buffer solution pH 4.0	Merck	Germany
Buffer solution pH 10.0	Merck	Germany

- ***Samples preparation***

Beef tripe, which comprises 20% fat content, was utilized as the source of fat for the formulation. The additives utilized for the preparation of the burger were incorporated in accordance with the specifications outlined in Tables 2 and 3. Subsequently, the composite mixture was formed into patties with a diameter of 12 cm and subsequently stored at a temperature of 4°C for a duration of 9 days. Testing and analysis were conducted at intervals of day 0, day 5, and day 10 (Soltanizadeh & Ghiasi-Esfahani, 2014).

- ***pH Measurement***

The pH of the specimen was determined using a pH meter subsequent to the preparation of a suspension, which was achieved by combining 15 grams of the burger sample with 150 milliliters of deionized water and allowing the mixture to homogenize for a duration of 2 minutes. It is important to acknowledge that prior to utilization, the pH meter underwent calibration with buffer solutions having pH values of 4.0 and 10.0 (Rahman *et al.*, 2023).

- ***Moisture content***

The moisture content of the cooked burgers was quantified using the method outlined by the AOAC (2005). In this procedure, a mass of 3 grams of the sample was placed in a container and subsequently measured using a precision balance. Subsequently, the container containing the sample was subjected to heating in an oven at a temperature of 100 degrees Celsius until a consistent weight differential was attained. The weight obtained was interpreted as the quantity of moisture that the sample had relinquished. The moisture content of the sample was calculated using Formula 1 and is expressed as grams of moisture per 100 grams of the sample (Gholami et al., 2017).

$$\%Moisture\ Content = \frac{Initial\ sample\ weight(g) - Heated\ sample\ weight(g)}{Initial\ sample\ weight\ (g)} \times 100 \quad (1)$$

- ***Protein content***

The protein content of the samples was determined utilizing the Kjeldahl method, in accordance with the standards established by the AOAC (2005) (Al-Mentafji, 2016). Initially, the samples were subjected to drying at a temperature of 130°C for a duration of one hour, followed by a cooling period. Following precise weighing, the samples were subjected to digestion with concentrated sulfuric acid in the presence of a catalyst until a green solution was obtained. Distillation was conducted through the

Table 2. Formulation of the control sample

Ingredient	Beef tripe	Soy protein	Grated onion	Wheat flour	Gluten	Salt	Red pepper	Oil	Water
Percent %	30	12	12	4	1	1.1	1.1	8	30.8

Table 3. Research Treatments

Treatment	**Formulation**
Sample 1 (control)	without alginate and konjac
Sample (2)	0.5% alginate + 0.5% konjac
Sample (3)	1% alginate
Sample (4)	1% konjac

addition of a 50% sodium hydroxide solution, whereby the liberated nitrogen gas was subsequently captured in boric acid. The resultant solution was subsequently diluted with 0. 1 N sulfuric acid, following which the protein concentration was determined utilizing Equation 2. In this equation, the variable (A) denotes the volume in milliliters of sulfuric acid used for titration of sample, whereas the variable (B) represents the volume in milliliters of sulfuric acid utilized for the blank sample (Mohsen Milani Alireza Rahman, 2022).

$$\text{Protein content} = \frac{(A-B) \times 100 \times 0.1 \times 14 \times 6.25}{1000} \quad (2)$$

- ***Total fat***

The quantification of total fat was conducted employing the Soxhlet extraction method in accordance with the protocol established by the Association of Official Analytical Chemists (AOAC, 2005) (Al-Mentafji, 2016). Initially, a precise mass of 5 grams of the sample was obtained and subsequently enveloped in filter paper. Subsequently, the sample was positioned within a Soxhlet apparatus. The flask of the apparatus, which had been weighed prior to the experiment, was subsequently filled to two-thirds of its total volume with ether dipropanol solvent. The apparatus was subjected to thermal treatment for a duration of 8 to 16 hours at a controlled temperature ranging from 50 to 60 °C to facilitate the complete extraction of fat from the sample. Upon completion of the process, the solvent was removed through evaporation, and the flask was subsequently dried in an oven at a temperature of 103 °C until a constant weight was achieved. The percentage of fat was determined by utilizing Equation 3, wherein F represents the weight of the extracted fat, and P denotes the initial weight of the sample (Tababaian, Ateye; Najafi, Ali; Nouri, 2022).

$$Fat\,\% = \frac{F}{P} \times 100 \quad (3)$$

- ***Ash content***

The ash content of the samples was quantified through incineration, following the methodology established by the Association of Official Analytical Chemists (AOAC, 2005) (Al-Mentafji, 2016). Initially, the empty crucible was subjected to heating at a temperature of 550°C within an electric furnace, following which it was allowed to cool in a desiccator. An approximate mass of 2 to 3 grams of the sample was carefully introduced into the crucible and subjected to controlled combustion over a flame within a fume hood. This process persisted until the complete dissipation of the smoke was observed. The sample container was subjected to thermal treatment in an electric furnace at a temperature of 550°C until the formation of light ash was observed. Subsequently, the container was allowed to cool in a desiccator before being weighed. The ash percentage was calculated using the equation provided below: (Roodbar & Rahman, 2018).

$$\text{Ash}\,\% = \frac{weight\ of\ crucible - (weight\ of\ crucible + ash)}{weight\ of\ sample\ (g)} \times 100 \quad (4)$$

- ***Color evaluation***

The surface coloration of the burger samples was quantitatively assessed at three distinct locations on each sample using a Konica Minolta colorimeter, which features a measurement aperture of 8 mm in diameter. The colorimetric data were represented in accordance with the CIE system, utilizing the parameters L* (lightness), a* (redness), and b* (yellowness). The L* value represents lightness on a scale where 0 corresponds to darkness and 100 signifies lightness. The a* value quantifies redness, with values exceeding 60 indicating a red hue, while values below 60 indicate a green hue. Conversely, the b* value reflects yellowness, with values above 60 denoting yellow and values below 60 denoting blue. A bloom time of 30 minutes was established as a parameter for the study. The overall color change (ΔE) was determined using Equation 5: (Varmazyar,Elham; Rahman, Alireza; Hosseinmard, 2024)

$$\Delta E^{*} = [(\Delta L^{*})^{2} + (\Delta a^{*})^{2} + (\Delta b^{*})^{2}]^{1/2} \quad (5)$$

- ***Cooking characteristics***

Prior to analysis, the burger samples were thawed in a domestic refrigerator maintained at a temperature of 4°C for a duration of 12 hours. Subsequently, three burger samples from each formulation were subjected to cooking on a hot plate maintained at a temperature of 150°C until the internal temperature at the geometric center of each burger reached 75°C. In order to mitigate the formation of an additional surface crust layer, each burger was rotated at two-minute intervals. Subsequent to the cooking process, the specimens were allowed to cool for a duration of approximately one hour at a temperature of 21°C prior to obtaining their weight. The weight, thickness, and diameter of each of the three burgers from each batch were measured at room temperature both prior to and subsequent to the cooking process, utilizing a Vogelsang balance for precision. The subsequent relationships were employed equations 6 and 7 to assess the dimensional alterations, specifically the reduction in diameter and thickness, as well as the moisture and fat retention levels in the burger samples (Olivas-Méndez *et al.*, 2022).

$$\text{Cooking loss (\%)} = \frac{raw\ uncooked\ burger\ weight - cooked\ burger\ weight}{raw\ uncooked\ burger\ weight} \times 100 \quad (6)$$

$$\text{Diameter reduction (\%)} = \frac{raw\ uncooked\ burger\ diameter - cooked\ burger\ diameter}{raw\ uncooked\ burger\ diameter} \times 100 \quad (7)$$

- ***Water holding capacity***

A sample of the burger, weighing 5 grams, was encased in filter paper, specifically of the Whatman No. 4. The sample was subsequently inserted into a centrifuge tube. The sample was subjected to centrifugation at a relative centrifugal force of 252 × g for a duration of 10 minutes. The volume of water released was determined by calculating the difference in the weight of the sample prior to and subsequent to centrifugation, with the result expressed as a percentage. The moisture content of the burger sample was quantified in accordance with the methodology established by the AOAC (2005) (Al-Mentafji, 2016). The water-holding capacity was quantified using equation 8 (Lee & Hong, 2020).

$$\text{Water holding capacity (\%)} = \frac{Burger\ sample\ moisture\ content - free\ water\ content)}{Burger\ sample\ moisture\ content} \times 100 \quad (8)$$

- ***Sensory evaluation***

The sensory evaluation was conducted utilizing the 5-point hedonic scale. The prepared samples were randomly assigned codes and subsequently presented to a trained evaluation group consisting of eight evaluators, accompanied by a sensory evaluation form. The judges were presented with four individually numbered, sliced samples for evaluation. A glass of water was positioned adjacent to the samples to facilitate oral rinsing between each assessment, thereby ensuring accurate and optimal evaluation. The evaluators who received training were instructed to assign ranks to the treatments on a scale from 0 to 5, evaluating the overall quality of each sample. A rank of 5 was designated for the highest quality sample, while a rank of 0 was assigned to the lowest quality sample. The ranking system utilized the following scale: 0 signified "unusable," 1 represented "unacceptable," 2 indicated "fairly acceptable," 3 denoted "acceptable," 4 corresponded to "satisfactory," and 5 was characterized as "excellent. " (Pematilleke *et al.*, 2021).

- ***Statistical analysis***

The results derived from the experimental data are presented as the mean ± standard deviation of the measurements, with each measurement being based on three independent replicates. The experimental data were subjected to one-way analysis of variance (ANOVA) for comparative analysis. Statistically significant differences among the mean values, contingent upon the overall significance of treatment effects, were assessed utilizing Duncan's multiple range post hoc test. Statistical analyses of the obtained results were conducted utilizing SPSS software, version 26. A significance level of $p \leq 0.05$ was adopted for all comparisons of data. Figures were generated utilizing Excel 2013 software.

Results and Discussion

- ***Protein***

The findings from the protein assessment of the burger samples, as detailed in Table 4, indicated that the incorporation of varying concentrations of gums did not yield any statistically significant differences in protein content among the samples ($p \geq 0.05$). This lack of significant variation may be attributed to the minimal proportions of gums employed in the formulation. According to the Iranian national standard No.2304 pertaining to the chemical characteristics of frozen raw burgers, the protein content must be a minimum of 14%. Furthermore, for burgers containing 60% red meat, the protein content is required to be at least 11. 5%. In the current investigation, the protein content of burger samples comprising 60% meat was observed to range from 12.01% to 12.36% Consequently, the protein content of all samples assessed fell within the parameters established by the Iranian national standard. In a specific investigation, the incorporation of safflower seed gum into low-fat burger formulations demonstrated a notable enhancement in both water and fat retention capacities; however, this modification did not produce any significant alterations in the protein content. The findings of the current study align with previous research, indicating that hydrocolloids exert a more significant influence on texture and moisture properties than on protein content (Varmazyar, Elham; Rahman, Alireza; Hosseinmard, 2024). A further study demonstrated that the incorporation of xanthan gum into low-fat burger patties effectively decreased moisture loss and enhanced the textural properties, while not significantly altering the protein content. The findings of this study align with those of previous research, indicating that while additives may influence sensory quality, they do not necessarily impact the protein content (Gómez et al., 2020).

- ***Ash***

The findings of the current study (Table 4) indicate that the samples exhibiting the lowest ash content were sample 1 (void of alginate and konjac) and sample 2 (comprising 0. 5% alginate and 0. 5% konjac) ($p \leq 0.05$) This observation may be attributable to the presence of ash within the gum constituents. According to the Iranian national standard No.2304 pertaining to the chemical properties of frozen raw burgers, the permissible ash content is stipulated to not exceed 2. 5% In the current study, the ash content of all samples was assessed in accordance with the guidelines established by the Iranian national standard. The ash content is influenced by the constituent components of the burger, which include meat, oil, gums, water, and spices. The observed elevation in ash content within low-fat treatments that incorporated gum, in comparison to control treatments, can be attributed to the intrinsic ash content of the gum, which ranges from 5% to 7%.

Another investigation revealed that duck burgers reconstituted with alginate, konjac, and carrageenan hydrocolloids exhibited a higher ash content compared to the control sample (Kim *et al*., 2018).

- ***Fat***

The results of the fat evaluation conducted on the burger samples, as presented in Table 4, indicated that the sample exhibiting the highest fat content was sample 1, which did not include alginate or konjac ($p \leq 0.05$) This observation can be attributed to the incorporation of gums as a fat substitute within the formulation of the burger samples. Conversely, in accordance with the Iranian national standard No. 2304 pertaining to the chemical characteristics of frozen raw burgers, the fat content in burgers containing 60% red meat should not exceed 17%. In the current investigation, the fat content of the burger samples was found to range between 11.12% and 12.03% Consequently, the fat content of all samples fell within the parameters established by the Iranian national standard. A supplementary investigation indicated that the incorporation of alginate gum in conjunction with other ingredients in meat products can significantly augment their nutritional value, improve oil retention, and enhance product stability *(Vasile et al.*, 2019).

- ***pH***

The results of the pH assessment conducted on the burger samples, as delineated in Table 5, demonstrate that there were no statistically significant differences in pH levels among the samples on day 0 ($p \geq 0$). This observation indicates that all samples demonstrated comparable pH levels at the commencement of the experiment, suggesting that no particular treatment exhibited a significant advantage at this initial phase. On days 5 and 10, sample 1, which was devoid of both alginate and konjac, demonstrated the highest pH values. Throughout the duration of the study, a significant elevation in the pH levels of the samples was observed. This observed increase may be ascribed to the chemical alterations in the composition of burgers that transpire over time. These changes result from the interactions among the raw materials, as well as the impacts of microbial and enzymatic activities. The pH value serves as a pivotal parameter affecting the emulsion stability of meat products, including burgers. Any modification in the pH of the product negatively influences its functional properties, particularly its ability to retain water (Varmazyar, Elham; Rahman, Alireza; Hosseinmard, 2024).

Table 4. Comparison of protein, fat, and ash content in burger samples containing alginate and konjac hydrocolloid gels as fat substitutes

	Fat (%)	Ash (%)	Protein (%)
Code (1)	12.30±0.17 ^{a}	30.10±0.1 ^{bA}	12.01±0.2 ^{aA}
Code (2)	10.96±0.33 ^{b}	30.07±0.1 ^{bA}	12.30±0.1 ^{aA}
Code (3)	11.23±0.30 ^{b}	52.06±0.1 ^{aA}	12.36±0.2 ^{aA}
Code (4)	11.12±0.33 ^{b}	41.01±0.1 ^{abA}	12.36±0.2 ^{aA}

Different lowercase letters indicate significant differences in the column ($p < 0.05$). Sample (1): No alginate and konjac (control); Sample (2): 0.5% alginate + 0.5% konjac; Sample (3): 1% alginate; Sample (4): 1% konjac.

Table 5. pH changes of burger samples containing alginate and konjac hydrocolloid gels as fat substitutes over time

	Days		
	0	5	10
Code (1)	6.68±0.02 ^{aA}	6.68±0.02 ^{aA}	6.77±0.02 ^{aA}
Code (2)	6.39±0.01 ^{aA}	6.46±0.00 ^{bA}	6.54±0.00 ^{cA}
Code (3)	6.38±0.00 ^{aA}	6.47±0.01 ^{bA}	6.58±0.00 ^{bA}
Code (4)	6.40±0.01 ^{aA}	6.45±0.00 ^{bA}	6.53±0.01 ^{cA}

Different lowercase letters indicate significant differences in the column and different uppercase letters indicate significant differences in the row ($p<0.05$).Sample (1): no alginate and konjac (control), sample (2): 0.5% alginate + 0.5% konjac, sample (3): 1% alginate, sample (4): 1% konjac

- ***Moisture content***

The findings of the current study, as presented in Table 6, indicate that on day 0, the highest moisture content was observed in Sample 1, which did not contain alginate or konjac. This suggests that the burger devoid of these moisture-retaining agents exhibited a greater moisture level at the initiation of the experiment, potentially attributable to the lack of moisture-retaining constituents. On days 5 and 10, the sample exhibiting the lowest moisture content was identified as sample 1, which lacked the addition of alginate and konjac. This observation suggests that, over time, the burger devoid of additives experienced a greater degree of moisture loss. This phenomenon may be attributed to the control sample's reduced capacity for moisture retention when compared to the samples that contain alginate and konjac. This observation can be substantiated by the significantly higher moisture-retaining capacity exhibited by the samples containing gum in comparison to the control sample devoid of gum. Consequently, the incorporation of gums exerted a noteworthy influence on the retention of moisture content within the burgers. However, it was observed that, over time, the moisture content of the samples exhibited a significant decline. This decline may be attributed to storage conditions that induce moisture loss in the burgers. Furthermore, the inclusion of additives such as alginate and konjac has been shown to contribute to moisture retention and mitigate deterioration in quality. Alginate is recognized for its properties as a humectant, which contributes to the preservation of moisture and, consequently, the juiciness of the burger. The incorporation of this substance has the potential to diminish moisture loss over an extended period. Analogous to alginate, konjac exhibits significant water holding properties, which contribute to the enhancement of texture and the minimization of cooking loss. In general terms, it can be concluded that gums play a significant role in moisture retention and in mitigating quality degradation. Research indicates that the incorporation of safflower seed gum into low-fat burgers can substantially enhance the water and oil retention characteristics of the product. The gum exhibits a water holding capacity of 574% and an oil retention capacity of 986%, thereby contributing to moisture retention and minimizing cooking loss (Poursaeid, M., Shahiri restani Haba, H., Aghajanzadeh Suraki, 2021). A study indicated that the incorporation of kappa carrageenan gum into sausage formulations significantly influenced both the physicochemical and textural properties of the product. An increase in the concentration of carrageenan gum resulted in a corresponding enhancement of both moisture content and water holding capacity (Rather & Masoodi, 2024). In a parallel investigation, the incorporation of xanthan and carrageenan gums was found to enhance the moisture retention capacity of low-fat sausages (Poursaeid, M., Shahiri restani Haba, H., Aghajanzadeh Suraki, 2021). Researchers have documented that the incorporation of konjac gel, transglutaminase, and alginate significantly enhanced the quality of reduced-salt meat emulsions. This improvement is evidenced by increased moisture content and greater emulsion stability (Lee & Hong, 2020). Alginate is recognized for its properties as a humectant, which contributes to the moisture retention in burgers. The incorporation of this element has the potential to diminish moisture loss over time (D. Lin *et al*., 2020). Research indicates that lean ground beef incorporated with combinations of alginate and carrageenan exhibits a significantly higher moisture content than samples containing either alginate or carrageenan alone, as well as the control sample (Lee & Hong, 2020). A separate investigation revealed that duck burgers reconstituted using alginate, konjac, and carrageenan hydrocolloids exhibited a greater moisture content in comparison to the control sample (Kim *et al*., 2018).

- ***Cooking loss***

The results presented in Table 7 regarding the cooking loss of the burger samples indicate that sample 1, which lacked alginate and konjac, exhibited the highest cooking loss. This finding suggests that the absence of alginate and konjac in the formulation renders the burger more susceptible to moisture loss and a decline in quality during the cooking process. This phenomenon may be attributed to the lack of moisture-retaining materials, which are essential for preserving the integrity of the product. The sample exhibiting the lowest cooking loss was identified as sample 2, which incorporated a combination of 0. 5% alginate and 0. 5% This finding suggests that the synergistic effect of alginate and konjac functions to effectively retain moisture, thereby mitigating the degradation of product

Table 6. Moisture changes of burger samples containing alginate and konjac hydrocolloid gels as fat substitutes over time

	Days		
	0	**5**	**10**
Code (1)	58.71 ±0.02 ^{aA}	55.75±0.11 ^{bA}	52.09±0.47 ^{bA}
Code (2)	57.96±0.01 ^{bA}	56.63±0.32 ^{aA}	53.99±0.18 ^{aA}
Code (3)	57.90±0.00 ^{bA}	56.63±0.32 ^{aA}	53.99±0.18 ^{aA}
Code (4)	54.21±024 ^{bA}	56.34±0.31 ^{aA}	57.91±0.01 ^{aA}

Different lowercase letters indicate significant differences in the column and different uppercase letters indicate significant differences in the row ($p<0.05$).Sample (1): no alginate and konjac (control), sample (2): 0.5% alginate + 0.5% konjac, sample (3): 1% alginate, sample (4): 1% konjac.

quality. These two hydrocolloids, characterized by their moisture-retaining properties, serve to enhance the hydration and texture of the burger. Over the course of the study, a notable reduction in the cooking loss of the samples was observed. This phenomenon may be attributed to the beneficial influence of additives on the physical and chemical properties of the burgers, thereby facilitating the preservation of the final product's quality over an extended period. Cook loss is defined as the reduction in both weight and volume of a food product that occurs during the cooking process. This phenomenon typically arises as a result of moisture and fat loss during the cooking process, which can substantially affect the final quality of the product. In the preparation of burgers, cook loss can lead to diminished juiciness, flavor, and texture of the final product, thereby negatively impacting the overall consumer experience (Patinho *et al*., 2021).

Hydrocolloids possess the capability to retain fat and moisture, thereby mitigating shrinkage and cooking losses in burger formulations (Patinho *et al*., 2021). This phenomenon may be attributed to the entrapment of lipids and water within the stable gel network formed by the gum. This structural configuration leads to a diminished release of water throughout the baking process, thereby mitigating shrinkage and enhancing baking efficiency (Sayed, M. E., Bakr, A. S., Gaafar, A. M., Ismaiel, A. I. and Salem, 2020). In a comparable investigation, the incorporation of carrageenan gum into low-fat meat products resulted in the formation of a gel network that significantly improved moisture absorption and retention, mitigated shrinkage, and enhanced the cooking efficiency of the product (Atashkar *et al*., 2018). In a separate investigation, it was demonstrated that the incorporation of varying concentrations of gum into grain formulations, employed as a fat substitute, effectively diminished shrinkage and cooking loss in low-fat burgers. However, this modification also resulted in a significant increase in texture hardness and moisture retention capacity(Yousefi *et al*., 2018). In a separate investigation, it was noted that the incorporation of guar gum into low-fat meat emulsions, which consisted of varying concentrations of guar gum (0. 5%, 10%, and 15%) utilized as a fat substitute, resulted in an enhancement of cooking efficiency (Rather *et al*., 2017). Numerous studies have demonstrated that the incorporation of various gums into low-fat burger formulations can effectively minimize cooking losses and enhance the overall quality of the final product (Yousefi *et al*., 2018). Furthermore, the incorporation of aloe vera and various hydrocolloids contributes to moisture retention and improves the overall quality of the burger (Soltanizadeh & Ghiasi-Esfahani, 2014).

Table 7. Changes in cooking loss of burger samples containing alginate and konjac hydrocolloid gels as fat substitutes over time

	Days		
	0	**5**	**10**
Code (1)	29.69±0.97 ^{aA}	28.15±0.37 ^{aA}	26.19±0.41 ^{aA}
Code (2)	22.43±0.32 ^{cA}	22.07±0.13 ^{dA}	21.43±0.07 ^{dA}
Code (3)	24.22±0.25 ^{bA}	23.79±0.16 ^{bA}	23.19±0.03 ^{bA}
Code (4)	23.26±0.29 ^{bcA}	23.00±0.16 ^{cA}	22.47±0.16 ^{cA}

Different lowercase letters indicate significant differences in the column and different uppercase letters indicate significant differences in the row ($p<0.05$).Sample (1): no alginate and konjac (control), sample (2): 0.5% alginate + 0.5% konjac, sample (3): 1% alginate, sample (4): 1% konjac.

- ***Water Holding Capacity***

The findings presented in Table 8 demonstrate that, across all time intervals examined, sample 1—devoid of alginate and konjac—exhibited the lowest water holding capacity. This suggests that the absence of alginate and konjac in the burger formulation correlates with diminished water holding capabilities. Over time, there was a marked decline in the water holding capacity of the samples. Gums, utilized as food additives in the formulation of low-fat burgers, are instrumental in preserving moisture and enhancing the overall quality of these products. The unique properties of these materials facilitate the retention of water and lipids, thereby mitigating the deterioration of quality during the cooking process. Researchers have indicated that the gum derived from the Qodomeh seed exhibits considerable water holding capacity (574%) and oil retention capacity (986%). The incorporation of this gum into low-fat burger formulations may significantly enhance water holding capabilities and mitigate quality degradation of the product. The incorporation of gum arabic into low-fat burgers significantly enhanced their water-holding capacity, thereby mitigating moisture loss during the cooking process and subsequently improving overall consumer acceptability when compared to control burgers (Yousefi *et al*., 2018). The researchers recognized that the moisture retention capacity among the various treatments reflects the enhanced water-binding ability of Shirazi Qodomeh seed gum. Moreover, it was observed that the moisture retention capacity exhibited a significant increase in correlation with higher concentrations of the gum. The formulation of the beef burger that included 0. 9% gum exhibited the highest moisture retention capacity, recorded at 84.3%. Furthermore, the incorporation of xanthan and guar gums significantly improved the moisture retention capacity of reduced-fat sausages (Mokhtar & Eldeep, 2020) (Sayed-Ahmad *et al*., 2018). Research indicates that frozen konjac glucomannan gel enhances the water holding capacity and decreases the syneresis rate, all the while preserving a dense and porous microstructure (D. Lin *et al*., 2020).

- ***Diameter Reduction***

The results presented in Table 9 reveal that, across all time intervals assessed, the most significant reduction in diameter was observed in sample 1, which lacked both alginate and konjac. This finding suggests that the absence of these gelling agents influenced the susceptibility of the burger to diameter reduction. This phenomenon may be attributable to the lack of

Table 8. Changes in the water holding capacity of burger samples containing alginate and konjac hydrocolloid gels as fat substitutes over time

	Days		
	0	**5**	**10**
Code (1)	23.10±0.15 ^{dA}	22.09±0.32 ^{dA}	20.35±0.12 ^{dA}
Code (2)	28.65±0.43 ^{aA}	27.73±0.25 ^{aA}	27.32±0.08 ^{aA}
Code (3)	24.52±0.20 ^{cA}	23.46±0.17 ^{cA}	23.72±0.12 ^{cA}
Code (4)	26.12±0.33 ^{bA}	24.96±0.12 ^{bA}	24.49±0.45 ^{bA}

Different lowercase letters indicate significant differences in the column and different uppercase letters indicate significant differences in the row ($p<0.05$).Sample (1): no alginate and konjac (control), sample (2): 0.5% alginate + 0.5% konjac, sample (3): 1% alginate, sample (4): 1% konjac moisture-retaining compounds typically found in gums. A significant quality factor in the assessment of burgers is the extent to which the diameter of the burger decreases during the cooking process. Various factors influence the diameter of burgers, including the proportions of fat, meat, and moisture content. The relationship between meat content, fat content, and moisture levels is directly correlated with the reduction in the diameter of burgers. The size of the burger particles and components, as well as the dimensions of the apertures in the meat grinder, are inversely related to the integrity of the burger matrix and directly correlated with the extent of shrinkage observed during cooking. Larger particle sizes and larger grinder openings tend to result in a compromised structural cohesiveness of the burger, thereby leading to increased shrinkage (Basati & Hosseini, 2018). One of the primary challenges encountered in the production of burgers is the reduction in diameter that occurs during the cooking process. This phenomenon typically arises as a result of moisture and fat loss that occurs during the cooking process. Research indicates that the diameter reduction of burgers is significantly influenced by both fat and moisture content. Specifically, increased fat levels are associated with greater reductions in diameter and enhanced shrinkage values. Moreover, the reduction of moisture and fat content during the cooking process constitutes a significant factor that impacts both heat and mass transfer, consequently influencing the shrinkage of burgers. The incorporation of ingredients such as soy protein has the potential to mitigate the loss of fat and moisture, consequently decreasing the extent of shrinkage (Bagheri & Khashaninejad, 2020).

The researchers have identified that gums, specifically xanthan gum, exhibit high viscosity and possess the capacity to form viscous solutions. These properties contribute to the stabilization of the burger's structure, thereby inhibiting a reduction in its diameter during the cooking process. Research indicates that burgers incorporating xanthan gum exhibit reduced diameter loss in comparison to those that do not include this additive (Basati & Hosseini, 2018).

The gum extracted from quinoa seeds exhibits a substantial capacity for water and oil retention, thereby effectively preserving the structural integrity of burgers throughout the cooking process (Bagheri & Khashaninejad, 2020).

Carrageenan, with its gelling and protein-reactive properties, helps retain moisture and prevents burgers from shrinking in diameter. It also enhances the overall quality of the final product (Poyato *et al*., 2015).

Table 9. Changes in diameter reduction of burger samples containing alginate and konjac hydrocolloid gels as fat substitutes over time

	Days		
	0	**5**	**10**
Code (1)	40.58±0.86 ^{aA}	36.44±0.29 ^{aA}	35.85±0.16 ^{aA}
Code (2)	36.98±0.44 ^{bA}	35.60±0.40 ^{bA}	35.15±015 ^{aA}
Code (3)	38.17±1.29 ^{bA}	36.26±0.16 ^{aA}	36.56±1.32 ^{bA}
Code (4)	37.58±019 ^{bA}	35.53±0.31 ^{bA}	33.59±0.36 ^{bA}

Different lowercase letters indicate significant differences in the column and different uppercase letters indicate significant differences in the row ($p<0.05$).Sample (1): no alginate and konjac (control), sample (2): 0.5% alginate + 0.5% konjac, sample (3): 1% alginate, sample (4): 1% konjac.

Carboxymethyl cellulose functions as a non-caloric stabilizer, effectively inhibiting the formation of ice crystals in frozen products. Additionally, it aids in moisture retention, thereby decreasing shrinkage in burgers (He *et al*., 2021).

- ***Colorimetric Results***

The findings pertaining to the color components L*, a*, and b* are outlined in Tables 10, 11, and 12, respectively. Throughout all time intervals examined, the highest value of the color component L* was attributed to sample 2, which contained 0. 5% alginate and 0. 5% Conversely, the lowest value of the color component L* was recorded for sample 4, which consisted of 1% konjac. Over the elapsed period until day 5, no statistically significant differences were detected in the color component L* of the samples. However, a significant decrease in this component was observed from day 5 to day 10. The L* index quantifies the degree of lightness and darkness, with a scale ranging from 0 to 100, where 0 represents the darkest shade and 100 denotes the lightest (Kutz *et al.*, 2021). The observed decline in the L* color component of the samples between day 5 and day 10 suggests the occurrence of both chemical and physical transformations over the given time period. This decline may be attributed to oxidative processes or alterations in the protein and lipid compositions. These modifications may influence the ultimate quality of the product. Throughout all examined time intervals, the color component a* exhibited its lowest value in sample 2, which comprised 0. 5% alginate and 0. 5% konjac Conversely, the highest value of the color component a* was recorded in sample 1, which did not contain either alginate or konjac. Over the course of the study, there was a significant increase in the color component a* of the samples. The color index a* serves as a metric for quantifying the redness of samples, with a range extending from +120 to -120, where +120 denotes absolute red and -120 indicates absolute green A positive score signifies that the sample exhibits a red coloration, while a negative score indicates the presence of a green coloration in the sample (Kutz *et al*., 2021).

The observed increase in the chromatic component a* over time signifies alterations in the chemical and physical properties of the product. This phenomenon may be attributed to processes such as oxidation, as well as modifications in the composition of proteins and lipids. These modifications may influence the ultimate quality of the product. Throughout all time intervals analyzed, sample 1 (which did not include alginate or konjac) exhibited the highest value for the color component b*, whereas the lowest value for b* was recorded in sample 4 (which contained 1% konjac), with statistical significance noted at $p \leq 0.05$ Over the course of the study, the b* color component of the samples exhibited a statistically significant increase ($p \leq 0.05$) A positive score on the color index b* reflects the extent of yellowness in the sample, whereas a negative score signifies the degree of blueness. Specifically, a positive value indicates increasing yellowness, whereas a negative value corresponds to increasing blueness, with the scores ranging from +120 (indicating absolute yellowness) to -120 (indicating absolute blueness) (Majzoobi *et al*., 2014).

On the 5th and 10th days of observation, as presented in Table 13, the sample exhibiting the most significant overall color change (ΔE) was sample 2, which consisted of 0. 5% alginate and 0. 5% konjac. This pronounced color change may be attributed to the unfavorable interaction between alginate and konjac, resulting in a porous structure that enhances the permeability of oxygen. This phenomenon may enhance the oxidation of lipids or myoglobin, thereby exacerbating the observed color alterations. Conversely, the sample exhibiting the lowest overall color change (ΔE) was identified as sample 3, which contained 1% alginate. This finding suggests a superior stability of color in this particular formulation. A higher concentration of alginate is likely to enhance moisture retention by establishing a more robust gel network, thereby inhibiting the exposure of oxidation-sensitive compounds (such as lipids and myoglobin) to oxygen. Throughout the duration of the study, there was a marked increase in the overall color change (ΔE) observed in the samples. The overall color change (ΔE) serves as a significant criterion for assessing the quality and stability of various food products and materials. The notable increase in ΔE observed across all samples over time is consistent with established expectations, given that meat products are inherently susceptible to oxidation and degradation of pigments. Nevertheless, Sample 3, which contained 1% alginate, exhibited a decreased rate of color degradation, thereby supporting the hypothesis regarding the protective function of alginate against color-degrading agents (Lourenço *et al*., 2020). The researchers conducted a study that demonstrated the efficacy of edible alginate films infused with bioactive compounds derived from pineapple peel in the preservation of color and color intensity in beef. Additionally, these films were found to significantly inhibit lipid oxidation during a storage period of five days at a temperature of 4°C (Lourenço *et al*., 2020).

Research findings indicate that post-cooking assessments demonstrated a reduction in the indices of brightness, redness, and yellowness across all examined samples. The analysis revealed significant disparities in brightness indices among the cooked samples, with the highest index recorded for the sample containing 0. 1% gum, measuring at 47. 42, and the lowest index observed in the sample with 0. 9% gum, which was measured at 2. 39 The color attributes of both raw and cooked meat, as well as meat products, are primarily influenced by the presence of meat pigments. Additionally, variations in pigmentation that occur during the cooking process further contribute to these color characteristics. Low-fat products exhibit darker and redder coloration in comparison to their high-fat counterparts. The observed darker and redder hue in low-fat meat products can be ascribed to a reduction in light scattering, which is a consequence of the diminished fat content (Hughes *et al*., 2020).

Researchers conducted an investigation into the impact of incorporating Shirazi Qodomeh seed gum, methyl cellulose, and a synergistic combination of these two polysaccharides as an edible coating on the quality attributes and oil absorption properties of fried potato products. The authors reported that the application of Shirazi Qodomeh seed gum significantly influenced the brightness and yellowness indices, while not affecting the redness index. The incorporation of Shirazi Qodomeh seed gum at varying concentrations resulted in a significant reduction in the redness, yellowness, and brightness of the product color when compared to the control treatment. Furthermore, the incorporation of guar gum resulted in a substantial decrease in the brightness, redness, and yellowness indices of low-fat meat kebabs when compared to the control treatment (Hughes *et al*., 2020).

Table 10. Changes in the color component L* of burger samples containing alginate and konjac hydrocolloid gels as fat substitutes over time

	Days		
	0	**5**	**10**
Code (1)	56.61±0.31 ^{bA}	55.60±0.13 ^{cA}	54.28±0.11 ^{dA}
Code (2)	57.74±0.11 ^{aA}	57.51±0.06 ^{aA}	56.78±0.03 ^{aA}
Code (3)	56.86±0.18 ^{bA}	56.76±0.17 ^{bA}	56.58±0.07 ^{bA}
Code (4)	56.05±0.28 ^{cA}	56.60±0.13 ^{bA}	56.36±0.09 ^{cA}

Different lowercase letters indicate significant differences in the column and different uppercase letters indicate significant differences in the row ($p<0.05$).Sample (1): no alginate and konjac (control), sample (2): 0.5% alginate + 0.5% konjac, sample (3): 1% alginate, sample (4): 1% konjac

Table 11. Changes in the color component a* of burger samples containing alginate and konjac hydrocolloid gels as fat substitutes over time

	Days		
	0	**5**	**10**
Code (1)	16.06±0.02 ^{aA}	16.30±0.11 ^{aA}	17.35±0.05 ^{aA}
Code (2)	13.15±0.07 ^{dA}	14.27±0.05 ^{dA}	13.90±0.03 ^{dA}
Code (3)	13.69±0.03 ^{cA}	14.59±0.16 ^{cA}	14.12±0.04 ^{cA}
Code (4)	14.28±0.09 ^{bA}	14.95±0.12 ^{bA}	14.31±0.02 ^{bA}

Different lowercase letters indicate significant differences in the column and different uppercase letters indicate significant differences in the row ($p<0.05$).Sample (1): no alginate and konjac (control), sample (2): 0.5% alginate + 0.5% konjac, sample (3): 1% alginate, sample (4): 1% konjac

Table 12. Changes in the color component b* of burger samples containing alginate and konjac hydrocolloid gels as fat substitutes over time

	Days		
	0	**5**	**10**
Code (1)	18.34±0.05 ^{abA}	19.14±0.07 ^{aA}	19.70±0.10 ^{aA}
Code (2)	18.45±0.06 ^{aA}	18.96±0.03 ^{bA}	19.19±0.07 ^{bA}
Code (3)	18.28±0.06 ^{bA}	18.50±0.05 ^{cA}	18.60±0.04 ^{cA}
Code (4)	17.95±0.05 ^{cA}	18.14±0.02 ^{dA}	18.39±0.04 ^{dA}

Different lowercase letters indicate significant differences in the column and different uppercase letters indicate significant differences in the row ($p<0.05$).Sample (1): no alginate and konjac (control), sample (2): 0.5% alginate + 0.5% konjac, sample (3): 1% alginate, sample (4): 1% konjac

Table 13. Comparison of overall color change (ΔE) of burger samples containing alginate and konjac hydrocolloid gels as fat substitutes over time

	Days		
	0	**5**	**10**
Code (1)	0.0±0.00 ^{aC}	1.09±0.07 ^{cB}	2.73±0.10 ^{bA}
Code (2)	0.0±0.00 ^{aC}	3.05±0.13 ^{aB}	3.29±0.07 ^{aA}
Code (3)	0.0±0.00 ^{aB}	1.93±0.05 ^{bA}	1.93±0.04 ^{cA}
Code (4)	0.0±0.00 ^{aC}	1.82±0.02 ^{bB}	2.89±0.04 ^{bA}

Different lowercase letters indicate significant differences in the column and different uppercase letters indicate significant differences in the row ($p<0.05$).Sample (1): no alginate and konjac (control), sample (2): 0.5% alginate + 0.5% konjac, sample (3): 1% alginate, sample (4): 1% konjac

- ***Sensory Test***

The analysis of the sensory scores for the burger samples, as presented in Table 14, indicates that there were no statistically significant differences in the odor scores among the samples on both the fifth and tenth days ($p \geq 0.05$) On day 0, sample 1, which did not contain alginate or konjac, exhibited the highest odor score ($p \leq 0.05$) Over the course of the experiment, there was a significant decrease in the odor score of the samples ($p \leq 0.05$) The reduction in odor score observed on day 10 may be attributed to oxidative processes or chemical alterations within the product, which could impact its sensory quality. On days 0 and 5, the statistical analysis revealed no significant difference in the color score of the samples ($p \geq 0.05$) On the tenth day of the evaluation, sample 1, which did not contain alginate or konjac, exhibited the lowest color score. Conversely, sample 4, which included 1% konjac, recorded the highest color score. The differences observed were statistically significant ($p \leq 0.05$) Over the course of the study, a significant decline in the color score of the samples was observed ($p \leq 0.05$) The observed substantial alterations in the color scores suggest a notable impact of alginate and konjac on the color retention properties of the burgers. Sample 4, which contained 1% konjac, exhibited superior retention of color quality in comparison to the other samples. In all examined time intervals, sample 1, which lacked alginate and konjac, exhibited the lowest texture score ($p \leq 0.05$) Over time, a significant reduction in the texture score of the samples was observed ($p \leq 0.05$) The observed lowest texture score in Sample 1, which was devoid of alginate and konjac, suggests that the omission of hydrocolloids may result in a deterioration of the textural quality of the burgers. This underscores the significance of additives, such as alginate and konjac, in preserving the appropriate texture of food products. On Day 0, Sample 1, which was devoid of alginate and konjac, attained the highest sensory evaluation score for taste. This finding suggests that, at the onset of the experiment, the flavor profile of this particular sample was rated more favorably in comparison to the other samples analyzed. Nevertheless, at various time intervals, the taste score associated with Sample 1 exhibited a statistically significant reduction in comparison to the scores of the other samples. This reduction may suggest a detrimental impact resulting from the absence of hydrocolloids, specifically alginate and konjac, which are typically instrumental in preserving the flavor and sensory attributes of meat products. Over the period of observation, there was a notable decline in the taste scores assigned to the samples. Over time, the composition of burgers may undergo both chemical and physical changes that can significantly influence their taste. The oxidation of lipids and the degradation of proteins may result in alterations in flavor profiles and a reduction in sensory quality (Domínguez *et al.*, 2019) (Özer & Seçen, 2018).

On days 0 and 5, the overall acceptance scores of the samples did not exhibit a statistically significant difference ($p \geq 0.05$) On day 10, sample 1, which did not contain alginate and konjac, exhibited the lowest overall acceptance score ($p \leq 0.05$) Over time, there was a significant decrease in the overall acceptance score of the samples ($p \leq 0.05$) The decline in the overall acceptance score observed on day 10 may be attributed to fluctuations in the product quality over time. The observed alterations may be attributed to factors such as oxidation, moisture loss, or textural modifications that occur over time. Specifically, sample 1, which lacked both alginate and konjac, may have been more adversely affected, as these additives are typically known to play a significant role in preserving moisture and texture. The researchers' findings indicate that the incorporation of gum into the grain exhibited a favorable impact on the sensory attributes and overall acceptability of the low-fat burger. This enhancement was characterized by an increased intensity in the color, appearance, odor, and flavor profiles of the samples (Yousefi *et al*., 2018). The incorporation of gums into protein systems has been shown to enhance the water-holding capacity of gels utilized in food products. The influence of the structural and molecular properties of the gums, in conjunction with factors such as pH and ionic strength, is significant in this context. The incorporation of xanthan and carboxymethyl cellulose markedly enhanced the water-holding capacity and diminished the cooking loss in soy-based burgers. The combination of these gums demonstrated a high level of sensory acceptance, suggesting their efficacy in enhancing both physicochemical and sensory properties (Basati & Hosseini, 2018). Research indicates that the incorporation of mixed gels composed of konjac and gellan gum into low-fat frankfurters enhances sensory attributes and prolongs shelf life, ultimately resulting in an elevated water content score (C.-C. Lin & Metters, 2006). Other studies have demonstrated that the incorporation of konjac gum in the formulation of low-fat sausages results in enhanced textural attributes and serves to partially mitigate shortcomings in rheological properties (Atashkar *et al*., 2018). Research indicates that the incorporation of konjac gum in conjunction with linseed gum, along with additional components, can significantly improve the texture, shape, color, and flavor of sausage products (Jiang *et al*., 2019). Researchers have indicated that the

Table 14. Changes in sensory scores of burger samples containing alginate and konjac hydrocolloid gels as fat substitutes during storage time

		Storage time (Day)		
Parameter	**Sample**	**Day 0**	**Day 5**	**Day 10**
Smell	**Code (1)**	5.00 ± 0.00 aA	4.00 ± 0.00 aA	2.00 ± 1.00 aA
	Code (2)	4.00 ± 0.00 bA	3.66 ± 0.57 aA	2.66 ± 0.57 aA
	Code (3)	4.00 ± 0.00 bA	3.66 ± 0.57 aA	3.33 ± 0.57 aA
	Code (4)	4.33 ± 0.57 bA	3.66 ± 0.57 aA	3.33 ± 0.57 aA
Color	**Code (1)**	5.00 ± 0.00 aA	3.33 ± 0.57 aA	1.66 ± 0.57 cA
	Code (2)	5.00 ± 0.00 aA	3.66 ± 0.57 aA	2.66 ± 0.57 bA
	Code (3)	5.00 ± 0.00 aA	4.00 ± 0.00 aA	3.00 ± 0.00 abA
	Code (4)	5.00 ± 0.00 aA	4.00 ± 0.00 aA	3.66 ± 0.57 aA
Texture	**Code (1)**	3.66 ± 0.57 bA	3.00 ± 0.00 bA	2.00 ± 1.00 bA
	Code (2)	5.00 ± 0.00 aA	4.00 ± 0.00 aA	3.66 ± 0.57 aA
	Code (3)	4.66 ± 0.57 aA	3.66 ± 0.57 aA	3.33 ± 0.57 aA
	Code (4)	4.66 ± 0.57 aA	4.00 ± 0.00 aA	3.66 ± 0.57 aA
Taste	**Code (1)**	5.00 ± 0.57 bA	3.00 ± 0.00 bA	2.00 ± 1.00 bA
	Code (2)	4.66 ± 0.00 aA	4.00 ± 0.00 aA	3.66 ± 0.57 aA
	Code (3)	4.66 ± 0.57 aA	3.66 ± 0.57 aA	3.33 ± 0.57 aA
	Code (4)	4.66 ± 0.57 aA	4.00 ± 0.00 aA	3.66 ± 0.57 aA
General Acceptance	**Code (1)**	4.33 ± 0.57 aA	3.33 ± 0.57 aA	1.66 ± 0.57 bA
	Code (2)	4.66 ± 0.57 aA	3.66 ± 0.57 aA	3.00 ± 1.00 aA
	Code (3)	4.33 ± 0.57 aA	3.66 ± 0.57 aA	3.33 ± 0.57 aA
	Code (4)	4.66 ± 0.57 aA	4.00 ± 0.00 aA	3.66 ± 0.57 aA

Different lowercase letters indicate significant differences in the column and different uppercase letters indicate significant differences in the row ($p<0.05$).Sample (1): no alginate and konjac (control), sample (2): 0.5% alginate + 0.5% konjac, sample (3): 1% alginate, sample (4): 1% konjac incorporation of konjac gum, at levels of up to 0. 6%, into meatless sausages resultsin enhanced quality and overall acceptability of the product (Majzoobi *et al*., 2014). In a conducted study, it was observed that the sensory evaluation score for overall acceptability of the reconstituted duck burger containing 1% alginate and a combination of 0. 5% alginate with 0. 5% konjac surpassed that of the control sample. The study concluded that the incorporation of 1% alginate or 0. 5% alginate in conjunction with 0. 5% konjac into the reconstituted duck burger formulation enhanced the quality attributes of the product (Kim *et al*., 2018).

Conclusion

The current investigation explores the influence of hydrocolloid additives, specifically alginate and konjac, on the physicochemical properties of low-fat burgers. The findings indicate that no statistically significant differences in protein content were observed across all samples. This lack of distinction is likely attributed to the minimal percentage of gums incorporated. Nonetheless, the protein content of the samples conformed to the established range set forth by the Iranian national standards. The samples that did not contain alginate and konjac exhibited the lowest ash content. Furthermore, all samples were found to conform to the standards established by Iranian national regulations. The observed elevation in ash content within the samples containing gums can be attributed to the intrinsic ash composition of the gums themselves. The sample devoid of alginate and konjac exhibited the highest fat content. The incorporation of these gums as fat substitutes led to a reduction in the total fat content of the burgers, with all samples conforming to the established standards of the Iranian national guidelines. No statistically significant differences were observed in the pH levels of the samples on day zero. However, over the course of the study, changes in pH were noted in certain samples, suggesting that the inclusion of gums influenced their pH levels. Burgers formulated without hydrocolloid gums exhibited a higher moisture content on day 0; however, a decline in moisture content was observed over time. The incorporation of gums in formulations contributes to the retention of moisture and the mitigation of quality degradation. The sample lacking alginate and konjac exhibited the highest cooking loss, thereby suggesting that the incorporation of these additives positively influences moisture retention and overall quality in burger production. The sample devoid of gums exhibited the greatest reduction in diameter, highlighting the detrimental impact of the absence of hydrocolloids on the structural integrity of the burger. The sample comprising 0. 5% alginate and 0. 5% konjac was identified as the most favorable specimen based on its elevated sensory evaluation scores, enhanced moisture retention capabilities, and reduced cooking loss. The findings of the current study indicate that the incorporation of hydrocolloids, specifically alginate and konjac, significantly enhances the physicochemical properties of low-fat burgers. Furthermore, these additives contribute to the preservation of the final product quality. These findings underscore the significance of selecting appropriate hydrocolloids to enhance the quality of meat products.

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