



Characteristics and Application of Edible Film from Durian Seed-corn Starch with Butterfly Pea Flower Extract

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ABSTRACT

Background: Plastic packaging significantly contributes to environmental waste, highlighting the need for biodegradable alternatives like edible films. This study investigates the effect of butterfly pea flower (*Clitoria ternatea*) extract, recognized for its antioxidant properties, alongside different concentrations of sorbitol as a plasticiser, on the mechanical, chemical and sensory attributes of edible films used for beef sausage coatings.

Methods: The study employed a non-factorial randomized block design to evaluate eight treatment combinations of sorbitol concentrations (10% and 14% v/v) and Butterfly Pea flower extract levels (0, 4%, 6% and 8% v/v). The product's chemical and mechanical properties were assessed through tests such as antioxidant activity, moisture content, pH, thickness, elongation and tensile strength. Statistical analysis using ANOVA, Tukey, Friedman methods and de Garmo index identified significant differences in formulations.

Result: The optimal treatment involved a combination of T2S2 treatment, comprising 4% butterfly pea flower extract and 14% sorbitol. The parameters recorded were as follows: antioxidant activity 148.83 ppm, moisture content 12.47%, thickness 0.178 mm, elongation 34.15%, tensile strength 0.0071 MPa, pH 7.5, color rating 3.56 (neutral), taste 4 (like), texture 3.52 (neutral) and aroma 3.64 (neutral). Thus, the distinct formulation in this study produces a biodegradable film layer rich in antioxidants that has applications in sustainable food packaging.

Key words: Corn starch, Durian seed starch, Edible film, Sorbitol.

INTRODUCTION

Mismanagement of plastic waste has resulted in considerable environmental and public health issues. Insufficient recycling methods and the incineration of plastics can emit hazardous compounds, such as dioxins, which are produced during the degradation of plastic materials. Dioxins are linked to serious health issues such as liver inflammation, cancer, hepatitis and neurological disorders (Ratnawati, 2020). Plastic waste obstructs water systems, leading to heightened risks of flooding. Consequently, there is an increasing demand for sustainable alternatives to plastic packaging, including edible films, which pose fewer risks to human health and the environment (Jyothsna and Nair, 2024; Utami and Swasono, 2024).

Edible films are thin, consumable layers derived from natural food ingredients and represent a viable alternative to conventional plastic packaging. Their advantages include biodegradability, utilization of renewable materials and the capacity to regulate the transfer of air, carbon dioxide, moisture, aromas and other solutes from food products (Iversen *et al.*, 2022; Hazarika *et al.*, 2023). Films are generally composed of three primary material types: lipids, composites and hydrocolloids (Widayanti *et al.*, 2022). Hydrocolloid-based polysaccharides, particularly starch, are favored due to their capacity to enhance film thickness and function as effective air barriers (Bisht *et al.*, 2022). Starch-based films, particularly those with high amylose content, exhibit moisture resistance and rapid degradation, rendering them well-suited for food packaging applications.

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Durian (*Durio zibethinus*) seed starch and corn (*Zea mays*) starch are high in starch content 66.49% and 72.40%, respectively which makes them ideal for edible film production and economical to source (Gamay *et al.*, 2024; Pi *et al.*, 2025). The combination of durian seed and corn starch utilizes the distinct properties of each starch: corn starch, characterized by its high amylose content, improves film formation and strength, whereas durian seed starch, as an agricultural byproduct, offers a cost-effective and plentiful alternative. They collaboratively create a film characterized by enhanced flexibility, durability and cost efficiency.

Sorbitol, a naturally sweet plasticizer, is used in starch-based edible films to improve their flexibility and mechanical properties (Kumar *et al.*, 2022). Carboxy methyl cellulose (CMC) serves as a stabilizer, enhancing the film's

texture, thickness and stability (Habib *et al.*, 2024). This study presents a novel approach by combining durian seed and corn starch with sorbitol in optimized ratios, building on previous research on edible films made solely from durian seed starch and sorbitol. Butterfly pea flower (*Clitoria ternatea*) extract, rich in flavonoid levels, enhances the film's functional properties by providing antioxidant activity. This enhances the shelf life of packaged foods by inhibiting lipid oxidation, preserving food quality and extending freshness (Zhao *et al.*, 2019). The antioxidant properties of butterfly pea make it an ideal choice for packaging solutions requiring protection from oxidation.

This study aims to develop an edible film utilizing a combination of durian seed, corn starch, sorbitol and butterfly pea flower extract. This study evaluates the mechanical, chemical and sensory properties of the film and assesses its effectiveness as a coating for beef sausage products. The innovation is found in the distinct formulation of durian seed starch, corn starch, sorbitol and butterfly pea extract, resulting in a biodegradable, antioxidant-rich edible film that may have applications in sustainable food packaging.

MATERIALS AND METHODS

The study used a non-factorial randomized block design (RBD) to assess the effects of butterfly pea flower extract and sorbitol on the properties of edible films. The initial factor, butterfly pea flower extract, was utilized at concentrations of 0%, 4%, 6% and 8% (v/v), selected for their antioxidant properties and influence on film structure. The second factor, sorbitol, was applied at 10% and 14% (v/v) to enhance film flexibility. The extract was used for its antioxidant properties and film structure, while sorbitol was applied for film flexibility. Eight treatment combinations were tested, with RBD controlling potential variability.

Preparation of durian seed starch

Durian seeds were washed and peeled, then cut into thin slices 2 cm. The sliced durian seeds were soaked with CaCO_3 as much as 5% (b/v) for 12 h to remove mucus from durian seeds. After the durian seeds are smooth, the next is filtered with a filter cloth to separate the starch from the water-insoluble components. During the precipitation process, sodium metabisulphite ($\text{Na}_2\text{S}_2\text{O}_5$) was added as much as 0.5% of the weight of durian seeds. Furthermore, the starch was dried using an oven at 50°C for 6 h. The dried starch is powdered in a mortar and sieved through a No. 80 (Rahmawati *et al.*, 2022).

Extraction of butterfly pea flowers

The extraction of butterfly pea flowers began by cutting fresh Butterfly Pea flowers into small pieces and 3 g of the flowers were weighed. The flowers were then brewed with 100 ml of distilled water, a polar solvent, at 60°C for 10 min. During heating, 0.7 g of citric acid was added to the solution. Citric acid prevents the decomposition of phytochemical compounds during the extraction process (Jeyaraj *et al.*, 2021).

Preparation of Edible film

Durian seed and corn starch were weighed as much as 10 g, dissolved in 100 ml of distilled water at a 80°C and stirred until homogeneous. When the temperature reached 60°C, 10%, 14% (v/v) sorbitol plasticiser and 2% CMC of the total starch concentration were added. A concentration of 0, 4%, 6%, 8% (v/v) Butterfly Pea flower extract was added to the solution at 80°C. The following process was the gelatinisation process, which lasted for 10 min. The cooked edible film solution was cooled to a temperature of $\pm 40^\circ\text{C}$ to remove the remaining oxygen trapped in the solution due to the heating process. Then, the solution was poured on edible film moulds measuring 18.5 × 18.5 cm. The casted solution was dried using an oven at 40°C for 7 h until plastic. The finished edible film was cooled at room temperature to facilitate release from the mould (Rahmawati *et al.*, 2022; Chandla *et al.*, 2025).

Application of Edible film for coating on sausage products

First, remove the sausage from its wrapper. Prepare the edible film solution by varying the butterfly pea extract and sorbitol concentrations according to the treatment combinations. Each sausage is coated by dipping it into the edible film solution for 5 min. After dipping, the sausages are removed from the solution, drained, then a hair dryer is used at 40°C for 35 min to dry, protecting the product from heat damage. Repeat the coating process twice to ensure that all sausage parts are evenly coated (Prakoso *et al.*, 2023).

Data analysis

The chemical and mechanical properties of edible films made from durian seed starch and corn starch were evaluated using various tests: antioxidant activity through the IC_{50} DPPH method (Widayanti, 2022), moisture content analysis (Nofiandi *et al.*, 2016), pH measurement with a Hanna pH tester (Rahmawati *et al.*, 2021), thickness measurement using digital callipers accurate to 0.01 mm (Rahmawati *et al.*, 2021) and elongation and tensile strength tests using a universal testing machine (Sasongko, 2024). Organoleptic properties were assessed by having 25 untrained panellists evaluate the colour, taste, aroma and texture of sausages coated with the edible films, using a hedonic scale of 1-5 (from "dislike" to "like very much"). The study evaluated the chemical and mechanical properties of edible films made from durian seed and corn starch using various tests, including antioxidant activity, moisture content analysis (Nofiandi *et al.*, 2016), pH measurement (Rahmawati *et al.*, 2021), thickness measurement and elongation and tensile strength tests. The organoleptic properties were assessed by 25 untrained panellists, who evaluated the color, taste, aroma and texture of sausages coated with the films. Data from mechanical and chemical tests were analysed using Minitab 19 software to perform an Analysis of Variance (ANOVA), with significant differences identified using the Tukey method at a 95% confidence level ($\alpha=0.05$).

Organoleptic test data were analysed using the Friedman method at a 5% significance level. The de garmo effectiveness index test was utilized to identify the optimal treatment among various formulations. This method synthesizes multiple criteria from mechanical, chemical and organoleptic results to ascertain the most effective treatment overall. This comprehensive analysis identified the optimal treatment, which was subsequently investigated through scanning electron microscopy (SEM) to assess the microstructure of the edible film.

RESULTS AND DISCUSSION

Chemical characteristics

The study evaluates the chemical properties of edible films using Butterfly Pea flower extract and sorbitol, focusing on antioxidant activity, pH and moisture content, to evaluate their functional qualities and initial application in food product protection. Table 1 presents comprehensive data on the chemical characteristics, elucidating the performance of edible films across various formulations.

Antioxidant activity IC_{50}

The study found that edible films containing different concentrations of butterfly pea flower extract and sorbitol showed moderate antioxidant activity. Control treatments (T1S1 and T1S2) exhibited weak activity due to the lack of Butterfly Pea extract. The IC_{50} values decreased with increasing concentrations of Butterfly Pea extract, with T4S1 and T4S2 showing the highest antioxidant capacities. This indicates a positive relationship between the concentration of Butterfly Pea extract and its antioxidant capacity, as active anthocyanin compounds stabilize free radicals and reduce oxidative potential (Gew *et al.*, 2024). Control films (T1S1 and T1S2) had weak antioxidant activity. Antioxidant strength is classified based on IC_{50} values: 50-100 ppm is vital, 100-150 ppm is moderate and values exceeding 150 ppm are weak (Cui *et al.*, 2021; Nurjannah, 2022). Incorporating butterfly pea extract significantly enhances the antioxidant activity of edible films, offering potential for applications in food packaging where oxidative protection is essential for prolonging product freshness and shelf life.

Moisture content

The moisture content of edible films, ranging from 12.6% to 13.38%, is crucial for assessing their effectiveness in microbial resistance and structural stability. Treatment T4S2, containing 8% butterfly pea flower extract and 14% sorbitol, had the highest moisture content at 13.38%, while T1S1 had the lowest at 12.6%. This is due to hydrophilic components improving water retention. Sorbitol, a plasticizer in edible films, increases water retention by increasing film flexibility but also increases moisture content, potentially affecting microbial stability. Hydrophilic films, primarily starch and CMC, increase moisture content due to free hydroxyl groups interacting with water (Rahmawati *et al.*, 2019). Research shows that films with higher hydrophilic components have better water retention (Widayanti *et al.*, 2022). Thickness also influences moisture levels, with thicker films showing higher moisture content due to increased film matrix volume.

pH

The study found that the pH values of edible films ranged from 7.1 to 7.85, with a minor decrease with higher concentrations of butterfly pea flower extract. This is likely due to the acidic properties of anthocyanins and phenolic compounds in the extract (Narayanan *et al.*, 2023). Elevated sorbitol concentrations also affected the pH. A neutral to slightly acidic pH range is beneficial for edible films, as it preserves bioactive compounds' stability and inhibits microbial growth (Wang *et al.*, 2024). Maintaining pH near neutrality enhances compatibility with food products, minimizing potential effects on taste or quality. The pH range suggests edible films are suitable for food coatings, providing protective and preservative benefits while maintaining food's organoleptic qualities.

Mechanical characteristics

The mechanical properties of active edible films are examined, focusing on thickness, tensile strength and elongation tests Table 2. Mechanical testing of edible films assesses their durability for use as protective coatings on food products.

Table 1: Chemical characteristics of active edible film from durian seed-corn starch.

Treatment code	Treatment		Parameters		
	Butterfly pea flower extract (%)	Sorbitol (%)	Antioxidant activity IC_{50} (ppm)	Moisture content (%)	pH
T1S1	0	10	154.465±0.813 ^b	12.6±0.990 ^d	7.85±0.070 ^a
T2S1	4		132.135±0.211 ^d	12.9±0.919 ^c	7.55±0.212 ^{ab}
T3S1	6		122.23±0.424 ^e	13.2±0.354 ^c	7.2±0.004 ^{cd}
T4S1	8		101.73±0.254 ^g	13.31±0.636 ^{cd}	7.1±0.006 ^d
T1S2	0	14	164.695±0.516 ^a	12.31±0.636 ^{bc}	7.75±0.070 ^{ab}
T2S2	4		148.83±0.693 ^c	12.47±0.919 ^{abc}	7.5±0.008 ^{bc}
T3S2	6		131.6±0.042 ^d	13.20±0.566 ^{ab}	7.2±0.006 ^{cd}
T4S2	8		117.265±0.261 ^f	13.38±0.495 ^a	7.1±0.005 ^d

Notes: Different superscript letters denote statistically significant differences ($p < 0.05$).

Thickness

This study produced edible films with thicknesses ranging from 0.119 mm (T1S1) to 0.207 mm (T4S2) (Table 2), all meeting the Japanese Industrial Standard, (1975) maximum thickness of 0.25 mm. The thickness increase was observed with higher concentrations of sorbitol and butterfly pea flower extract, due to the elevated solid content in the film formulation. Sorbitol, acting as a plasticiser, likely increased film thickness by enhancing polymer chain mobility and molecular cohesion (Widayanti *et al.*, 2022). The T4S2 treatment, with the highest concentrations of sorbitol and Butterfly Pea flower extract, produced the thickest edible film at 0.207 mm. Increased thickness can improve barrier properties, but may negatively affect mechanical properties like flexibility and tensile strength (Ballesteros-Márquez *et al.*, 2020). The thickness values demonstrate the appropriateness of these edible films for food coating applications, offering sufficient barrier protection while adhering to JIS's maximum standards.

Tensile strength

Tensile strength refers to the maximum pulling force a film can withstand before failure (Chandla *et al.*, 2020). The tensile strength of edible film incorporating Butterfly Pea flower extract and sorbitol treatments varied between 0.0051 and 0.0093 MPa. The highest tensile strength was observed in the treatment combination T1S1, which consisted of 0% Butterfly Pea flower extract and 10% sorbitol (Table 2). The minimum tensile strength value standard for edible film is 0.3 MPa according to the Japanese Industrial Standard, (1975). However, all active films did not meet this standard, indicating a relatively low tensile strength (Rahmawati *et al.*, 2022). The presence of soluble solids can result in stronger cross-links in starch polymers, affecting the strength required to break these films. Adding plasticizers can reduce the film's stiffness and lower its tensile strength. The tensile strength of potato starch edible film peaked at 9.26 MPa with a sorbitol concentration of 0.6% (v/v), then declined to 4.12 MPa at a concentration of 1.2% sorbitol (Ramdhani *et al.*, 2022).

The addition of antioxidants from butterfly pea flower extract also affected the decrease in tensile strength value.

Elongation

The elongation percentage of edible film is a measure of its quality, indicating its elasticity and resistance to tearing. The elongation percentage is determined by the ratio between the initial and final elongation changes of the film. The average elongation percentage on edible film with a combination of butterfly pea flower extract concentration and sorbitol ranges from 10.61-36.5%. The T4S2 treatment, which contains 8% Butterfly Pea flower extract and 14% sorbitol, yields the highest elongation percentage at 36.5%, while the T1S1 treatment, which contains 0% and 10% sorbitol, has the lowest at 10.61% (Table 2). The percentage of edible film elongation is considered poor if less than 10% and excellent if exceeding 50%. The combination of butterfly pea flower extract concentration and sorbitol significantly differs from the percentage elongation of edible film. Sorbitol can make the film structure more flexible and soft by increasing the distance between molecules and reducing hydrogen bonds (Julianto, 2011).

Organoleptic test results

Flavour

A study conducted by 25 untrained panellists revealed that the taste of edible film applied to sausages varied between 2.68 and 4 (dislike). The lowest value was 2.68 from the T2S1 treatment, while the highest was 4 from the T3S2 treatment (Fig 1). The panellists' responsibilities in acceptability treatment were significant, with the highest value being 4 from the T3S2 treatment. The difference was due to the amount of sorbitol and butterfly pea extract given and the thickness of the film. The panellists found that the taste of an edible film with butterfly pea flower extract and sorbitol was sweet, depending on the amount of sorbitol added (Sasongko and Agustina, 2024).

Aroma

The study analyzed the aroma of an edible film coated with butterfly pea flower extract and sorbitol on 25 panellists

Table 2: Mechanical characteristics of active edible film from durian seed-corn starch.

Treatment code	Treatment		Parameters		
	Butterfly pea flower extract (%)	Sorbitol (%)	Thickness (mm)	Tensile strength (MPa)	Elongation (%)
T1S1	0	10	0.119±0.001 ^d	0.0093±0.007 ^a	10.61±0.863 ^d
T2S1	4		0.124±0.003 ^d	0.0091±0.007 ^a	19.165±0.757 ^c
T3S1	6		0.152±0.002 ^c	0.0090±0.003 ^{ba}	21.96±0.481 ^{bc}
T4S1	8		0.157±0.007 ^c	0.0082±0.002 ^b	23.19±0.64 ^{3b}
T1S2	0	14	0.176±0.003 ^b	0.0080±0.001 ^b	24.55±0.707 ^b
T2S2	4		0.178±0.023 ^b	0.0071±0.001 ^c	34.15±0.693 ^a
T3S2	6		0.200±0.006 ^a	0.0060±0.002 ^d	35.50±0.707 ^a
T4S2	8		0.207±0.001 ^a	0.0051±0.003 ^e	36.50±0.707 ^a

Notes: Different superscript letters denote statistically significant differences ($p < 0.05$).

(Fig 2). The panellists' average liking value for the film ranged from 3-3.64 (neutral). The treatment combination T1S1, which contained 0% butterfly pea flower extract and 10% sorbitol, had the lowest value of 3. The highest value was 3.64. Statistical testing showed no significant difference in panellist responses to aroma. However, the application of edible film to beef sausage produced a less strong aroma, making it difficult for panellists to assess. This aligns with Husna *et al.* (2022) research, which found that extracts from Butterfly Pea flowers do not contain aromas that allow panellists to identify the aroma they produce.

Colour

The organoleptic evaluation of 25 panellists revealed a preference for the colour of an edible film with Butterfly Pea flower extract and sorbitol, ranging from 2.88 to 3.56. The lowest value was recorded at 2.88, indicating neutrality, while the highest value was 3.56, indicating neutrality. The Friedman test results showed no significant difference in panellists' acceptance of the film colour. The lowest rating was given to the treatment combination T1S1 (0% butterfly pea flower extract and 10% sorbitol), as the resulting film color was pale (Fig 3). The treatment combination T2S2

(4% butterfly pea flower extract and 14% sorbitol) produced a stable, not too pale and intense color, not affecting the appearance of sausage products without edible coating. This stability is due to the 4% concentration of Butterfly Pea flower extract, which results in a lower pH value, allowing optimal dye binding (Palimbong and Pariama, 2020). The difference in colour assessment was not significant due to the effect of adding anthocyanin compounds and the thickness of the coating. The greater the concentration of Butterfly Pea flower extract, the darker the edible film's color.

Texture

The results of organoleptic analysis of 25 untrained panellists showed that the assessment of the texture of edible film with the addition of butterfly pea flower extract and sorbitol ranged from 2.92-3.8 (neutral-love). The average favourability of edible film texture can be seen in Fig 4. The lowest score was for the T1S1 treatment, which had a hard and stiff texture due to retrogradation during cooling. The highest score was for the T4S2 treatment, which had a chewy and stable texture. The study suggests that adding sorbitol in large quantities can reduce the hard texture in starch. The intricate texture of edible films is due

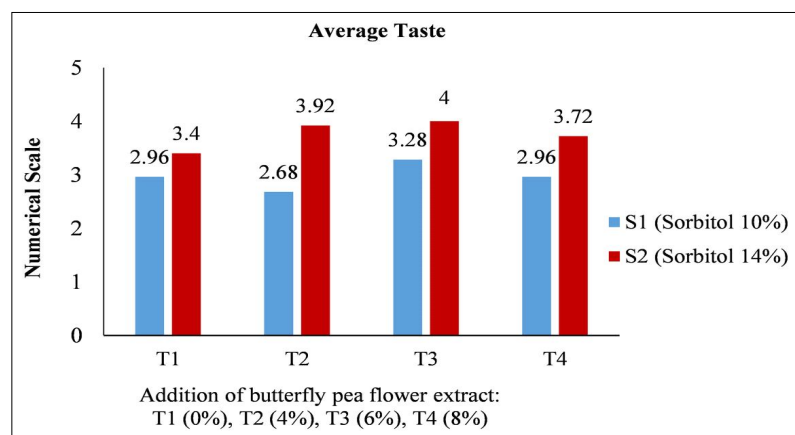


Fig 1: Average taste preferences of edible film-coated sausages.

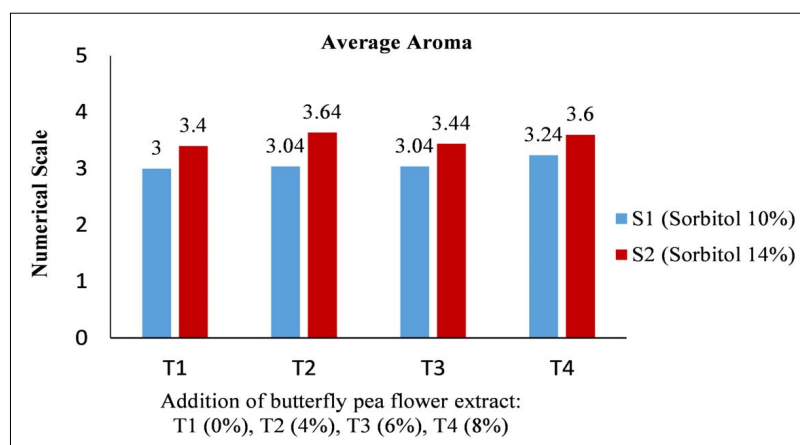


Fig 2: Average preference for the aroma of edible film-coated sausages.

to retrogradation during cooling after drying, where amylose molecules exit starch granules (Rahmadi *et al.*, 2023). A combination of T4S2 (butterfly pea flower extract 8% and sorbitol 14%) produces a chewy, stable texture, significantly affecting the sausage product without edible coating. Large quantities of sorbitol reduce intermolecular hydrogen bonds in starch, resulting in a chewier texture (Nofiandi *et al.*, 2016).

Best treatment

The de garmo method was used to evaluate the best treatment for an edible film product, considering parameters like tensile strength, elongation, thickness, moisture content, antioxidant activity, pH and organoleptic tests, with the highest weight treatment being the best (Fig 5). The best treatment for T2S2 (butterfly pea flower extract

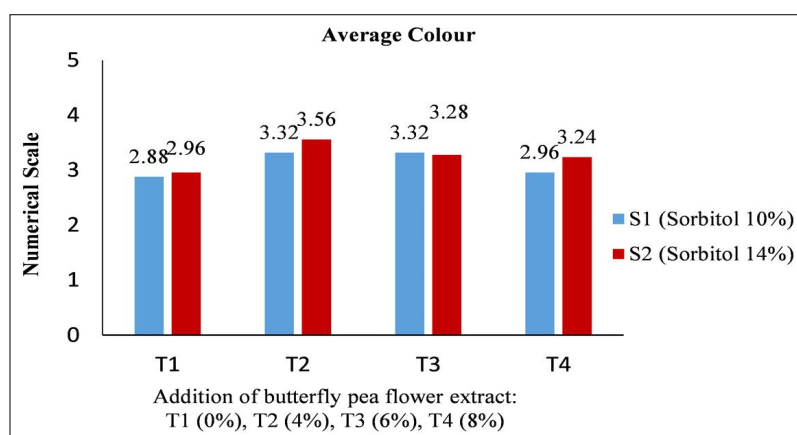


Fig 3: Average preference for the colour of edible film-coated sausages.

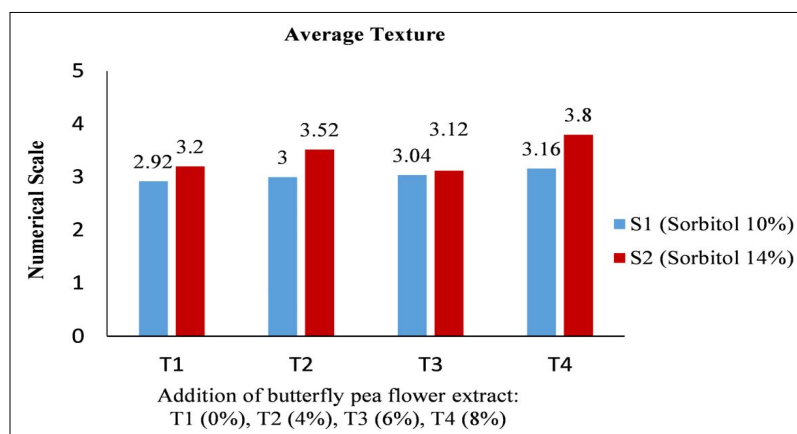


Fig 4: Average preference for the texture of edible film-coated sausages.

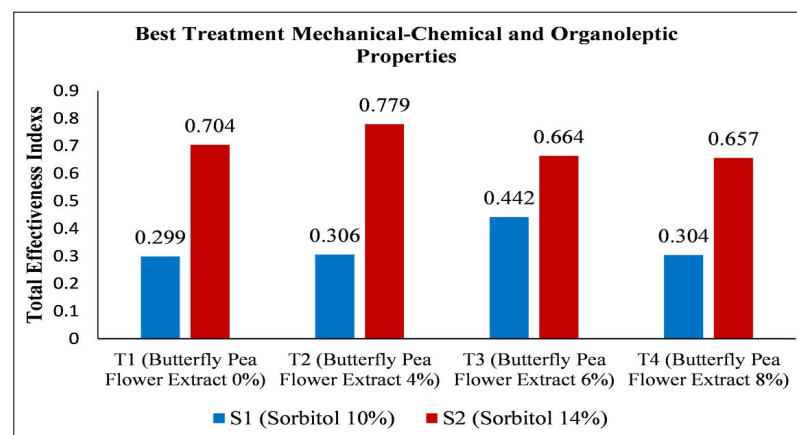


Fig 5: Histogram of the best treatment on mechanical, chemical and organoleptic characteristics.

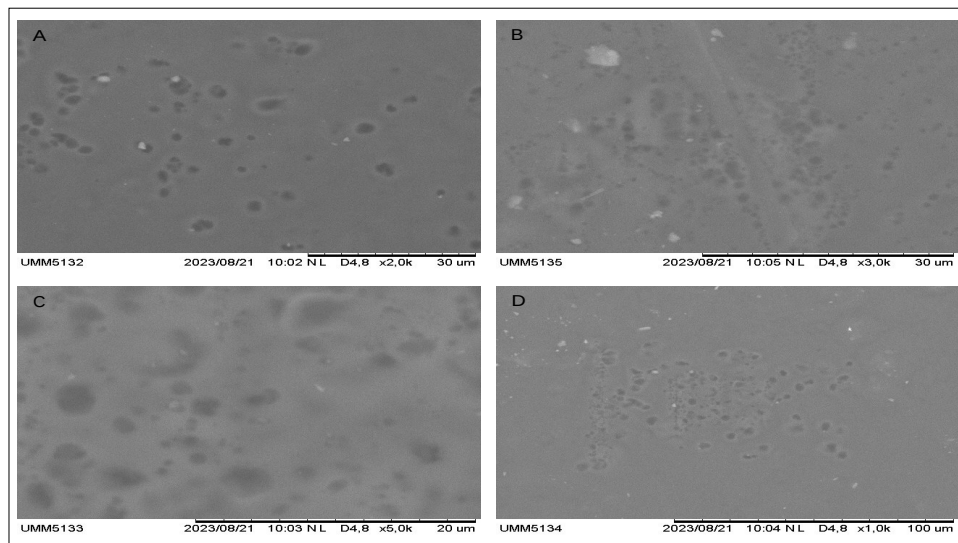


Fig 6: Morphological appearance of the results of SEM testing magnification 1000x (A), 2000x (B), 3000x (C), 5000x (D).

4% and sorbitol 14%) was calculated based on chemical parameters, mechanical-chemical and organoleptic properties antioxidant activity 148.83 ppm, moisture content 19.35%, thickness 0.178 mm, elongation 34.15%, tensile strength 0.0071 MPa, pH 7.5, colour 3.56 (neutral), taste 4 (like), texture 3.52 (neutral) and aroma 3.64 (neutral).

Scanning electron microscopic (SEM)

SEM results of *edible film* made from durian seed starch provide information about the film's microscopic structure and surface morphology in the best treatment. The results of SEM test observations of the *edible film* surface on the best sample with different magnification images are presented in Fig 6. The study reveals that the use of 4% Butterfly Pea flower extract and 14% sorbitol in edible film from durian seed and corn starch results in a hollow, inhomogeneous surface structure. The presence of high amylose and high amylopectin affects the film's surface structure, while blue palm extract affects its homogeneity and morphology (Rahmadi *et al.*, 2023). The addition of blue palm extract to a film surface affects its homogeneity and morphology, affecting its mechanical properties. The use of plasticizer and biopolymer type, such as durian seed starch and corn starch, also affect film properties (Lestari *et al.*, 2020).

CONCLUSION

The study found that the combination of sorbitol concentration and butterfly pea flower extract significantly impacted tensile strength and antioxidant activity parameters in edible film application on beef sausage. However, no significant impact was found on elongation, thickness, moisture content and pH parameters. The organoleptic evaluation showed that the treatment with 4% Butterfly Pea flower extract and 14% sorbitol had the best results, with antioxidant activity of 148.83 ppm, moisture

content of 19.35%, thickness of 0.178 mm, elongation of 34.15%, tensile strength of 0.0071 MPa, pH 7.5 and organoleptic values of color 3.56 (neutral), taste 4 (like), texture 3.52 (neutral) and aroma 3.64 (neutral).

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Disclaimers

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Conflict of interest

The authors declare that there are no conflicts of interest regarding the publication of this article. No funding or sponsorship influenced the design of the study, data collection, analysis, decision to publish, or preparation of the manuscript.

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