ISSN: 2347-467X, Vol. 08, No. (1) 2020, Pg. 333-339

Current Research in Nutrition and Food Science

www.foodandnutritionjournal.org

The Physical Characteristics of Whey Based Edible Film Added with Konjac

FAHRULLAH FAHRULLAH[1,2], LILIK EKA RADIATI[1], PURWADI[1] and DJALAL ROSYIDI[1]*

[1]Faculty of Animal Science, University of Brawijaya, Malang, Indonesia.
[2]Faculty of Agricultural Science, Muhammadiyah University of Gorontalo, Indonesia.

Abstract

This research aims to observe the physical characteristics of whey-based edible film added with konjac at different levels (2%; 2.5%; and 3%). The research was conducted as laboratory experiment, and the observed variables were film thickness, tensile strength, elongation at break, water vapour transmission rate (WVTR), and followed with microstructure observation. The research was conducted in a completely randomized design and analyzed with analysis of variance followed with least significant different test. The physical measurement of the edible film showed that the thickness was at 2.94 - 3.70 x 10^{-3} mm, the tensile strength was at 5.72 - 7.44 N, the elongation at break was around 57.50 - 70.93%, and the WVTR was at 7.96 - 8.45 $g.mm^{-2}.day^{-1}$. Moreover, the microstructure observation showed that the molecules in the edible film were distributed evenly. The research concludes that the addition of konjac could improve the physical characteristics of whey-based edible film and the best konjac addition was at 2.5%.

Article History

Received: 14 September 2020
Accepted: 11 April 2020

Keywords

Film,
Konjac,
Physical properties,
Whey.

Introduction

Edible film is a thin coating made from edible ingredients which is commonly used to improve the shelf life of food products. The films are identified as consumable thin layer placed above or in between food components. It is widely used as an alternative packaging material that is safe for the environment as the film is made from renewable materials.[1] Biodegradable food films have vital importance in food study, according to their reception to the condition and their use in the food packaging industry.[2] On its application, the film acts as a barrier to inhibit transmission of moisture, oxidation, light, volatile gas, lipid, and soluble materials which

CONTACT Djalal Rosyidi djalal_tht@ub.ac.id Faculty of Animal Science, University of Brawijaya, Malang, Indonesia.

Doi: http://dx.doi.org/10.12944/CRNFSJ.8.1.31

harm the food products. Moreover, edible film could also act as additive carrier such as vitamin, mineral, antioxidant, antimicrobials, preservatives, and other materials aimed to improve the physical characteristics of the food.

There is an increasing demand for nutritious and healthy foods across all sections of the society. Various approaches have been developed to enhance the food shelf-life and quality. One of the emerging approaches is by applying edible films to the food products. The films were made from food-grade biopolymers and had multiple functions when applied to the food, such as enhancing the natural structure of the food and provide resistance against moisture loss. In addition, the film allows controlled exchange of gasses for respiration. These systems can also be used as carrier agent for prolonged protection and controlled release of different active ingredients such as vitamins, antimicrobial compounds and antioxidants.[3]

Whey is known as byproduct of dairy manufacturing, even though it contained various proteins. Whey has showed the potential to be used for edible film as the produced film showed preferable characteristics, which were transparent, elastic, odorless, and could retain the aroma of the coated food products. The addition of other materials such as hydrocolloid (protein and polysaccharides), fat or combination the materials could be done to improve the characteristics of whey-based edible film. However, it should be noted that hydrocolloids have low water permeability caused from the hydrophilic characteristic of the polysaccharides.[4]

One of the polysaccharides which can be used in making edible film is konjac. Glucomannan, the main component of Konjac, is a soluble dietary fiber which can be utilized in making the edible film. The combination of whey and konjac is expected to initiate interaction which will build the structure and functional characteristics, such as gelation in the edible film.

The most found drawbacks of edible film are on its brittle, easy to break and inelastic characteristics. In order to solve the problem, plasticizer is commonly added to suppress protein chain interaction and improve film flexibility, thus increasing the mechanical properties of the film as well. Research[5] has showed that the addition of plasticizer would prevent film brittleness during handling or storing. The ability of plasticizer to reduce the polymer interaction would be affected by the polymer concentration, and the type of polymer or plasticizer (molecular size and configuration, the total of free hydroxyl group, and plasticizer compatibility to the polymer). However, even though the addition of plasticizers could increase the film extensibility and flexibility, a large number of plasticizers would decrease film elasticity, mechanical resistance and barrier properties. In this research, we aim to observe the physical characteristics of whey-based edible film added with konjac at different levels (2%; 2.5%; and 3%) by using 30% glycerol as the plasticizer.

Materials and Methods

Materials

Materials used in to make the whey-based edible film in this research were whey protein isolate (CV. Makmur Sejahtera, Indonesia), konjac, 30% glycerol (w/w) (CV. Makmur Sejahtera, Indonesia) as plasticizer, and aquadest.

Methods

Edible Film Production

The edible film was made by following6,7,8,9 with modification on the konjac extract (KN Food, Indonesia) addition. The edible film solution was divided into three treatments based on the konjac extract concentrations (T1 = 2% konjac extract, T2 = 2.5% konjac extract and T3 = 3% konjac extract). One liter of edible film solution consisted of 25 gr whey powder; konjac extract at 0.5 g (T1), 0.625 g (T2), and 0.75 g (T3); glycerol at 0.75 ml (T1), 0.78 ml (T2), and 0.82 (T3), and aquadest. The whey powder konjac, and glycerol were diluted in aquadest and then heated at 90 ^{o}C for 30 minutes. The edible film solution was then poured to the mold and rested at room temperature for 24 hours. The dried edible film was then taken off the mold and stored for 24 hours before tested for physical characteristics and observed on its microstructure.

Film Physical Characteristics Measurement

The observed parameters in this study include characteristics and microstructure of the edible film. The film thickness was measured by using micrometer screw model MDC-25M (Mitutoyo, MFG, Japan) with 0.001 mm accuracy. The elongation at break was measured by using Universal Instrument Tensile Strength Meter (ASTM D882-1). The film was cut at 10 x 5 cm area and stretched at 50 mm/minute speed. The elongation was then measured by following formula:

Elongation (%) = L/L0 x 100%,

Description:
L = length of the edible film at break (mm)
L0 = initial length (mm)

The water vapor transmission rate (WVTR was observed by firstly cut the edible film into circle with 2.8 cm diameter. The film was then placed to cover a glass filled with 3 g silica gel. The covered glass was then placed into desiccator. The sample weight was measured every 24 hours for 5 days. The WVTR is presented in the unit of $g.mm^{-2}.day^{-1}$, and calculated by following formula:

WVTR = n/(t x A)

Description:
n = Weight change (gram)
t = time (day)
A = Edible film surface area (mm^2)

Film Microstructure
The film microstructure was observed with scanning electron microscopy (SEM JEOL JSM 5310 LV). The film was cut at 0.5 x 0.5 cm area, then placed on carbon covered plate and coated with gold. The sample was then placed on the SEM device for microstructure observation.

Statistical Analysis
The research was conducted in a completely randomized design with three replications. All of the data were analyzed by using analysis of variance (ANOVA), and followed with least significant difference (LSD) test at P<0.05 level to determine significant differences and P<0.01 for highly significant differences. The analysis was employed in SPSS 16.0 program. The best treatment was chosen by using multiple attribute method. The measured attributes include film thickness, elongation and water vapour transfer rate.

Results and Discussions
Thickness
The characteristics of whey-based edible film added with konjac is presented in Table 1. The analysis of variance showed that the addition of konjac at different level showed highly significant differences (P<0.01) to the thickness of the edible film. The higher konjac addition indicates a higher edible film thickness.

The result is caused by the condition that konjac addition would increase the soluble total solid in the film, thus increase the thickness of the edible film. The least significant difference (LSD) test showed that the addition of konjac at different level showed a highly significant difference (P<0.01) between each konjac concentration.

Table 1: Film thickness, tensile strength, elongation and WVTR at different konjac concentrations

Parameters	Treatments		
	T1	T2	T3
Thickness (mm)	$0.0294±0.0018^a$	$0.0326±0.0020^b$	$0.0370±0.0010^c$
Tensile strength (N)	$5.72±0.43^a$	$6.76±0.17^b$	$7.44±0.74^b$
Elongation (%)	$57.50±7.22^a$	$69.33±8.94^b$	$70.93±7.50^b$
WVTR (g.mm-2.day-1)	7.96±0.89	8.45±1.68	7.64±1.23

Description: abc Different superscript showed highly significant differences (P<0.01)

Tensile Strength

The analysis of variance (Table 1) also showed that the addition of konjac at different level gave a highly significant difference ($P<0.01$) to the tensile strength of the film. The result showed that higher konjac addition would increase the tensile strength of the produced edible film. The LSD test showed that the addition of konjac at different concentration also gave a highly significant difference ($P<0.01$). The result indicates that thicker edible film shown to have higher tensile strength, noting that film thickness has a positive correlation with the molecular weight inside the film.

Elongation

The analysis of variance (Table 1) showed that the addition of konjac with different levels showed a significant difference ($P<0.05$) to the elongation of the edible film. The higher addition of konjac also shown to give higher elongation of the film. Furthermore, the LSD test showed that the addition of konjac at different concentrations give significant difference ($P<0.05$) to the elongation of the whey-based edible film. The increased elongation is caused by the high gel strength in the film.

Water Vapour Transmission Rate (WVTR)

The analysis of variance showed that different konjac addition did not give significant difference ($P<0.05$) to the WVTR of the edible film. However, even though the result was not statistically different, the higher addition of konjac tend to increase the WVTR of the whey-based edible film as well. The insignificant effect of konjac addition to the WVTR of the film is caused by the permeability coefficient in the film, which consisted of diffusion and solubility coefficient. Moreover, the LSD test also showed that the addition of konjac did not give significant effect ($P>0.05$) to the WVTR of the edible film as well.

Microstructure

The microstructure observation aimed to understand the characteristics of the edible film. The microstructure of the whey-based edible film added with konjac was observed with Scanning Electron Microscope (SEM) method, and the results are presented in Figure 1.

In figure 1, it can be seen that 2% konjac addition (a) showed uneven distribution and several cracks in the surface area. The condition is caused by the hydrogen bonds in the film which had not reached its maximum bonding capacities. In 2.5% konjac addition (b) the surface area of the film was more compact and evenly distributed compared to the 2% (a) and 3% (c) konjac addition. In this research, it can be seen that the addition of konjac would improve the internal structure of the film indicated by the decreased cracks and firmer film.

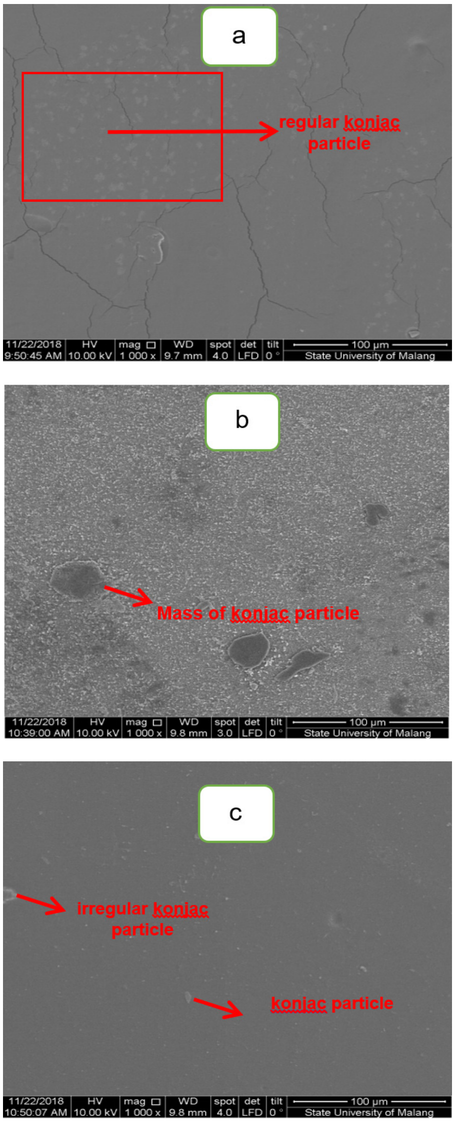

Fig. 1: Microstructure of the whey-based edible film added with konjac at 2% (a) 2.5% (b) and 3% (c) and glycerol as plasticizer with 1000x magnification

Discussions

The edible film thickness in this study is shown to be affected by the increase of film component along with the increase of konjac addition. The polymers in konjac would increase film viscosity during gelatinization, thus the film suspension would experience gelation and resulted in an increased film thickness. A similar result showed that the thickness of edible film would be mainly affected by the total solids concentration in the edible film solution.[10] Moreover, the result is in accordance with Henrique[11] who showed that film permeability, solubility and thickness are characteristics mainly affected by the dry matter content.

The addition of konjac in the edible film would initiates a complex protein bond which would increase the molecular weight in the film. The result of tensile strength measurement in this research is similar with reports by Rodríguez *et al.,*[12] and Sanyang *et al.,*[13] on the starch-based edible film. The obtained result is added by the effect of plasticizer addition, as the compound would reduce the intermolecular bonds between polysaccharide chains and promote the production of hydrogen bond between plasticizer and polysaccharide molecule instead. The heating of polysaccharide with water would ignite a simultaneous bonding and releasing of water to create strong three dimensional matrixes which become the basis of a strong gel. Moreover, polysaccharide is also known to have the ability to maintain the edible film compactness and stability, thus the higher polysaccharide concentration would improve the tensile strength of the film and prevent brittleness as well.

The increase of the edible film elongation in this research was caused by the polysaccharide content in the konjac which affect the matrix strength and elasticity in the film. Chen *et al.,*[14] described that konjac had a good gelation performance, biocompatibility, and biodegradability, which showed its potential to be used as edible film. Wang[15] stated that konjac had the properties to create strong gel. The increase of WVTR in this research was caused by hydrophilic characteristics of the konjac. Konjac has been known to contained glucomannan, a hydrophilic polysaccharide which increase the hydrophilic properties when applied in the film (Qiao *et al.,*[16]). The hydrophilic materials would have a weak water vapour resistance, thus the use of the material in the edible film would affect the film's water vapour permeability. On the other hand, hydrophilic materials had a good oxygen, carbon dioxide, and lipid inhibition. Even though the whey in the film solution would decrease the solubility coefficient through intermolecular disulfide bond, yet the effect is negated by the plasticizing effect of whey molecule in konjac matrix which increase diffusion coefficient. Both effect thus would affect the WVTR of the whey-based film.[17]

According to Wang[15], the rough microstructure of the edible film indicates a weak tensile strength capacity of the film.

Another research showed that the ingredients used would correlates with the physicochemical properties of the edible film, which can be seen through microstructure observation.[18]

The usage of glycerol as plasticizer in this study is regarding that the materials had the good plasticizer characteristics for edible film. Research by Wirawan *et al.,*[19] showed that glycerol was more preferable than sorbitol to be used as plasticizer in terms of flexibility and elasticity. The higher gap between polymer molecules would resulted in a more flexible edible film. The polymer molecules distribution in the edible film would affect film elasticity, thus the wider gap between molecules in the edible film would resulted in more distributed surface in SEM observation. Atarés *et al.,*[20] added that the increase of konjac addition would increase the tensile strength of the edible film and affect the intermolecular force between film microstructure.

In addition to improve the film characteristics, konjac consumption could provide various health benefits. Research by Zhang *et al.,*[21] showed that adding konjac in diet could absorb cholesterol and glucose in the gastrointestinal tract. Moreover, konjac had high water soluble dietary fiber,[22] and the compound would help control obesity, improve intestinal activities and prevent cardiovascular disease.[23] He *et al.,*[24] mentioned that konjac (*Amorphophallus konjac*) could be hydrolyzed with β-mannase to produce glucomannan which had health benefit when consumed, such as improving gut flora.S[25] The addition of konjac in the edible film, thus offer health benefit potential aside from protecting the food products.

Conclusion

The research concludes that the addition of konjac could improve the physical characteristics of whey-based edible film. The best konjac addition was found at 2.5%, with film thickness at 0.0326±0.0020 mm, tensile strength at 6.76±0.17 N, elongation at 69.33±8.94%, and WVTR at 8.45±1.68 g.mm-2.day-1. Furthermore, the SEM observation showed the film had a compact and distributed surface.

Acknowledgment

Authors would like to thank BUDI-DN Scholarship and Lembaga Dana Pendidikan (LPDP) by the Indonesian Ministry of Finance which provide funding for the research.

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

Conflict of Interest

There was no conflict of interest associated with this study by any of the authors.

References

1. Bourtoom, T. Edible films and coatings: characteristics and properties. *International Food Journal.* 2008; 15 (3): 237-248.
2. Sadeghizadeh-Yazdi J., Habibi M., Kamali A. A., and Banaei M. Application of edible and biodegradable starch-based film in food packaging: a systematic review and meta-analysis. *Curr. Res. Nutr Food Sci Jour.* 2019; 7 (3): 624-637.
3. Gutierrez T. J. Surface and nutraceutical properties of edible films made from starchy sources with and without added blackberry pulp. *Carbohydr Polym.* 2017; 165: 169–179.
4. Pavlath A. E., and Orts W. Edible films and coatings: why, what and how? in: Embuscado M. E., Huber. K., (Ed), Edible Films and Coatings for Food Applications, Springer. 2009; 1-23.
5. Vieira M. G. A., Da-Silva M. A., Dos-Santos L. O., and Beppu M. M. Natural based plasticizers and biopolymer films: A review. *Eur Polym J.* 2011; 47: 254-263.
6. Sobra P. J. A., Menegalli F. C., Hubinger M. D., and Roques M. A. Mechanical water vapor barrier and thermal properties of gelatin based edible. *Journal Food Hydrocoloids*. 2001; 15 (4): 423-432.
7. Yoshida C. M. P., and Antunes A. J. Characteriztion of whey protein emulsion film. *Brazilian Journal of Chemical Engineering*. 2004; 21 (2): 247-252.
8. Gounga M. E., Xu S. Y., and Wang Z. Whey protein isolate-based edible films as affected by protein concentration, glycerol ratio and pollulan addition in film formulation, *J Food Enggineering*. 2007; 83 (4): 521-530.
9. Oses J., Fernandes-Pan I., Mendoza M., and Mate J. I. Stability of mechanical properties of edible film based on whey protein isolate during storage at different relative humidity. *Journal Food Hydrocololloids*. 2009; 23 (1): 125-131.
10. Suryaningrum T. D., Dwi, Jamal B., and Nurochmawati. A study on the edible film production from carrageenan. *Jurnal Penelitian Perikanan Indonesia.* 2005; 11 (4): 1-13.
11. Henrique C. M., Teofilo R. F., Sabino L., Ferreira M. M. C., and Cereda M. P. Classification of Cassava Starch Film by Physicochemical Properties and Water Vapor Permeability Quantification by FTIR and PLS. *Journal of Food Science*. 2007; 74: 184-189.
12. Rodríguez M., Osés, J., Ziani K., and Maté J. I. Combined effect of plasticizers and surfactants on the physical properties of starch based edible films. *Food Research International.* 2006; 39: 840-846.
13. Sanyang M. L., Sapuan S. M., Jawaid M., Ishak M. R., and Sahari J. Effect of plasticizer type and concentration on tensile, thermal and barrier properties of biodegradable films based on sugar palm. *Polymers.* 2015; 7(6):

1106-1124.

14. Chen J. F., Zhang W. Y., and Li X. Adsorption of Cu(II) ion from aqueous solutions on hydrogel prepared from konjac glucomannan, *Polym Bull.* 2016; 73: 1965–1984.
15. Wang W. Introduction to Konjac. Andi Johnson Konjac Company Ltd. 2016; 5-403.
16. Quao D., Tu W., Zhong L., Zhong W., Binjia Z., and Fatang J. Microstructure and mechanical/hydrophilic features of agar-based films incorporated with konjac glucomannan, *Polymers*. 2019; 11(12): 1952.
17. Leuangsukrerk M. T., Phupoksakul K., Tananwong C., Borompichaichanrtkul and Janjarasskul T. Properties of konjac glucomannan whey protein isolate blend films, Department of Food Technology, Faculty of Science, Chulalongkorn University; 2014.
18. Mostafavi F. S., Kadkhodaee R., Emadzadeh B., and Koocheki A. Preparation and characterization of tragacanth-locust bean gum edible blend films. *Carbohydrate Polym.* 2016; 139: 20-27.
19. Wirawan S. K., Prasetya A., and Ernie. The effect of plasticizer to the characteristics of edible film made from pectin. *Reaktor*. 2013; 14 (1): 61-67.
20. Atarés L., Bonilla J., and Chiralt A. Characterization of sodium caseinate-based edible films incorporated with cinnamon or ginger essential oils. *J Food Eng*. 2010; 100 (4): 678–687.
21. Zhang Y., Xie B., and Gan X. Advance in application of konjac glucomannan and its derivatives. *Carbo. Polym.* 2005; 60: 27-31.
22. Fang W., and Wu P. Variations of konjac glucomannan from *Amorphophallus konjac* and its refined powder in china. *Food Hydrocolloids.* 2004; 18: 167-170.
23. Li B., Xia J., Wang Y., and Xie B. Grain-size effect on the structure and anti-obesity activity of konjac flour. *Journal Agricultural and Food Chemistry.* 2005; 53: 7404-7407.
24. He Z., Zhang J., and Huang D. A kinetic correlation for konjac powder hydrolysis by β-mannase from Bacillus licheniformis. *Biotechnology Letters*. 2001; 23: 389-393.
25. Yen S. L., Lin M. S., and Chen H. L. Partial hydrolysis enhances the inhibitory effects of konjac glucomannan from *Amorphophallus konjac* C. Koch on DNA damage induced by fecal water in Caco-2 cells. *Journal Food Chemistry.* 2010; 119: 614-618.