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The Effect of Chitosan and Polyvinyl Alcohol Combination on Physical Characteristics and Mechanical Properties of Chitosan-PVA-*Aloe vera* Film

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Abstract
***Background**: Wound is a condition where there is damage or disruption to the anatomical structure and function of the skin. Wounds that are not treated properly can lead to infection. As wound dressings, film dressings have many advantages such as being elastic, flexible, transparent, and can adapt to the wound shape. Film's characteristics of are affected by the plasticizer and the polymer. Combination of chitosan and polyvinyl alcohol (PVA) is able to improve the mechanical properties of the film such as its swelling capacity, tensile strength, and elongation at break. **Objective**: This study aims to determine the effects of chitosan and PVA in various concentrations on the physical characteristics and mechanical properties of the film. **Methods**: Film was prepared by solvent casting method, using chitosan and alginate in various concentrations of 0% to 1.5%, 1.5% Aloe vera, and 6% propylene glycol. Films' characteristics and mechanical properties were evaluated, such as swelling index, tensile strength, elongation at break, and Young's modulus. **Results**: The result showed that chitosan and PVA polymers had a significant effect on the swelling index, tensile strength, elongation at break, and Young's modulus. The effect of chitosan and PVA combination on the swelling index, tensile strength, and elongation at break is due to the hydrogen bonding between the hydroxyl group of PVA and the amine group of chitosan. **Conclusion**: The combination of chitosan and polyvinyl alcohol influenced the film's physical and mechanical properties. Film with chitosan and polyvinyl alcohol ratio of 1.5%:1.5% have best characteristics compared to others.*

***Keywords**: aloe vera, chitosan, film dressing, mechanical properties, polyvinyl alcohol*

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INTRODUCTION

Skin wounds are the loss or damage to part of the body tissue caused by surgery, a blow, a cut, temperature changes, chemicals, pressure, or diseases such as carcinoma (Shankar *et al*., 2014). Skin wounds damage the protective function of the skin caused by a loss in the continuity of the epithelial tissue. This can occur with or without damage to other tissues such as muscles, bones, and nerves (Rodrigues *et al*., 2019). Wound care may include washing, administering ointments, and dressing the wounds. Wound washing often uses normal saline because it adjusts the pH of the skin and removes the dirt that sticks to the skin layer (Purnama *et al*., 2017; Gonzalez *et al*., 2016).

One wound-healing therapy is wound dressing (Oliveira *et al*., 2020). Modern wound dressing preparations and materials include plasters, film dressings, hydrogels, hydrocolloids, foams, medical collagen sponges, and gauze (Olivera *et al*., 2020; Han & Ceilley, 2017). The characteristics and properties of an ideal wound dressing include providing moisture to the wound area, preventing excess exudate production, preventing infection, providing low-cost treatment, providing comfort by relieving pain, using non-toxic materials, thermal insulation, and not causing pain (Matica *et al*., 2019; Tavakoli & Clark., 2020). Film dressing preparations have emerged as one of the most attractive topical preparations for effective drug delivery. They are defined as non-solid dosage forms that produce a film in situ after application to the skin or other body parts (Bornare *et al*., 2018). The advantages of film preparations include easy application, patient comfort owing to the non-invasive route of administration, and cost-effectiveness in formulation development (Patel *et al*., 2012). The type of wound dressing in the form of a film has many advantages: it is very elastic, flexible, can adapt to the shape of the wound and the body, and can be made transparent (Dhivya *et al*., 2015).

Chitosan is a natural polymer that forms films and acts as a coating material. This is because chitosan has a strong ionic bond between the negatively charged hydroxyl group and positively charged amine group, which can increase the moisture barrier (Liu *et al*., 2018; Arzate-Vazquez *et al*., 2012; Pratama *et al*., 2018). However, the use of pure chitosan films is very difficult because of their sensitivity to environmental conditions and poor mechanical properties (Peng & Li, 2014). Chitosan films also have high water vapor permeability (Liu *et al*., 2017). The flexibility of chitosan films can be improved by combining them with other polymers and plasticizers (Naqvi *et al*., 2021). Mixed polymer systems can be used to form films that are flexible, transparent, thin, and have good mechanical strength.

PVA is a hydrophilic synthetic polymer that is biocompatible, biodegradable, and can dissolve in water (Chandrakala *et al*., 2013). The polymer also has good elongation and surface tension properties (Rafieian *et al*., 2021) along with good tensile strength (TS). Therefore, PVA can be used for film formation (Birck *et al*., 2014; Srinivasa *et al*., 2003). PVA can form strong films but has several disadvantages such as poor adhesive properties, low gas diffusion, and low fluid absorption for wound dressings (Kamoun *et al*., 2017; Mok *et al*., 2020).

Aloe vera has anti-inflammatory, wound healing, antioxidant, and antimicrobial (Rahman *et al*., 2017). It is expected that *Aloe vera* could increase the activity of chitosan during wound healing. The use of mixed polymer combinations, such as chitosan and PVA, could help improve the flexibility properties of chitosan and the physical properties of PVA, thereby increasing its ability to absorb wound exudate.

This study aimed to investigate the effect of two variables in formulations, chitosan and PVA concentrations, and to explore the physical characteristics of new chitosan-PVA-*Aloe vera* films. The combination of chitosan and PVA can produce strong films with improved adhesion that can absorb wound exudates and maintain product biocompatibility. The ideal film should be elastic, not easily broken, suitable for skin pH, and have a high swelling ability.

MATERIALS AND METHODS

Materials

The chitosan polymer 107 cps was obtained from Biotech. Co.Ltd, Indonesia, Polyvinyl alcohol was obtained from Merck, Germany, *Aloe vera* powder was obtained from PT. Haldin Pacific Semesta, Indonesia, and propylene glycol were obtained from PT. Bratachem, Indonesia, and glacial acetate acid were obtained from Merck KGaA (Germany). All chemicals were of pharmaceutical grade.

Tools

Oven (MMM Medcenter Einrichtungen GmbH, Munchen), analytical scales (Ohaus PA-2102 C, USA), pH meter Trans Instrumen HP9010 PH-ORP-Temperature Meter (Walklab Series, Singapore), Desiccator, Digital thickness gauge (Syntex, China), tensile strength tester (MT, Moisture Analyzer HB43-S (Mettler Toledo, Switzerland), hotplate (Thermo

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Scientific, USA), and Fourier transform infrared spectroscopy (Alpha II, Bruker, USA).

Methods

Preparation of chitosan-PVA-*Aloe vera* films

The films were prepared by the solvent casting method using combinations of chitosan and PVA, as shown in Table 1. *Aloe vera* 1.5% was also added, along with propylene glycol 6% as a plasticizer. The chitosan solutions were prepared by dissolving chitosan in 1% (v/v) aqueous acetic acid, and the solution was stirred for 2 h with a magnetic stirrer. PVA solutions were prepared in distilled water at 90 ˚C under magnetic stirring at 250 rpm for 2 h, and *Aloe vera* powder was dissolved in water. PVA and *Aloe vera* solutions were poured into the chitosan solution and mixed with a magnetic stirrer at 250 rpm for 1 h. Propylene glycol was added to the mixed solution as a plasticizer. The solution was sonicated for 15 min to remove air bubbles. After the mixture was homogenized, the chitosan-PVA-*Aloe vera* film was prepared by pouring 5 ml of the solution into a Petri dish and drying at 40 ˚C in an oven for 5.5 hours. The film was weighed every hour until a constant weight was achieved. After drying, the chitosan-PVA-*Aloe vera* films were peeled off and stored in a desiccator until the evaluation tests.

Table 1. Formula Design of the Chitosan-PVA-*Aloe vera* Film

Polyvinyl Alcohol (PVA) (%w/v)	Chitosan (% w/v)			
	0	0.5	1	1.5
0	F1	F5	F9	F13
0.5	F2	F6	F10	F14
1	F3	F7	F11	F15
1.5	F4	F8	F12	F16

Organoleptic observations

The organoleptic evaluation of the film was carried out visually, including color, odor, elasticity, and surface texture.

Weight evaluation

The weight evaluation was carried out by taking three (3) films at random from each formula and replication for 3 times. Mean values were calculated. (Ali *et al*., 2016).

pH evaluation

The pH of the film was measured by immersing the chitosan-PVA-*Aloe vera* film in 20 ml distilled water for 1 h and calculating the change in the pH of the system using a digital pH meter (Walklab Series, Singapore).

Film thickness evaluation

This test was performed using the Digital Thickness tool (Syntex, China) by measuring ten parts of each film area. The film thickness was calculated as the average of ten individual measurements. The evaluation was performed in triplicate.

Moisture content (MC)

The films were weighed and stored for 24 h in a desiccator filled with silica gel. After storage, the film was weighed to determine the percentage moisture content using the following equation:

$$\text{MC} = \frac{\text{initial weight} - \text{final weight}}{\text{initial weight}} \text{ x } 100$$

Swelling index

The film sample (1cm^2) was weighed using an analytical balance, soaked in distilled water for 5, 10, 15, and 20 min, blotted with filter paper, and weighed accurately. The swelling index of the film was calculated using the following equation (Hajian *et al*., 2017).

$$\text{Swelling Ratio: } \frac{W_1 - W_o}{W_o} \text{ x } 100\%$$

W_1 is the weight of the wet film and W_o is the initial film weight.

Mechanical properties

Tensile strength was measured using a tensile tester (MTS bionix, China). The film was clamped between the two pull handles and pulled at a crosshead speed of 10 mm/min (Jantrawut *et al*., 2017). The tensile strength, elongation at break, and Young's modulus were calculated using the following formulas:

$$\text{Tensile strength (N/mm2)} = \frac{\text{Breaking Force (N)}}{\text{The cross} - \text{sectional area of the film (mm2)}}$$

$$\text{Elongation at break (\%)} = \frac{\text{Increasing in length at breaking point (mm)}}{\text{initial length (mm)}} \text{ x } 100$$

$$\text{Young's modulus} = \frac{F/A}{\Delta l/lo} = \frac{stress}{strain}$$

Folding endurance

Folding endurance is achieved by folding the film at the same point repeatedly until the film breaks or is folded up to 300 times without breaking.

Data analysis

The weight, thickness, pH value, moisture content, swelling index, tensile strength, elongation at break, and Young's modulus data were all statically examined using the two-way analysis of variance (ANOVA) method with a 95% confidence level (α=0.05) followed by a Post Hoc test. All experiments were performed in triplicate.

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Table 2. Organoleptic evaluation of chitosan-PVA-*Aloe vera* film

Formula	**Organoleptic Observations**		
	Color	**Consistency**	**Odor**
F1	Transparent	not forming a film, easy to break, can't peel off	*Aloe vera*
F2	Transparent	not forming a film, easy to break, can't peel off	*Aloe vera*
F3	Transparent	not forming a film, easy to break, can't peel off	*Aloe vera*
F4	Transparent	not forming a film, easy to break, can't peel off	*Aloe vera*
F5	Yellowish	not forming a film, easy to break, can't peel off	*Aloe vera*
F6	Yellowish	not forming a film, easy to break, can't peel off	*Aloe vera*
F7	Yellowish	a little can be peeled off, easy to break	*Aloe vera*
F8	Yellowish	a little can be peeled off, easy to break	*Aloe vera*
F9	Yellowish	a little can be peeled off, easy to break	*Aloe vera*
F10	Yellowish	Smooth texture, flat surface, and not easy to break	*Aloe vera*
F11	Yellowish	Smooth texture, flat surface, and not easy to break	*Aloe vera*
F12	Yellowish	Smooth texture, flat surface, and not easy to break	*Aloe vera*
F13	Yellowish	Smooth texture, flat surface, and not easy to break	*Aloe vera*
F14	Yellowish	Smooth texture, flat surface, and not easy to break	*Aloe vera*
F15	Yellowish	Smooth texture, flat surface, and not easy to break	*Aloe vera*
F16	Yellowish	Smooth texture, flat surface, and not easy to break	*Aloe vera*

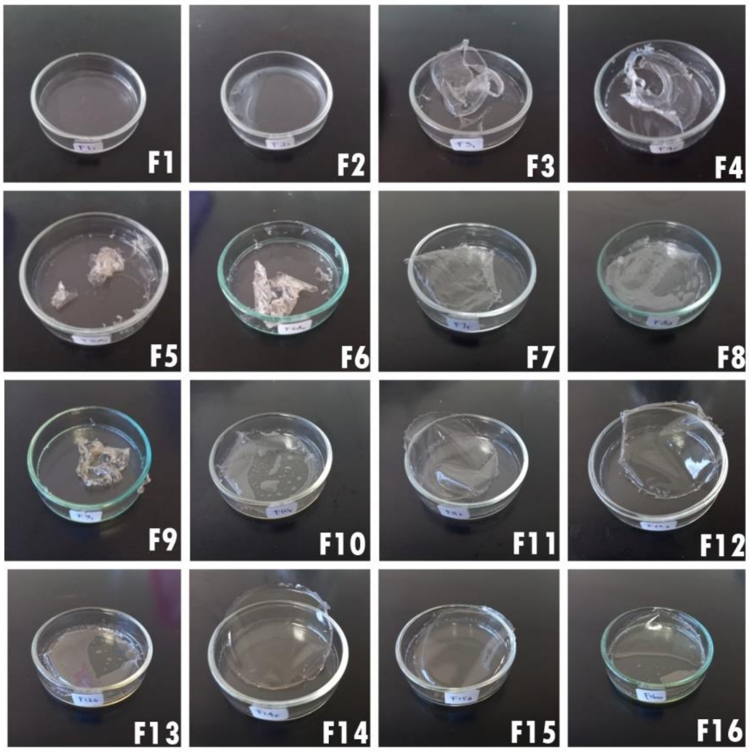

Figure 1. Photograph of chitosan-PVA-*Aloe vera* film with chitosan concentration 0.5%, 1%, 1.5% and PVA concentration 0.5%, 1%, and 1.5%

RESULTS AND DISCUSSION

The chitosan-PVA-*Aloe vera* film formulation is presented in Table 1. The results of the chitosan-PVA-*Aloe vera* film preparation are shown in Table 2 and Figure 1. From the sixteen formulas, six formulas could form films with good characteristics, such as easy to peel off, not easily broken, and having a smooth texture. The selected formulas (Table 3) were used for further evaluation.

Table 3. Selected Formulas of Chitosan-PVA-*Aloe vera* Film (% w/v)

Formula	Concentration (%)	
	Chitosan	Polyvinyl Alcohol (PVA)
F10	1	0.5
F11	1	1
F12	1	1.5
F14	1.5	0.5
F15	1.5	1
F16	1.5	1.5

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Organoleptic evaluation

The results of the organoleptic tests of the chitosan-PVA-*Aloe vera* films are shown in Table 2 and Figure 1. All formulas had the same odor and color. Chitosan-PVA-*Aloe vera* film has an *Aloe vera* odor with a light-yellow color. The texture of the chitosan-PVA-*Aloe vera* films was smooth and not easy to break.

Weight evaluation

Weight evaluation aims to determine the effect of varying the concentration of chitosan and PVA. The results of the weight evaluation of the chitosan-PVA-*Aloe vera* films are shown in Table 4. The two-way ANOVA statistical test for weight evaluation showed a significant difference between the other formulas (Table 6). The post-hoc Tukey HSD test showed that all formulas were significantly different (sig. value 0.000 < 0.05). Increasing the concentrations of chitosan and PVA affected the film weight. With increasing polymer concentration, the number of solids increased, affecting the weight of the film.

Thickness evaluation

The thicknesses obtained from the six formulae are listed in Table 4. The film thickness increased owing to the increase in chitosan and PVA concentrations. This is due to the large amount of water bound during the formulation process (El-Maghraby & Mona., 2015). The thickness of a film affects its flexibility, strength, and comfort. The acceptable film thickness is 0.05-1 mm (Karki., et al., 2016). The two-way ANOVA statistical test revealed a significant difference between the formulas (Table 6). Based on the post-hoc Tukey HSD test, all formulas were significantly different (sig. value 0.000 < 0.05). There was an interaction effect between chitosan and PVA on the film thickness.

Moisture content (MC)

The moisture content of the film can affect its mechanical strength, adhesive properties, and brittleness. The moisture content of the chitosan-PVA-*Aloe vera* films is shown in Table 4. The two-way ANOVA statistical test revealed a significant difference between the formulas (Table 6). The post hoc Tukey HSD test revealed that PVA 1.5% was significantly different (sig. value 0.000 < 0.05) with PVA 0.5% and 1.0%. Chitosan and PVA play a role in increasing the water content. The moisture content of the films increased with increasing chitosan concentration. The hydrophilic nature of chitosan and PVA caused an increase in the moisture content of the films. However, the significant effect of chitosan on increasing the water content was due to the higher number of amino and hydroxyl groups than PVA; thus, chitosan can absorb excess water molecules (Cazón *et al*., 2019; Chopra *et al*., 2022).

pH evaluation

As shown in Table 4, all chitosan-PVA-*Aloe vera* films had pH value of 5.24-5.67. Chitosan-PVA-*Aloe vera* film is acceptable for the skin because the skin has a pH of 4-6 (Prakash *et al*., 2017). pH plays a role in wound healing. Acidic pH provides an advantage in the wound healing process, which can increase the proliferation and migration of fibroblast cells (Jones *et al*., 2015). The two-way ANOVA statistical test for pH (Table 6) revealed a significant difference between the formulas. Based on the post-hoc Tukey HSD test, all formulas were significantly different (sig. value 0.000 < 0.05).

Swelling index

According to the observation, the films have good swelling ability and can maintain good structure (Figure 2). The swelling index values ranged from 272 % to 341 % (Table 4). The two-way ANOVA statistical test for swelling index showed a significant difference between the formulas (Table 6). The Tukey's HSD test showed that PVA 0.5% was significantly different (sig. value 0.000 < 0.05) from PVA 1% and 1.5%. Increasing the concentration of chitosan increased the swelling index of the film. Otherwise, as the PVA concentration increased, the film swelling ability decreased. This is due to the absorption of water in the film owing to the presence of hydroxyl groups (-OH) from PVA and amines (-NH_2) from chitosan bound to water molecules through hydrogen bonds and the presence of a porous network on the film. The swelling index value for wound dressings is 200-500% (Saarai *et al*., 2011). The chitosan-PVA-*Aloe vera* film compositions met the swelling index requirements.

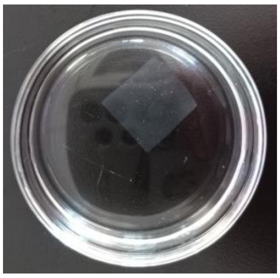

Figure 2. Photograph of swelling test on the chitosan-PVA-Aloe vera films

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Table 4. Physical Characteristics of the chitosan-PVA-*Aloe vera* film

Formula	Weight Evaluation (g)	Thickness (mm)	MC %	pH	Swelling Index %
F10	0.317 ± 0.002	0.131 ± 0.002	11.122 ± 0.164	5.67 ± 0.06	341.111 ± 8.389
F11	0.328 ± 0.007	0.154 ± 0.001	10.946 ± 0.066	5.51 ± 0.02	274.622 ± 7,337
F12	0.375 ± 0.005	0.209 ± 0.004	10.505 ± 0.273	5.33 ± 0.05	271.569 ± 6.560
F14	0.379 ± 0.002	0.161 ± 0.001	12.183 ± 0.099	5.53 ± 0.02	347.271 ± 2.779
F15	0.414 ± 0.006	0.189 ± 0.002	12.016 ± 0.091	5.45 ± 0.05	298.758 ± 4.411
F16	0.471 ± 0.005	0.234 ± 0.003	9.052 ± 0.289	5.24 ± 0.02	287.607 ± 9.255

Table 5. Mechanical Properties of Chitosan-PVA-*Aloe vera* Film

Formula	Tensile Strength (N/mm^2)	Elongation at Break (%)	Young's Modulus	Folding Endurance
F10	0.601 ± 0.019	27.63 ± 1,704	2.144 ± 0.135	> 300x
F11	0.654 ± 0.012	56.83 ± 3.512	1.154 ± 0.090	> 300x
F12	1.307 ± 0.065	64.33 ± 1.050	2.032 ± 0.095	> 300x
F14	0.615 ± 0.013	30.33 ± 3.855	1.850 ± 0.033	> 300x
F15	1.539 ± 0.050	43.10 ± 2.910	2.497 ± 0.089	> 300x
F16	2.194 ± 0.053	43.60 ± 1.803	2.123 ± 0.084	> 300x

Folding endurance

The folding endurance of the Chitosan-PVA-*Aloe vera* film is shown in Table 5. All formulas can be folded more than 300 times at the same point. This shows that the chitosan-PVA-*Aloe vera* film has good flexibility. Good film flexibility is > 300 times folded without breaking (Somepalli *et al.*, 2013). The polymer concentration affects folding power value (Nishigaki *et al*., 2012). The combination of chitosan and polyvinyl alcohol as a film-forming polymer can provide strength to the film such that it is not brittle or easily broken. The interaction between the -OH and $-NH_2$ groups of the two polymers can increase the strength (Nugraheni *et al*., 2018).

Tensile strength, elongation at break and young's modulus

The tensile strength test aims to determine the maximum strength that the film can withstand before the preparation is damaged by being pulled or stretched (Ma *et al*., 2021). The tensile strengths of the chitosan-PVA-*Aloe vera* films are shown in Table 5 and Figure 3. The folding endurance and tensile strength are related to the strength of the film. Plasticizers affect tensile strength value (Irfan *et al*., 2016). The two-way ANOVA statistical test for the tensile strength showed a significant difference between the formulas (Table 6). Based on the measurable results of ANOVA followed by the post-hoc Tukey HSD test, all formulas were significantly different (sig. value 0.000 < 0.05).

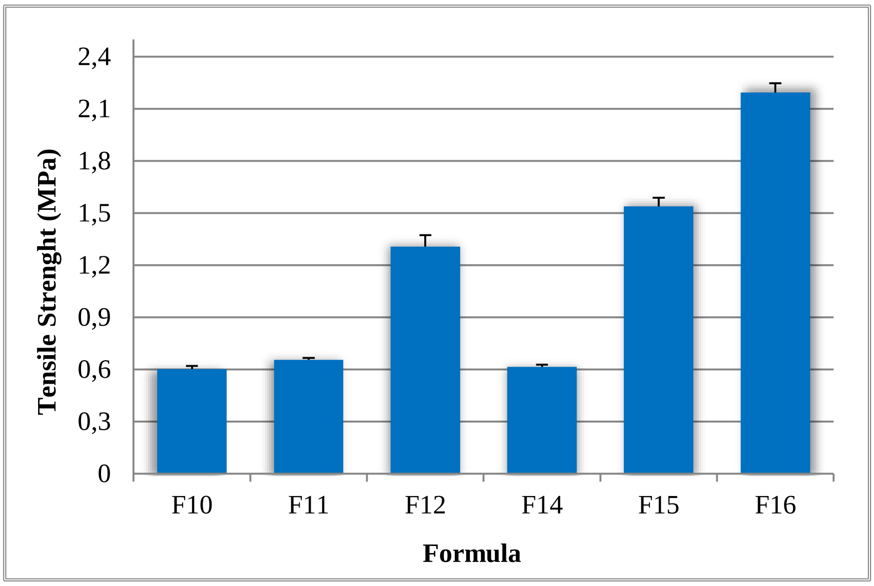

Figure 3. Tensile strength of the chitosan-PVA-*Aloe vera* film with different ratio of chitosan and PVA

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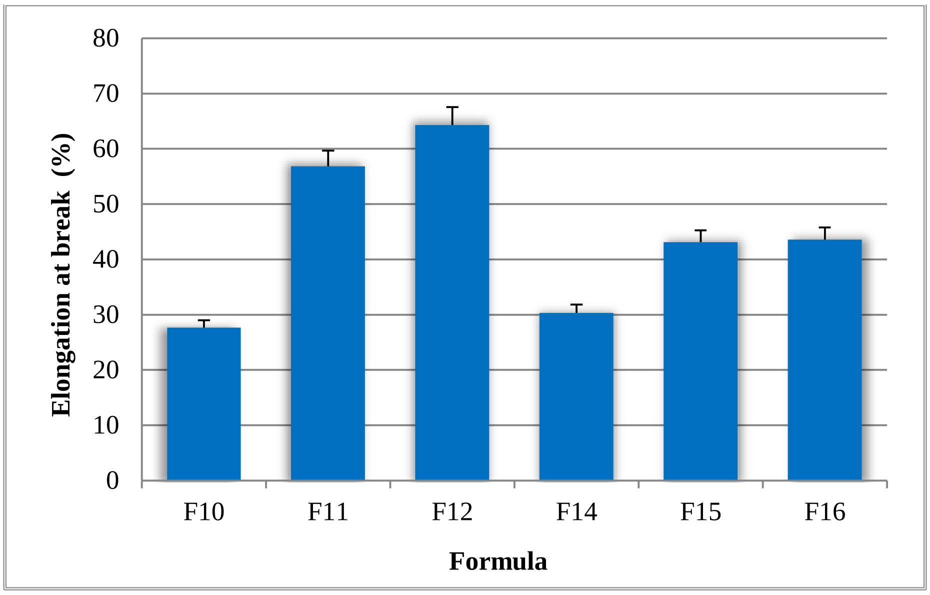

Figure 4. Elongation at break of the chitosan-PVA-*Aloe vera* film with different ratios of chitosan and PVA

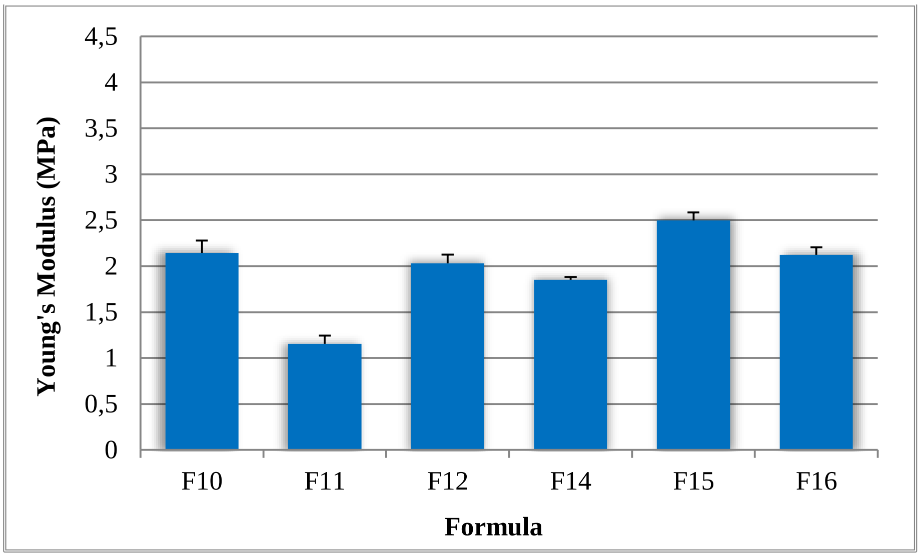

Figure 5. Young's modulus of the chitosan-PVA-*Aloe vera* film with different ratios of chitosan and PVA

Table 6. Results of the two-way ANOVA statistical test on the combination of chitosan and PVA

Film's characteristic	Statistical test results		
	Concentration of Chitosan	Concentration of Polyvinyl alcohol (PVA)	Interaction of the chitosan and PVA
Uniformity of weight	0.000[a]	0.000[a]	0.000[a]
Thickness	0.000[a]	0.000[a]	0.018[a]
pH value	0.000[a]	0.000[a]	0.008[a]
Moisture content (MC)	0.024[a]	0.000[a]	0.000[a]
Swelling degree	0.000[a]	0.000[a]	0.115[b]
Tensile Strength	0.000[a]	0.000[a]	0.000[a]
Elongation	0.000[a]	0.000[a]	0.000[a]
Young's modulus	0.000[a]	0.002[a]	0.000[a]

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The percentage elongation aims to determine the increase in length from the initial length to the point of breaking when the sample is pulled. Simultaneously, elongation-at-break refers to the point where the film can be stretched when it is torn or damaged. The elongation-at-break test was used to determine the flexibility of the film (Karki *et al*., 2016). The elongation-at-break value is below 15%, indicating that the material is easily brittle (El Hadi *et al*., 2017). Calculating of The elongation-at-break obtained using the six formulas were F10 (27.63%), F11 (56.83%), F12 (64.33), F14 (30.33%), F15 (43.10%), F16 (43.60%) (Table 5 and Figure 4). In the two-way ANOVA statistical test, sig = 0.000 < 0.05 means a significant difference (Table 6). From The post hoc Tukey HSD test, it was found that PVA 0.5% was significantly different (sig. value 0.000 < 0.05) from PVA 1% and 1.5%. PVA 1% was not significantly different from PVA 1.5%. The increase in elongation at break was due to the molecular interactions between chitosan and PVA through the formation of hydrogen bonds (Abraham *et al*., 2016). The maximum elongation-at-break was in the film with a combination formulation of chitosan 1% and PVA 1.5%. The Young's modulus indicates the stiffness or elasticity of the film. Films that have a high Young's modulus indicates that the film is not easily brittle (Karki *et al*., 2016). The Young's modulus of the Chitosan-PVA-*Aloe vera* film is shown in Table 5 and Figure 5. Based on the two-way ANOVA statistical test, the value of sig = 0.000 < 0.05 means a significant difference (Table 6). Tukey HSD test Young's modulus showed that PVA 1% was significantly different (sig. value 0.000 < 0.05) from PVA 0.5% and 1.5%. PVA 0.5% was not significantly different from PVA 1.5%.

The combination of chitosan and PVA polymers increased the tensile strength, elongation at break, and Young's modulus values. It was noted that increasing the amounts of chitosan and PVA increased the mean tensile strength, and increasing the amount of PVA increased the elongation value. The combination of chitosan and PVA reflects the effect of the interaction between the two polymers. This is due to the interaction between the -OH and -NH_2 groups on the polymer (Bahrami *et al*., 2002; Bonilla *et al*., 2014). The positively charged polysaccharide chitosan moved towards the negative charge of the hydroxyl group of PVA, which improved the tensile strength and elongation at break of the plastic film due to the intermolecular interactions between chitosan and PVA through hydrogen bond formation (Abraham *et al*., 2016). Thus, it can improve the mechanical properties of the films. The mechanical properties are affected by the type and amount of polymer mixes. A concentration that is too low can result in intermittent film formation or poor mechanical resistance. In contrast, high concentrations produce a thick and rigid film on the skin, which is uncomfortable to use and may delay drug release (El Fray *et al*., 2012).

CONCLUSION

Based on this study, the physical characteristic and mechanical properties of the chitosan-PVA-*Aloe vera* films were affected by both polymers: chitosan (1%, 1.5%) and PVA (0.5%, 1%, 1.5%). The increased concentrations of chitosan and PVA caused an increase in the mechanical properties. However, there was a decrease in the swelling index. Based on the results, films with chitosan 1.5% and PVA 1.5% had the best characteristics and mechanical properties (swelling index, tensile strength, and elongation at break) compared to the other formulations. Therefore, this film has the potential to be developed as a wound dressing material.

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AUTHOR CONTRIBUTIONS

Conceptualization, D. F. Z., R. S., E. H.; Methodology, D. F. Z., R. S.; Software, D. F. Z.; Validation, R. S., E. H.; Formal Analysis, D. F. Z.; Investigation, D. F. Z.; Resources, R. S., E. H.; Data Curation, D. F. Z.; Writing - Original Draft, D. F. Z., R. S.; Writing - Review & Editing, R. S., E. H.; Visualization, D. F. Z., R. S., E. H.; Supervision, R. S.; Project Administration, R. S.; Funding Acquisition, R. S.

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CONFLICT OF INTEREST

The authors declared no conflict of interest.

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REFERENCES

Abraham, A., Soloman, P. A., & Rejini, V. O. (2016). Preparation of Chitosan-Polyvinyl Alcohol Blends and Studies on Thermal and Mechanical Properties. *Procedia Technology*; *24*; 741–748. doi: 10.1016/j.protcy.2016.05.206.

Ali, M. S., Vijendar C., Sudheer Kumar D. & Krishnaveni J. (2016). Formulation and Evaluation of Fast Dissolving Oral Films of Diazepam. *Journal of Pharmacovigilance; 4;* 1-5. doi: 10.4172/2329-6887.1000210.

Arzate-Vázquez, I., Chanona-Pérez, J. J., Calderón-Domínguez, G., Terres-Rojas, E., Garibay-Febles, V., Martínez-Rivas, A. & Gutiérrez-López, G. F. (2012). Microstructural Characterization of Chitosan and Alginate Films by Microscopy Techniques and Texture Image Analysis. *Carbohydrate Polymers*; *87*; 289–299. doi: 10.1016/j.carbpol.2011.07.044.

Bahrami, S. B., Kordestani, S. S., Mirzadeh, H. & Mansoori, P. (2003). Poly (Vinyl Alcohol) – Chitosan Blends: Preparation, Mechanical and Physical Properties. *Iranian Polymer Journal*; *12*; 139–146.

Bonilla, J., Fortunati, E., Atarés, L., Chiralt, A. & Kenny, J. M. (2014). Physical, Structural, and Antimicrobial Properties of Polyvinyl Alcohol-Chitosan Biodegradable Films. *Food Hydrocolloids*; *35*; 463–470. doi: 10.1016/j.foodhyd.2013.07.002.

Bornare, S. S., Aher, S. S. & Saudagar, R. B. (2018). A Review*:* Film forming Gel Novel Drug Delivery System. *International Journal of Current Pharmaceutical Research*; *10*; 25-28.

Birck, C. *et al*. (2014). New Crosslinked Cast Films Based on PVA: Preparation and Psycho-Chemical Properties. *Express polymer Letter*; *8*; 941-952.

Chandrakala, H. N., Ramaraj, B., Shivakumaraiah, Lee, J. H. & Siddaramaiah. (2013). Polyvinyl Alcohol/Carbon-Coated Zinc Oxide Nanocomposites: Electrical, Optical, Structural and Morphological Characteristics. *Journal of Alloys and Compounds*; *580*; 392–400. doi: 10.1016/j.jallcom.2013.06.091.

Cazón, P., Velázquez, G. & Vázquez, M. (2019). Characterization of Bacterial Cellulose Films Combined with Chitosan and Polyvinyl Alcohol: Evaluation of Mechanical and Barrier Properties. *Carbohydrate Polymers*; *216*; 72–85. doi: 10.1016/j.carbpol.2019.03.093.

Chopra, H., Bibi, S., Kumar, S., Khan, M. S., Kumar, P. & Singh, I. (2022). Preparation and Evaluation of Chitosan/PVA Based Hydrogel Films Loaded with Honey for Wound Healing Application. *Gels*; *8*; 1-21. doi: 10.3390/gels8020111.

Dhivya, S., Padma, V. V., & Santhini, E. (2015). Wound Dressings - A Review. *BioMedicine (Netherlands)*; *5*; 24–28. doi: 10.7603/s40681-015-0022-9.

Dreifke, M. B., Jayasuriya, A. A. & Jayasuriya, A. C. (2015). Current Wound Healing Procedures and Potential Care. *Materials Science and Engineering C*; *48*; 651–662. doi: 10.1016/j.msec.2014.12.068.

El Fray, M., Niemczyk, A. & Pabin-Szafko, B. (2012). Chemical Modification of Chitosan with Fatty Acids. *Progress on Chemistry and Application of Chitin and Its Derivatives*; *17*; 29–36.

El-Hadi, A. M. (2017). Increase the Elongation at Break of Poly (Lactic Acid) Composites for Use in Food Packaging Films. *Scientific Reports*; *7*; 1-14.

El-Maghraby, G. M. & Abdelzaher, M. M. (2015). Formulation and Evaluation of simvastatin Buccal Film. *Journal of Applied Pharmaceutical Science*; *5*; 70–77. doi: 10.7324/JAPS.2015.50412.

Gennari, C. G. M., Selmin, F., Franzè, S., Musazzi, U. M., Quaroni, G. M. G., Casiraghi, A. & Cilurzo, F. (2017). A Glimpse in Critical Attributes to Design Cutaneous Film Forming Systems based on Ammonium Methacrylate. *Journal of Drug Delivery Science and Technology*; *41*; 157–163. doi: 10.1016/j.jddst.2017.07.009.

Gonzalez, A. C. D. O., Andrade, Z. D. A., Costa, T. F. & Medrado, A. R. A. P. (2016). Wound Healing - A Literature Review. *Anais Brasileiros de Dermatologia*; *9*; 614–620. doi: 10.1590/abd1806-4841.20164741.

Hajian, M., Mahmoodi, M. & Imani, R. (2017). In Vitro Assessment of Poly (Vinyl Alcohol) Film Incorporating Aloe Vera for Potential Application as a Wound Dressing. *Journal of Macromolecular Science, Part B: Physics*; *56*; 435–450. doi: 10.1080/00222348.2017.1330183.

Han, G. & Ceilley, R. (2017). Chronic Wound Healing: A Review of Current Management and Treatments. *Advances in Therapy*; *34*; 599–610.

Irfan, M., Rabel, S., Bukhtar, Q., Qadir, M. I., Jabeen, F. & Khan, A. (2016). Orally Disintegrating Films: A Modern Expansion in Drug Delivery

P-ISSN: 2406-9388
E-ISSN: 2580-8303

System. *Saudi Pharmaceutical Journal*; *24*; 537–546. doi: 10.1016/j.jsps.2015.02.024.

Jantrawut, P., Chaiwarit, T., Jantanasakulwong, K., Brachais, C. H. & Chambin, O. (2017). Effect of Plasticizer Type on Tensile Property and In Vitro Indomethacin Release of Thin Films based on Low-Methoxyl Pectin. *Polymers*; *9;* 1-14. doi: 10.3390/polym9070289.

Jones, E. M., Cochrane, C. A., & Percival, S. L. (2015). The effect of pH on the Extracellular Matrix and Biofilms. *Advances in Wound Care*; *4*; 431–439. doi: 10.1089/wound.2014.0538.

Karki, S., Kim, H., Na, S. J., Shin, D., Jo, K., & Lee, J. (2016). Thin films as an emerging platform for drug delivery. *Asian Journal of Pharmaceutical Sciences*, *11*, 559–574. doi: 10.1016/j.ajps.2016.05.004.

Kamoun, E. A., Kenawy, E. R. S. & Chen, X. (2017). A Review on Polymeric Hydrogel Membranes for Wound Dressing Applications: PVA-based Hydrogel Dressings. *Journal of Advanced Research*; *8*; 217–233. doi: 10.1016/j.jare.2017.01.005.

Liu, Y., Wang, S., Lan, W. & Qin, W. (2017). Fabrication and Testing of PVA/Chitosan Bilayer Films for Strawberry Packaging. *Coatings*; *7*; 1–16. doi: 10.3390/coatings7080109.

Liu, H., Wang, C. & Li, C. (2018). RSC Advances Dressing and Drug Delivery System in the Treatment of Wound Healing. *RSC Advances*; *8*; 7533–7549. doi: 10.1039/C7RA13510F.

Ma, S., Zheng, Y., Zhou, R. & Ma, M. (2021). Characterization of Chitosan Films Incorporated with Different Substances of Konjac Glucomannan, Cassava Starch, Maltodextrin and Gelatin, and Application in Mongolian Cheese Packaging. *Coatings*; *11*; 1–16. doi: 10.3390/coatings11010084.

Matica, M. A., Aachmann, F. L., Tøndervik, A., Sletta, H. & Ostafe, V. (2019). Chitosan as a Wound Dressing Starting Material: Antimicrobial Properties and Mode of Action. *International Journal of Molecular Sciences*; *20*; 1–33.

Mok, C. F., Ching, Y. C., Muhamad, F., Abu Osman, N. A., Hai, N. D. & Che Hassan, C. R. (2020). Adsorption of Dyes Using Poly(vinyl alcohol) (PVA) and PVA-Based Polymer Composite Adsorbents: A Review. *Journal of Polymers and the Environment*; *28*; 775–793. doi: 10.1007/s10924-020-01656-4.

Naqvi, S. M. K., Khan, Z., Mirza, E. H., Chandio, A., Manzoor, F., Niaz, R., Khan, A. A. & Al Khureif, A. A. (2021). Fabrication and Characterization of Polyvinyl Alcohol/Chitosan/Moringa-Extract Hydrogel Patch for Wound-Healing Applications. *Materials Express*; *11*; 107–115. doi: 10.1166/mex.2021.1895.

Nishigaki, M., Kawahara, K., Nawa, M., Futamura, M., Nishimura, M., Matsuura, K., Kitaichi, K., Kawaguchi, Y., Tsukioka, T., Yoshida, K. & Itoh, Y. (2012). Development of Fast Dissolving Oral Film Containing Dexamethasone as an Antiemetic Medication: Clinical Usefulness. *International Journal of Pharmaceutics*; *424*; 12–17. doi: 10.1016/j.ijpharm.2011.12.057.

Nugraheni, A. D., Purnawati, D. & Kusumaatmaja, A. (2018). Physical Evaluation of PVA/Chitosan Film Blends with Glycerine and Calcium Chloride. *Journal of Physics: Conference Series*; *1011*; *1-5*. doi: 10.1088/1742-6596/1011/1/012052.

Oliveira, A., Simões, S., Ascenso, A. & Reis, C. P. (2020). Therapeutic Advances in Wound Healing. *Journal of Dermatological Treatment*; *33*; 2-22. doi: 10.1080/09546634.2020.1730296.

Patel, H., Bhimani, B. & Patel, G. (2012). Transdermal Drug Delivery System as Prominent Dosage form for the Highly Lipophilic Drugs. *International Journal of Pharmaceutical Bio-Science*; *1*; 42-65.

Peng, Y. & Li, Y. (2014). Combined Effects of Two Kinds of Essential Oils on Physical, Mechanical and Structural Properties of Chitosan Films. *Food Hydrocolloids*; *36*; 287–293. doi: 10.1016/j.foodhyd.2013.10.013.

Prakash C, Bhargava P, Tiwari S, Majumdar B, Bhargava RK.(2017). Skin Surface pH in Acne Vulgaris: Insights from an Observational Study and Review of the Literature. *The Journal of Clinical and Aesthetic Dermatology*; *10*; 33-39.

Pratama, Y., Miranda, M. & Hintono, A. (2018). Karakteristik *Edible Films Aloe vera* dengan Emulsi Extra Virgin Olive Oil dan Kitosan. *Agritech*; *38*; 381-387.

Purnama, H., Sriwidodo, & Ratnawulan, S. (2017). Review Sistematik: Proses Penyembuhan dan Perawatan Luka. *Farmaka*; *15*; 255–256.

Rafieian, S., Mahdavi, H. & Masoumi, M. E. (2021). Improved Mechanical, Physical and Biological Properties of Chitosan Films using *Aloe vera* and Electrospun PVA Nanofibers for Wound Dressing

P-ISSN: 2406-9388
E-ISSN: 2580-8303

Applications. *Journal of Industrial Textiles*; *50*; 1456–1474. doi: 10.1177/1528083719866932.

Rodrigues, M., Kosaric, N., Bonham, C. A. & Gurtner, G. C. (2019). Wound Healing: A Cellular perspective. *Physiological Reviews*; *99*; 665–706. doi: 10.1152/physrev.00067.2017.

Saarai, A., Kasparkova, V., Sedlacek, T., Saha, P. (2011). A Comparative Study of Crosslinked Sodium Alginate/Gelatin Hydrogels for Wound Dressing. *Recent Researches in Geography, Geology, Energy, Environment and Biomedicine*; *22*; 384-389.

Shankar M., Ramesh B., Roopa Kumar D. & Niranjan Babu M. (2014). Wound Healing and It's Importance-A Review. *Der Pharmacologia Sinica*; *1*; 24-30.

Srinivasa, P. C., Ramesh, M. N., Kumar, K. R., & Tharanathan, R. N. (2003). Properties and Sorption Studies of Chitosan-Polyvinyl Alcohol Blend Films. *Carbohydrate Polymers*; *53*; 431–438. doi: 10.1016/S0144-8617(03)00105-X.

Somepalli, N., Moru, C. S., Gottipati, D. B. & Voruganti, V. K. (2013). Formulation and Evaluation of Buccal Films of Salbutamol Sulphate. *Mintage Journal of Pharmaceutical and Medical Sciences*; *2*; 1285-1305.

Tavakoli, S. & Klar, A. S. (2020). Advanced Hydrogels as Wound Dressings. *Biomolecules*; *10*; 1–20.

P-ISSN: 2406-9388
E-ISSN: 2580-8303