CELEBES Agricultural 6(1): 12 - 24 August (2025)

Research Article

The Role of Sorbitol in Enhancing the Performance of Whey Chia Seed-Based Edible Films: A Physical and Microscopic Evaluation

Peran Sorbitol dalam Meningkatkan Kinerja Edible Film Berbasis Whey dan Chia Seed: Kajian Fisik dan Mikroskopis

Fahrullah Fahrullah[1]*, Mesil Fiarani[1], Djoko Kisworo[1], Bulkaini Bulkaini[1], I Gede Nano Septian[1]

[1] Department of Animal Science. Faculty of Animal Science, University of Mataram, Mataram, Indonesia

*email:

Recived: June 2025
Accepted: August 2025
Published: October 2025

p-ISSN: 2723-7974
e-ISSN: 2723-7966
doi: 10.52045/jca.v6i1.982

Website:
https://ojs.untika.ac.id/index.php/faperta

Abstract: Edible film is a thin, edible film used as a food coating. The advantages of edible film include its biodegradability and its ability to maintain the quality and shelf life of the food product it covers. The objective of this study was to ascertain the impact of varying concentrations of sorbitol on the thickness, water vapor transmission rate, and microstructure of whey-chia seed edible film. The present study employed a Completely Randomized Design, comprising three distinct treatments, each with three replicates. The data obtained were analysed using Analysis of Variance, and if there were significant differences between treatments, these were followed by Duncan Multiple Range Test. The treatments incorporated the following: P1 (10% sorbitol), P2 (20% sorbitol), and P3 (30% sorbitol). The variables measured in this study were thickness, water vapor transmission rate and edible film microstructure. The findings demonstrated that the incorporation of sorbitol at varying concentrations elicited a highly significant effect ($P<0.01$) on the thickness of the edible film. However, the water vapor transmission rate test did not yield a significant difference ($P>0.05$). The mean thickness of the samples ranged from 0.0296 to 0.0303 mm, and the water vapor transmission rate ranged from 4.60 to 5.68 g/mm²/day. Microstructure analysis revealed that the incorporation of sorbitol enhanced the flexibility and uniformity of the distribution of the films at concentrations of 10% and 20%. However, at a concentration of 30%, the films exhibited increased rigidity and reduced flexibility. The utilization of a 20% sorbitol concentration was identified as the optimal treatment.

Keywords: Chia Seed, Film, Plasticizer, Sorbitol, Whey

Abstrak: Edible film adalah film tipis yang dapat dimakan yang digunakan sebagai pelapis makanan. Keunggulan edible film antara lain biodegradabilitasnya dan kemampuannya untuk menjaga kualitas dan umur simpan produk makanan yang dilapisinya. Tujuan dari penelitian ini adalah untuk mengetahui pengaruh variasi konsentrasi sorbitol terhadap ketebalan, laju transmisi uap air, dan struktur mikro edible film dari whey-chia seed. Penelitian ini menggunakan percobaan acak, yang terdiri dari tiga perlakuan berbeda, masing-masing dengan tiga ulangan. Data yang diperoleh dianalisis menggunakan Analisis Variansi, dan jika terdapat perbedaan yang signifikan antara perlakuan, hal ini dilanjutkan dengan Uji Rentang Ganda Duncan. Perlakuan-perlakuan tersebut adalah sebagai berikut: P1 (10% sorbitol), P2 (20% sorbitol), dan P3 (30% sorbitol). Variabel yang diukur dalam penelitian ini adalah ketebalan, laju transmisi uap air, dan struktur mikro edible film. Hasil penelitian menunjukkan bahwa penggabungan sorbitol pada berbagai konsentrasi memberikan efek yang sangat signifikan ($P<0,01$) terhadap ketebalan edible film. Namun, uji laju transmisi uap air tidak menghasilkan perbedaan yang signifikan ($P>0,05$). Ketebalan rata-rata sampel berkisar antara 0,0296 hingga 0,0303 mm, dan laju transmisi uap air berkisar antara 4,60 hingga 5,68 g/mm²/hari. Analisis mikrostruktur mengungkapkan bahwa penggabungan sorbitol meningkatkan fleksibilitas dan keseragaman distribusi film pada konsentrasi 10% dan 20%. Namun, pada konsentrasi 30%, film menunjukkan peningkatan kekakuan dan mengurangi fleksibilitas. Penggunaan konsentrasi sorbitol 20% diidentifikasi sebagai perlakuan yang optimal.

Kata kunci: Chia Seed, Film, Pemlastis, Sorbitol, Whey

Citation:
Fahrullah F, Fiarani M, Kisworo D, Bulkaini B, Septian IGN. 2025. The Role of Sorbitol in Enhancing the Performance of Whey Chia Seed-Based Edible Films: A Physical and Microscopic Evaluation. *CELEBES Agricultural*. 6(1): 12-24. doi: 10.52045/jca.v6i1.982

INTRODUCTION

The accelerated evolution of food technology has given rise to novel food products, thus necessitating the development of packaging solutions. Plastic packaging is the most widely used type of packaging used as a wrapper for processed food. The utilisation of this packaging has the potential to result in environmental contamination (Zhang et al., 2023) due to its prolonged decomposition time in natural environments (de Dicastillo et al., 2016). Consequently, consumers are increasingly demanding foods that are natural and free from synthetic compounds. The heightened awareness of environmental protection, coupled with consumers' demand for safe and healthy food, has precipitated the emergence of alternative packaging that is more environmentally friendly. This packaging, often referred to as edible film, is composed of materials that are edible to humans. The utilisation of such packaging constitutes a solution to the issue of environmental degradation, which is primarily attributable to synthetic packaging that is recalcitrant to decomposition (Hasan et al., 2022).

Edible film constitutes a thin, edible layer employed as a food coating. This layer possesses the advantage of being biodegradable and can maintain the quality and shelf life of the food product it covers (Carpena et al., 2021). Furthermore, it has been demonstrated that the material can act as a carrier matrix for active compounds, including antioxidants and antimicrobials (Mishra et al., 2018; Otoni et al., 2017). Whey, a product that is abundant in protein, is one of the potential raw materials that can be utilized in the manufacturing of edible film. The utilisation of whey as a base material for edible film manufacturing confers a number of advantages due to its environmentally friendly and biodegradable bioregeneration properties (Chen et al., 2019). As demonstrated in a number of preceding studies, the combination of whey protein with other polymeric materials has been shown to yield edible films that exhibit desirable characteristics (Fahrullah et al., 2022; Fahrullah et al., 2023; Fahrullah et al., 2024).

The selection of chia seed as an additive in the preparation of whey-based edible films is based on its nutritional potential and hydrophilic properties that can improve film performance. Another reason pertains to the fact that, due to their inherent properties, grain-based films can be metabolised in the human body along with food (Aleksanyan, 2023). This metabolic process has been shown to produce gels that are considered promising in the development of biodegradable packaging (Soukoulis et al., 2018). Chia seed has been identified as a promising ingredient in the food industry due to its ability to function as a stabilizer, thickener, additive, and fat replacer (Chaves et al., 2018; Chollakup et al., 2020; Zettel & Hitzmann, 2018).

A strategy that has been widely adopted for the purpose of enhancing the elasticity of edible films is the incorporation of plasticizers. In the realm of plasticizers, sorbitol and glycerol emerge as notable polyols due to their propensity to enhance the flexibility and elasticity of the resultant film (Chang & Nickerson, 2014; Fahrullah et al., 2020; Liang & Wang, 2018). Sorbitol is a hydrophilic plasticizer that has been shown to enhance the flexibility and stress distribution capability of films, thereby improving their mechanical quality (Haq et al., 2016). Whey protein has been demonstrated to possess advantageous film-forming properties, thereby providing strength and flexibility to the resultant film. In addition, whey protein has been shown to assist in the maintenance of moisture and emulsion. Concurrently, chia seeds have been shown to be rich in omega-3 fatty acids and fibre, which enhance the structural strength of the film and provide gel properties that are useful for flexibility and release control. However, the impact of varying sorbitol concentrations on the physical characteristics and microstructure of whey-chia seed-based edible films remains to be fully elucidated, particularly with regard to thickness, water vapor transmission rate, and film microstructure. Further research in this area is necessary to gain a more comprehensive understanding of the relationship between sorbitol concentration and the physical properties of edible films. The objective of this study is to investigate the characteristics of whey-chia seed films with varying sorbitol concentrations and to furnish information pertaining to their prospective application as an eco-friendly food packaging alternative. The selection of chia seed as an additive in the preparation of whey-based edible films is predicated on its nutritional potential and hydrophilic properties that can enhance film performance. Another reason pertains to the fact that, due to their inherent properties, grain-based films can be metabolized in the human body along with food (Aleksanyan, 2023). This metabolic process has been shown to produce gels that are considered promising in the development of biodegradable packaging (Soukoulis et al., 2018). Chia seed has been identified as a promising ingredient in the food industry due to its ability to function as a stabilizer, thickener, additive, and fat replacer (Chaves et al., 2018; Chollakup et al., 2020; Zettel & Hitzmann, 2018)

MATERIALS AND METHODS

Materials and Tools

The materials utilized in this research comprise whey protein, chia seed, sorbitol plasticizer, distilled water, silica gel, ethanol solution, filter paper and label paper. The equipment employed for this study included a thermometer, Erlenmeyer flask, petri dish, measuring cup, measuring tube, magnetic stirrer, Heidolph rotary evaporator, hot plate stirrer, screw micrometer, a set of SEM tools, and a desiccator. The present study was conducted at the Animal Product Technology Laboratory. The experimental design utilised was a Completely Randomized Design, comprising three treatments and three replicates.

Extraction of Chia Seed

The seeds of the Chia plant (*Salvia hispanica*) (Greenara, Indonesia) were subjected to a process of purification involving the application of ethanol on at least four occasions, with the objective of eradicating any extraneous contamination. Thereafter, the seeds were subjected to a mechanical process that resulted in their fragmentation into smaller particles. The following step involved the soaking (or maceration) of the chia seeds in pro-analysis ethanol for a period of three days. This was followed by the filtration of the chia seed filtrate using Whatman 41 filter paper. The filtrate was then processed with an evaporation device (Heidolph Rotary Evaporators-Hei-

VAP Value Digital G3) to produce a chia seed solution (Khazaei et al., 2014). During this process, it is imperative to meticulously regulate the temperature during the soaking and filtration steps to avert alterations in the chemical composition or properties of the chia seed solution. Typically, a temperature of approximately 25˚C to 40˚C is maintained during the processes of soaking and evaporation, with the objective of preserving the integrity of the substances involved. It is imperative that homogenisation is carried out at a consistent speed and duration to ensure uniform particle size and even distribution throughout the solution.

Preparation of Whey-Chia Seed Edible Film Solution

The mixture of whey, chia seed, and sorbitol was prepared using distilled water, with the volume of the final solution adjusted to 15 mL. The mixture of whey and chia seeds was then treated with a plasticizer, sorbitol, in accordance with the specified protocol. This mixture was subsequently subjected to heating at a temperature of 90˚C ± 2˚C on a hot plate. The application of a magnetic stirrer at a speed of 250 rpm was maintained for a duration of 30 minutes. The film solution was subsequently transferred into a Petri dish and left at room temperature for 24 hours, during which time the gelation time was observed. Following the formation of the edible film, it was wrapped in wrapping paper prior to undergoing further testing. This modification is based on the works of Fahrullah et al. (2020) and Maruddin et al. (2018).

Edible Film Thickness Analysis

The thickness of the edible film was measured using a coupler micrometer model MDC-25M (Mitutoyo, MFG, Japan). The thickness was calculated based on the average of five different points on the film, namely four points at the edge and one point in the centre.

Measurement of Water Vapor Transmission Rate on Edible Film

The water vapor transmission rate (WVTR) was measured by placing the edible film in a desiccator containing silica gel, with measurements taken at 24-hour intervals for a period of five days. The WVTR was calculated in g/mm²/day using the following formula (ASTM E96-95):

$$WVTR = \frac{n}{(t\ x\ A)}$$

Description:

The symbol 'n' is used to denote weight change, measured in grams (g).

The variable t denotes time in days.

The surface area is denoted by A, expressed in millimetres squared.

Microstructure of Edible Film

The microstructure of the edible film was analysed using a JEOL JCM-7000 Scanning Electron Microscope (SEM). The edible film samples were meticulously divided into sections measuring 0.5 × 0.5 cm, subsequently coated with layers of carbon and gold, and examined using a scanning electron microscope (SEM) to ascertain their microstructure.

Statistical Analysis

The treatments comprised the utilisation of sorbitol plasticizer in various concentrations (P1: sorbitol 10%, P2: sorbitol 20%, and P3: sorbitol 30%). The data obtained were analysed using Analysis of Variance (ANOVA), and if there were significant differences between treatments, these were followed by Duncan Multiple Range Test (DMRT) with a p-value of 0.05 using SPSS version 24. Concurrently, the microstructure variable of edible film was analysed descriptively.

RESULTS AND DISCUSSION

Edible Film Thickness Analysis

The thickness of whey-chia seed edible film, with different sorbitol usage, is demonstrated in Figure 1.

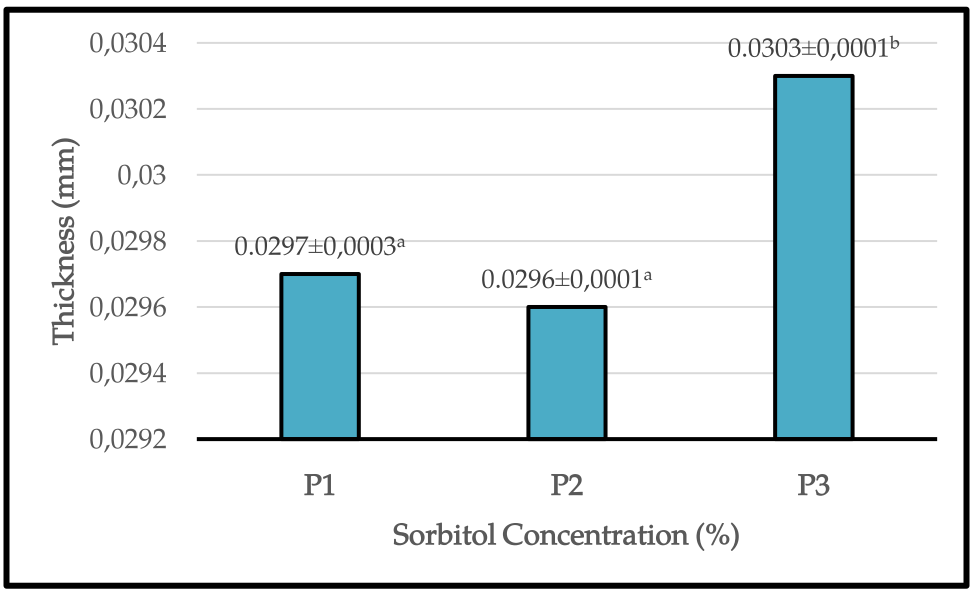

Figure 1. Thickness of whey-chia seed edible film using different concentrations of sorbitol.

The findings of the analysis of variance demonstrate that the utilisation of varying concentrations of sorbitol results in a highly significant discrepancy ($P < 0.01$) in the thickness value of whey-chia seed edible films. The data obtained revealed that the film thickness was recorded at 0.0297 mm at the 10% sorbitol concentration (P1), while at 20% (P2), it slightly decreased to 0.0296 mm, and at 30% (P3), the film thickness increased to 0.0303 mm. Despite the observed increase in thickness, the disparity between concentrations was not substantial, suggesting that at a concentration of 20% (P2), a saturation point may have been attained, wherein the subsequent addition of sorbitol would exert minimal influence on film thickness. This finding aligns with the conclusions of previous research, which demonstrated that plasticizers, such as sorbitol, can enhance film flexibility. However, the impact on the physical thickness of the film does not invariably correspond directly to the plasticizer concentration (Azevedo et al., 2015). Moreover, while sorbitol has been demonstrated to enhance the flexibility and strength of the film, its impact on thickness is more constrained due to sorbitol's propensity to soften the polymer structure of the film. However, this relationship is not invariably direct, as evidenced by the findings of H. Chen et al. As indicated by research undertaken by Capitani et al. (2016), Dick et al. (2016) and Hauser et al. (2016), a relationship has been identified between film thickness and the concentration of polymer added to the film solution. This study demonstrated that a 30% sorbitol concentration (P3) resulted in higher thickness compared to other treatments. The molecules of the plasticizer also have a role in damaging and rearranging the tissue in the film to form empty spaces, so that the plasticizer can enter the cavity in the film matrix, which has an impact on the thickness obtained (Rusli et al., 2017; Sanyang et al., 2016). The thickness of the edible film produced in this study is thinner than the thickness of edible films produced in previous studies using whey base material with the addition of gelatin, which ranged from 0.0350-0.0352 mm (Fahrullah et al., 2023).

Measurement of Water Vapor Transmission Rate on Edible Film

The WVTR of whey-chia seed edible film, with different sorbitol usage, is demonstrated in Figure 2.

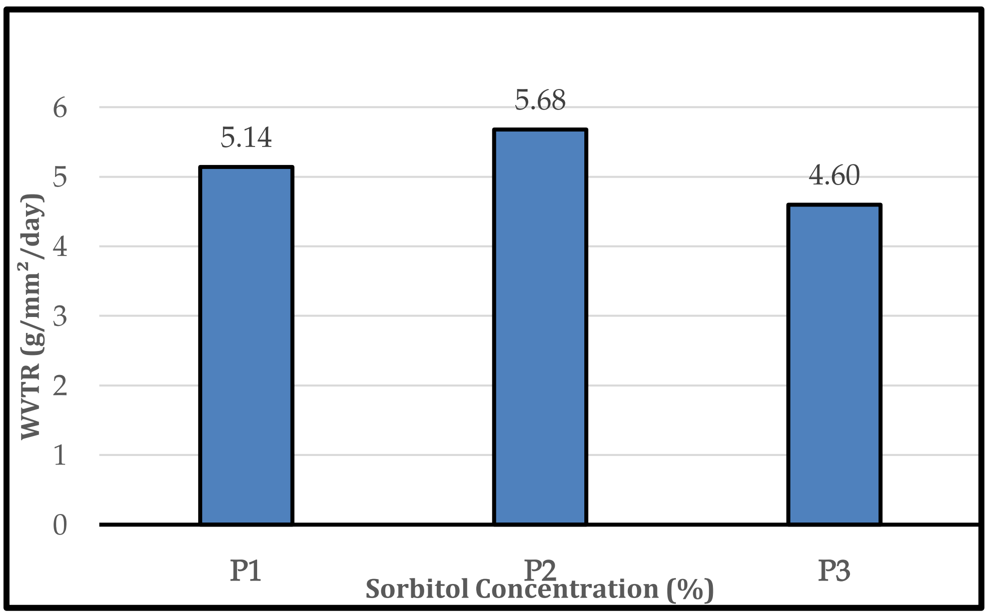

Figure 2. WVTR of whey-chia seed edible film using different concentrations of sorbitol.

Based on the results of the analysis of variance, the use of different concentrations of sorbitol did not give a significant difference ($P>0.05$) to the water vapor transmission rate of whey-chia seed edible film. At 10% sorbitol concentration (P1), the water vapor transmission rate was 5.14 g/mm²/day. At 20% concentration (P2), the water vapor transmission rate increased to 5.68 g/mm²/day, and at 30% concentration (P3), the water vapor transmission rate decreased to 4.60 g/mm²/day. The results of this study are still in accordance with the Japanese Industrial Standard (JIS, 1975) where the maximum value of film water vapor transmission rate is 10 (g/mm²/day). The effect of sorbitol concentration on water vapor transmission rate can be explained by the basic principle that sorbitol functions as a plasticizer that increases film flexibility. More flexible films tend to have more microscopic gaps, which allows water vapor to pass through the film more easily. Therefore, at a sorbitol concentration of 20% (P2), which shows the highest value for water vapor transmission rate, it can be assumed that sorbitol works optimally to increase the flexibility of the film, but in turn will enlarge the pores allowing more water vapor through the film.

However, at a sorbitol concentration of 30% (P3), although there was a slight increase in film thickness (see Figure 1), the water vapor transmission rate decreased. This decline was attributed to the impact of elevated sorbitol concentrations, which likely resulted in the film becoming more dense and reduced its permeability to water vapor (Mihalca et al., 2021). While the film thickness in P3 was higher compared to P1 and P2, this increase in thickness was not always accompanied by an increase in permeability. This may be due to the denser film structure, which can inhibit the water vapor transmission rate. In general, while higher concentrations of sorbitol resulted in increased film thickness, the optimal plasticizer effect on the water vapor transmission rate was observed at a concentration of 30% sorbitol. Sorbitol has a larger molecular size than glycerol (Juliani et al., 2022). This size increase will result in greater free volume between chains, which in turn will affect the transfer of water molecules.

Microstructure of Edible Film

A microstructural investigation was conducted on whey-chia seed edible films, with the objective of comprehending the extent to which the interaction between whey protein and chia seeds, in the presence of varying concentrations of sorbitol, influences the physical characteristics of the film. This investigation focused particularly on the distribution of polymeric materials. The Surface of the film was observed in greater detail by means of a Scanning Electron Microscope (SEM), which revealed the constituent particles of the materials contained in the whey-chia seed film. As Fahrullah & Ervandi (2021) have demonstrated, observation of the microstructure of the film is a vital element in determining its characteristics. The research that has been conducted produces microstructures in Figures 3, 4, and 5 with 1000 times magnification.

As illustrated in Figure 3, the microstructure of whey-chia seed edible films with a 10% sorbitol concentration is characterised by a rough surface with an uneven distribution. While the film retains the fundamental structure of the whey-chia seed polymer, certain regions exhibit a softer consistency and are more susceptible to separation. This distribution of sorbitol contributes to an enhancement in film flexibility. Conversely, a more pronounced structure is evident in specific regions, suggesting a potential increase in the thickness of the film. The mechanism of action of sorbitol is such that it functions by reducing the inter-molecular bonds within the polymer matrix. This results in the creation of micro-spaces, which in turn allow the film to be more flexible. This can be evidenced by the increased porosity and fissuring of the surface texture of the film, indicative of the effectiveness of sorbitol in enhancing the flexibility of the film. However, despite the enhanced flexibility of the film, the structural analysis reveals the presence of more compact and potentially more substantial regions, suggesting the possibility of a marginally increased film thickness. Such tighter areas may reduce the water vapor transmission rate, depending on the interaction between sorbitol and the other polymer matrix (Timilsena et al., 2015). As demonstrated in Figure 4, a concentration of 10% sorbitol appears to be within the optimal range for enhancing flexibility without significantly affecting the thickness of the film. The incorporation of 10% sorbitol has been shown to enhance the mechanical properties of edible films, particularly with regard to flexibility and elasticity. However, the non-uniform distribution of sorbitol within the matrix may have a detrimental effect on other properties, such as water vapor permeability.

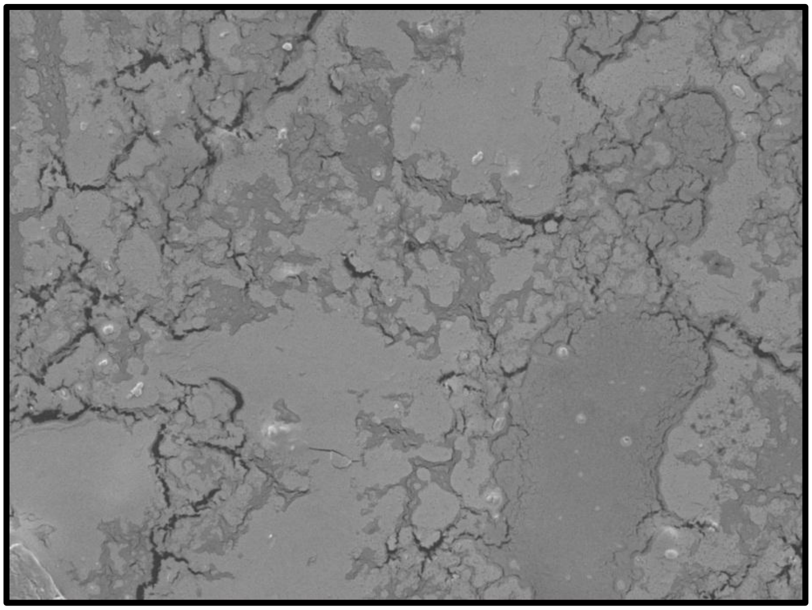

Figure 3. Microstructure of whey-chia seed edible film with 10% sorbitol.

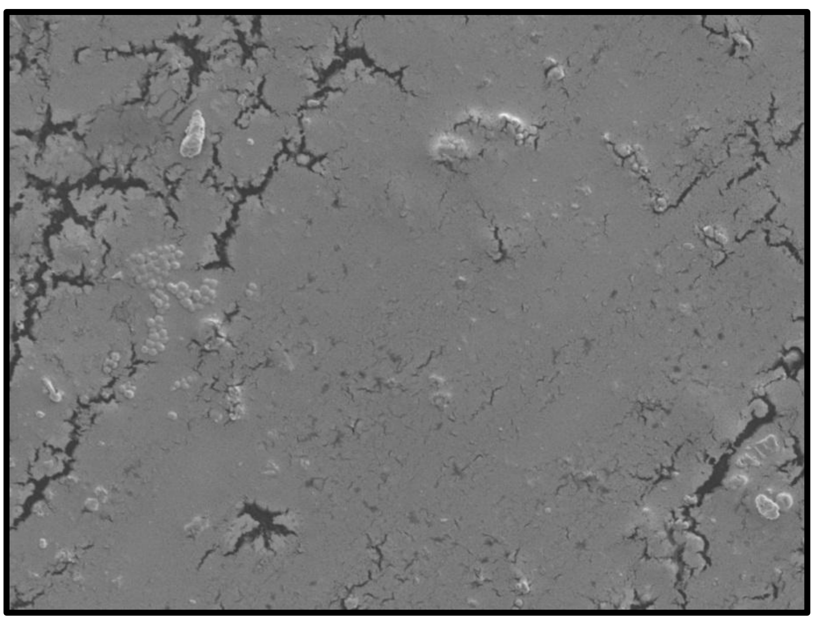

Figure 4. Microstructure of whey-chia seed edible film with 20% sorbitol.

As illustrated in Figure 4, the microstructure of the whey-chia seed edible film prepared with a 20% sorbitol concentration exhibits substantial alterations in comparison to the film constructed with a lower sorbitol concentration. As illustrated in Figure 4, the microstructure appears to be smoother, exhibiting a more uniform distribution of sorbitol. However, there are still some areas that demonstrate signs of looseness and the presence of small pores. This phenomenon can be attributed to the effect of sorbitol, which has been demonstrated to enhance the flexibility of the film and modify its distribution. The incorporation of 20% sorbitol resulted in a film that exhibited enhanced flexibility, characterised by an increased prevalence of microscopic gaps or spaces when compared to the 10% concentration. These microspaces indicate that sorbitol plays an effective role in softening the film structure, allowing the film to be more flexible and elastic (Liang & Wang, 2018). However, despite the increased stretchability and more even distribution of sorbitol, the film still retains some basic properties that allow for improvements in film thickness. Notwithstanding the negligible alterations in thickness observed when juxtaposed with the 10% sorbitol film, the presence of augmented interstices may exert an influence on additional properties, including the film's permeability to water vapor. Sorbitol 20% has been demonstrated to offer a superior equilibrium between flexibility and thickness, thereby ensuring optimal performance in a range of packaging applications. As demonstrated in Figure 4, the incorporation of 20% sorbitol into whey-chia seed edible films results in a more flexible and uniform structure, which may enhance the functional properties of the film.

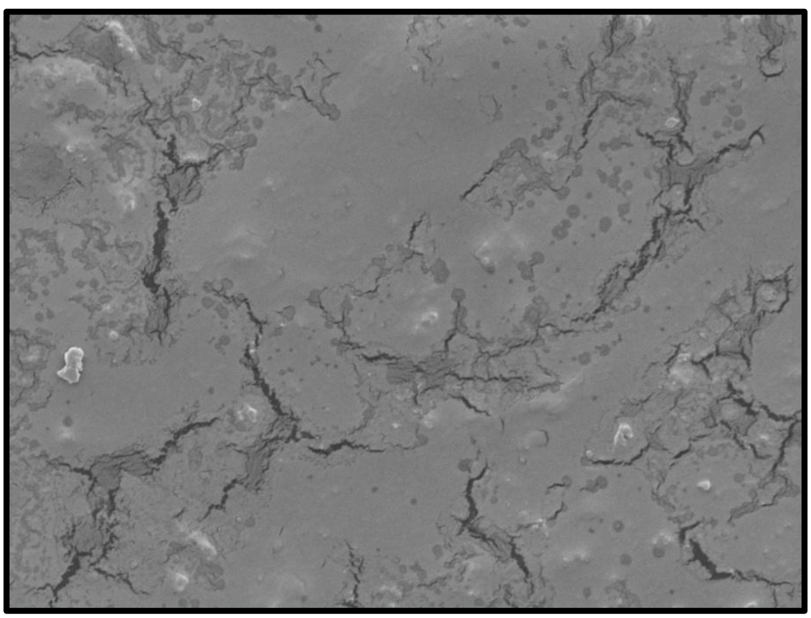

Figure 5. Microstructure of whey-chia seed edible film with 30% sorbitol.

As illustrated in Figure 5, the microstructure of whey-chia seed edible films prepared with a 30% sorbitol concentration exhibited a significant alteration in comparison to films with lower sorbitol concentrations (10 and 20%). In this figure, the film structure appears denser, with a more focused distribution of sorbitol in a few areas, leading to the appearance of a tighter surface and fewer microspaces compared to films with 10% and 20% sorbitol. The incorporation of 30%

sorbitol has been demonstrated to result in a substantial enhancement of the film's cohesion, manifesting as a notable reduction in microscopic gaps. This observation suggests that elevated sorbitol concentrations may enhance the viscosity and density of the resulting film, potentially resulting in a decrease in micro-spaces within the polymer matrix. Despite the increased thickness of the film (Figure 1), the reduction in the number of gaps could potentially result in a decrease in the water vapor transmission rate (Figure 2). This is due to the enhanced difficulty of water vapor movement through a more compact structure. This phenomenon may provide a rationale for the observed decline in water vapor transmission rate at 30% sorbitol, despite the concomitant increase in film thickness. This denser structure could also indicate that sorbitol functions more as a binder between the polymers than as a plasticizer, leading to a reduction in film flexibility. In summary, the incorporation of additional sorbitol has been demonstrated to exert a multifaceted influence on the material's properties. Not only does it affect flexibility, but it also modifies the manner in which the film engages with other components, thereby influencing its capacity to absorb moisture or establish barriers (Chen et al., 2024).

The microstructure of the film is influenced by several factors. Firstly, the heating process has a significant impact on the microstructure. Secondly, the homogenisation process also has an effect. Thirdly, the emulsion composition is also important. Finally, the arrangement of component structures in the final stage of drying is also important. Sorbitol functions as a plasticizer, which serves to widen the intermolecular distance in the film structure by reducing internal hydrogen bonds. The incorporation of plasticizer in the fabrication of edible film is intended to impart flexible properties to the film and curtail the interaction between protein chains, thereby enhancing the flexibility of the film. The selection of type and concentration of plasticizer exerts a substantial influence on the mechanical properties and permeability of the film (Fahrullah et al., 2024).

CONCLUSIONS

The present study demonstrated that the incorporation of sorbitol during the fabrication of whey-chia seed edible films had a significant impact on the thickness and microstructure of the resultant edible films. The film thickness increased with the increase of sorbitol concentration, but the change between concentrations was not significant. The highest water vapor transmission rate was found at 20% sorbitol concentration, while at 30% concentration, although the film thickness increased, the water vapor transmission rate decreased. Microscopic analysis revealed that the incorporation of sorbitol resulted in enhanced flexibility and a more uniform distribution at concentrations of 10% and 20%. However, at the 30% concentration, the films exhibited increased rigidity and reduced flexibility. It was established that the optimal concentration of sorbitol for the manufacture of edible films was 20%, since this concentration provided the best balance between thickness, flexibility and permeability.

REFERENCES

Aleksanyan KV. 2023. Polysaccharides for biodegradable packaging materials: past, present, and future (Brief Review). *Polymers,* 15 (2). https://doi.org/10.3390/polym15020451

ASTM E96-95.Standard Test Method for Water Vapor Transmission of Materials.

Azevedo VM., Silva EK., Pereira, CFG, da Costa, JMG., & Borges, SV. 2015. Whey protein isolate biodegradable films: Influence of the citric acid and montmorillonite clay nanoparticles on the physical properties. *Food Hydrocolloids*, 43. https://doi.org/10.1016/j.foodhyd.2014.05.027

Capitani MI., Matus-Basto A., Ruiz-Ruiz, J. C., Santiago-García, J. L., Betancur-Ancona, D. A., Nolasco, S. M., Tomás, M. C., & Segura-Campos, M. R. 2016. Characterization of biodegradable films based on Salvia hispanica L. protein and mucilage. *Food and Bioprocess Technology*, 9 (8). https://doi.org/10.1007/s11947-016-1717-y

Carpena M., Nuñez-Estevez B., Soria-Lopez A., Garcia-Oliveira,P., & Prieto MA. 2021. Essential oils and their application on active packaging systems: A review. *Resources,* 10(1). https://doi.org/10.3390/resources10010007

Chang C., & Nickerson MT. 2014. Effect of plasticizer-type and genipin on the mechanical, optical, and water vapor barrier properties of canola protein isolate-based edible films. *European Food Research and Technology*, 238 (1). https://doi.org/10.1007/s00217-013-2075-x

Chaves MA., Piati J., Malacarne LT., Gall RE., Colla E., Bittencourt PR.S., de Souza AHP., Gomes, STM., & Matsushita M. 2018. Extraction and application of chia mucilage (*Salvia hispanica* L.) and locust bean gum (*Ceratonia siliqua* L.) in goat milk frozen dessert. *Journal of Food Science and Technology*, 55 (10). https://doi.org/10.1007/s13197-018-3344-2

Chen H., Wang J., Cheng Y., Wang C., Liu H., Bian H., Pan Y., Sun J., & Han W. 2019. Application of protein-based films and coatings for food packaging: A review. *Polymers*, 11 (12). https://doi.org/10.3390/polym11122039

Chen Y., Wang J., Xu L., Nie Y., Ye Y., Qian J., Liu F., & Zhang L. 2024. Effects of different plasticizers on the structure, physical properties and film forming performance of curdlan edible films. *Foods*, 13 (23). https://doi.org/10.3390/foods13233930

Chollakup R., Pongburoos S., Boonsong W., Khanoonkon N., Kongsin K., Sothornvit R., Sukyai P., Sukatta U., & Harnkarnsujarit N. 2020. Antioxidant and antibacterial activities of cassava starch and whey protein blend films containing rambutan peel extract and cinnamon oil for active packaging. *LWT*, *130*. https://doi.org/10.1016/j.lwt.2020.109573

de Dicastillo C., Rodríguez F., Guarda A., & Galotto MJ. 2016. Antioxidant films based on cross-linked methyl cellulose and native Chilean berry for food packaging applications. *Carbohydrate Polymers,* (136). https://doi.org/10.1016/j.carbpol.2015.10.013

Dick M., Pagno CH., Costa, TH. M., Gomaa A., Subirade M., Rios AO., & Flôres, SH. 2016. Edible films based on chia flour: Development and characterization. *Journal of Applied Polymer Science*, 133 (2). https://doi.org/10.1002/app.42455

Fahrullah F., Radiati, LE., Purwadi P, & Rosyidi, D. 2020. The physical characteristics of whey based edible film added with konjac. *Current Research in Nutrition and Food Science*, 8 (1). https://doi.org/10.12944/CRNFSJ.8.1.31

Fahrullah F., & Ervandi M. 2021. Mikrostruktur edible film whey dangke dengan penambahan karagenan dan plasticizer sorbitol 35%. *Jurnal Ilmu dan Teknologi Peternakan Tropis*, 6 (2): 26–31. https://doi.org/10.33772/jitro.v8i1.14785

Fahrullah F., Kisworo D., Bulkaini B., Haryanto H., Wulandani BRD., Yulianto W., Noersidiq A., & Maslami V. 2023. The effects of plasticizer types on properties of whey-gelatin films. *Jurnal Biologi Tropis*, 23 (3): 414–421. https://doi.org/10.29303/jbt.v23i3.5283

Fahrullah F., Kisworo D., & Noersidiq A. 2023. Edible film based on whey-chia seed: physical characterization with addition of different plasticizers. *Jurnal Penelitian Pendidikan IPA*, 9 (10): 8554–8562. https://doi.org/10.29303/jppipa.v9i10.4978

Fahrullah F., Noersidiq A., Kisworo D., & Maruddin F. 2024. Evaluating physicochemical properties of whey-chia seed edible films for biodegradable packaging. *Tropical Animal Science Journal*, 47 (4); 519–528. https://doi.org/10.5398/TASJ.2024.47.4.519

Fahrullah F., Noersidiq A., & Maruddin F. 2022. Effects of Glycerol Plasticizer on Physical Characteristic of Whey-Konjac Films Enriched with Clove Essential Oil. *Journal of Food Quality and Hazards Control*, 9, 226–233. https://doi.org/10.18502/jfqhc.9.4.11377

Haq M. A., Jafri F. A., & Hasnain A. 2016. Effects of plasticizers on sorption and optical properties of gum cordia based edible film. *Journal of Food Science and Technology*, 53 (6). https://doi.org/10.1007/s13197-016-2227-7

Hauser C., Peñaloza A., Guarda A., Galotto MJ., Bruna JE., & Rodríguez FJ. 2016. Development of an active packaging film based on a methylcellulose coating containing murta (*Ugni molinae* Turcz) leaf extract. *Food and Bioprocess Technology*, 9 (2). https://doi.org/10.1007/s11947-015-1623-8

Juliani D., Suyatma NE., & Taqi FM. 2022. Pengaruh waktu pemanasan, jenis dan konsentrasi plasticizer terhadap karakteristik edible film K-Karagenan. *Jurnal Keteknikan Pertanian*, 10 (1). https://doi.org/10.19028/jtep.010.1.29-40

Khazaei N., Esmaiili M., Djomeh ZE., Ghasemlou M., & Jouki M. 2014. Characterization of new biodegradable edible film made from basil seed (*Ocimum basilicum* L.) gum. *Carbohydrate Polymers*, 102 (1). https://doi.org/10.1016/j.carbpol.2013.10.062

Liang T., & Wang L. 2018. Preparation and characterization of a novel edible film based on *Artemisia sphaerocephala* Krasch. gum: Effects of type and concentration of plasticizers. *Food Hydrocolloids*, 77. https://doi.org/10.1016/j.foodhyd.2017.10.028

Maruddin F., Ratmawati R., Fahrullah F., & Taufik M. 2018. Karakterisitik Edible film berbahan whey dangke dengan penambahan karagenan. *Jurnal Veteriner*, 19 (2). https://doi.org/10.19087/jveteriner.2018.19.2.291

Mihalca V., Kerezsi AD., Weber A., Gruber-traub C., Schmucker J., Vodnar DC., Dulf FV., Socaci SA., Fărcaș A., Mureșan CI., Suharoschi R., & Pop OL. 2021. Protein-based films and coatings for food industry applications. *Polymers,* 13(5). https://doi.org/10.3390/polym13050769

Mishra D., Khare P., Singh DK., Luqman S., Kumar, PVA., Yadav A., Das T., & Saikia BK. 2018. Retention of antibacterial and antioxidant properties of lemongrass oil loaded on cellulose nanofibre-poly ethylene glycol composite. *Industrial Crops and Products*, 114. https://doi.org/10.1016/j.indcrop.2018.01.077

Otoni CG., Avena-Bustillos RJ., Azeredo HMC., Lorevice MV., Moura MR., Mattoso LHC., & McHugh TH. 2017. Recent advances on edible films based on fruits and vegetables-A Review. *Comprehensive Reviews in Food Science and Food Safety*, 16 (5). https://doi.org/10.1111/1541-4337.12281

Rusli A., Metusalach M., Salengke S., & Tahir MM. 2017. Karakterisasi edible film karagenan dengan pemlastis gliserol. *Jphpi*, 20 (2): 219-229.

Sanyang ML., Sapuan SM., Jawaid M., Ishak MR., & Sahari J. 2016. Effect of plasticizer type and concentration on physical properties of biodegradable films based on sugar palm (*Arenga pinnata*) starch for food packaging. *Journal of Food Science and Technology*, 53 (1). https://doi.org/10.1007/s13197-015-2009-7

Soukoulis C., Gaiani C., & Hoffmann L. 2018. Plant seed mucilage as emerging biopolymer in food industry applications. *Current Opinion in Food Science,* 22. https://doi.org/10.1016/j.cofs.2018.01.004

Timilsena YP., Adhikari R., Kasapis S., & Adhikari B. 2015. Rheological and microstructural properties of the chia seed polysaccharide. *International Journal of Biological Macromolecules*, 81. https://doi.org/10.1016/j.ijbiomac.2015.09.040

Hasan, V, A. K., Mangaraj, M., S., M, P., Verma, D. K., & Srivastav, P. P. (2022). Trends in edible packaging films and its prospective future in food: A Review. *Applied Food Research*, 2 (1). https://doi.org/10.1016/j.afres.2022.100118

Zettel V., & Hitzmann B. 2018. Applications of chia (*Salvia hispanica* L.) in food products. *Trends in Food Science and Technology,* 80. https://doi.org/10.1016/j.tifs.2018.07.011

Zhang W., Azizi-Lalabadi M., Jafarzadeh S., & Jafari S. M. 2023. Starch-gelatin blend films: A promising approach for high-performance degradable food packaging. *Carbohydrate Polymers*, 320. https://doi.org/10.1016/j.carbpol.2023.121266