Food ScienTech Journal Vol. 4 (1) 2022 ISSN : 2685-4279 DOI:10.33512/fsj.v4i1.15711

Physical-Mechanical Properties of Edible Film Based on Beneng Taro (*Xanthosoma Undipes* K.Koch) Starch with Plasticizer

Serly Eka Puspita*, Fitria Riany Eris, and Rifqi Ahmad Riyanto

Food Technology Department, Faculty of Agriculture, Sultan Ageng Tirtayasa University, Indonesia

*E-mail: sarlyekap@gmail.com

Submitted: 13.06.2022; Revised: 19.06.2022; Accepted: 23.06.2022

ABSTRACT

Edible film is a thin layer as a coating for foodstuffs made from edible materials such as taro. One of the taro tubers that can be used as edible film is Beneng from Banten. Edible films made from starch have a weakness that is easy to tear and have low elasticity, to change the physical properties of the film from starch it is necessary to add a plasticizer. Plasticizers that are often added to the production of edible films are xylitol, sorbitol, polyethylene glycol, and glycerol. The purpose of this study was to determine the effect of the type of treatment and concentration of plasticizer on the physical-mechanical properties of edible film made from taro beneng starch. The treatment in this study was divided into 2 factors, the first factor was the type of plasticizer (sorbitol, glycerol and PEG), while the second factor was the concentration of the plasticizer (1%, 3%, and 5%). The tests carried out in this study were the tensile strength, elongation, thickness, water vapor transmission, and water solubility tests. The results showed that the type and concentration of plasticizer have a significant effect on the characteristics of the edible film. The interaction between the type and concentration of plasticizer has no significant effect on the water vapor transmission test. The best edible film in this study was the edible film with the addition of the plasticizer sorbitol with a concentration of 3%.

Keywords: Edible film; plasticizer; Beneng; starch

INTRODUCTION

Packaging on food products is an activity aimed at protecting and maintaining the quality and safety of food or beverages to the hands of consumers. The types of packaging circulating in Indonesia are very diverse, ranging from canned packaging, paper, plastic, to leaves. Plastic is one of the packaging materials that are often used, the use of plastic can pollute the soil and contribute to waste that is difficult to decompose also contains chemicals that are quite dangerous (Salamah, 2018). Currently, there have been many alternative packaging materials that have been developed such as edible film.

Edible film is a thin layer as a coating for food ingredients made from materials suitable for consumption. Edible film, in addition to being used as a packaging material, can also be used as a food coating (coating) or as a film placed between foods. Edible film can function as a barrier to inhibit moisture, oxygen, lipids, light and solutes (Ariska and Suyatno, 2015).

Edible film is a packaging made with starch-based ingredients from the type of tubers so that it is environmentally friendly (Saleh et al., 2017). One of the tubers that can be used as edible film is taro beneng which comes from Banten. According to Budiarto and Rahayuningsih (2017), taro beneng has a high carbohydrate content as a source to produce starch. According to the research of Rostianti et al. (2018), the starch content contained in taro beneng Kampung Pagerbatu is 84.96% while in the study of Kusumasari et al. (2019), taro beneng from Gapoktan Juhut has a starch content of 56.29%.

Edible film made of starch has the disadvantage of being easily torn and has low elasticity, to change the physical properties of the film from starch, it is necessary to add a plasticizer. Plasticizer is a non-volatile material that has a high boiling point so that if mixed with other materials, it can change the physical properties of the material (Marpongahtun, 2013). If a plasticizer is added to a material, it will make the polymer chain edible film produced have elasticity and flexibility properties so that it is not easily broken (Wattimena et al., 2016).

Plasticizers that are often added to the manufacture of edible film are xylitol, sorbitol, polyethyleneglycol (Marpongahtun, 2013) and glycerol (Afifah et al., 2018). The purpose of this study is to determine the effect of the type treatment and concentration of plasticizers on the physical-mechanical properties of edible film based on taro beneng starch.

MATERIALS AND METHODS

Tools and Materials

The materials used for made edible film were beneng taro from Juhut village, carrageenan (Moli), salt (Dolpin), water, sorbitol (Teknis), glycerol (Teknis), polyethylene glycol (PEG) 400 (Teknis), aquadest, silica gel, and vaseline. The tools used in this research include tools for made edible film were analytical balance sheet, thermometer (Goto), hot plate stirrer (Thermo Scientific), beaker glass (Pyrex), measuring cup (Pyrex), refrigerator (freezer), film mold, moisture content oven (Memmert), cabinet dryer, knife, filter paper, blender (Phillips), stirring rod, scissors (Joyko), desiccator, centrifugation, chopper (Mitochiba), blacu cloth, 100 mesh sieve, clamp rods, universal testing machine (MCT 2150), and micrometers (Mitutoyo). Procedures and formulations for made edible film refer to Sitompul and Zubaidah's research (2017). The treatment formulation in this research consisted of four formulations. Formulations are presented in Table 1.

Methods

The research had been carried out in three stages, namely beneng taro starch production, edible film production, and physico-mechanical properties testing. The physical tests carried out were the solubility in water and the rate of transmission of water vapor, while the mechanical tests carried out are tensile strength, elongation, and film thickness.

Beneng Taro Starch Production

The production of beneng taro starch refers to Jacoeb et al. (2014) which have been modified in raw materials. This process began with stripping, cutting, washing and soaking with saline solutions. Beneng taro cleaned again and continued with reducing the size. The beneng taro filtered using clothes and the water produced from the process precipitated for 6 hours at a temperature of 4°C. The water resulting from the settling process discharged. Washing of the starch produced by re-settling by adding 1: 1 water by volume at a temperature of 4°C for 12 hours. The starch dried at 50°C for 8-12 hours. The dried starch flakes mashed and sifted with a 100 mesh sieve to produce fine grains of beneng taro starch.

Edible Film Production

Edible film production refers to Sitompul and Zubaidah (2017) with modified raw materials. The process began with weighing a 5.25 grams (75% b/v) beneng taor starch and 1.75 grams (2.5% b/v) carragenan then dissolved with 150 ml aquadest and then stirred until a solution suspension was formed. The solution transferred into a 250 ml Beaker glass then heated over the *hotplate* at a temperature of ±70°C while stirring at a speed of 60 rpm for 15 minutes until it forms a gel. After the solution forms a gel, a plasticizer (sorbitol, glycerol and polyethylene glycol) with a concentration of 1, 3 and 5% (v/v) were added. The solution reheated at a temperature of ±70°C on the magnetic stirrer while stirring at a speed of 60 rpm for 15 minutes. Next the solution was allowed to stand to remove the air contained in the solution for 10 minutes. The solution then poured into edible film container with a size of 30 x 30 cm around 120 ml, then put in cabinet dryer for 15 hours with a temperature of 50°C. After drying, edible film allowed to stand for 1 hour to make it easier when removed from the container.

Water Vapor Transmission

Water vapor transmission test using samples in saucer cover containing saline solution. Then the saucer was put into a desiccator with a temperature of 25°C and RH 50%. The sample was weighed periodically for 7 hours with a weighing time interval of 1 hour (Rhim and Wang, 2013). The value of the rate of transmission of water vapor can be calculated using the formula:

$$\text{WVTR}=\frac{\Delta \text{W}}{\text{t x A}}$$

Description:

WVTR = Water Vapor Transmission Rate (g/m^2 h)
ΔW = Change in film weight (g)
t = Time (hours)
A = Film area (m^2)

Solubility in Water

The solubility of the film in water was obtained by drying film sample and filter paper in 105°C oven for 24 hours. Furthermore, the film sample and filter paper were weighed separately (W1) then soaked in aquadest 50 mL for 24 hours and stirred. After that, the film sample was dried again using a 105°C oven for 24 hours followed by weighing (W2) (Lismawati, 2017). The data obtained is then calculated using the formula:

$$\%\,Solubility = \frac{W1 - W2}{W1}\ X\ 100\%$$

Description:

Solubility = Solubility edible film in water (%)
W1 = Initial weight (g)
W2 = Final weight (g)

Tensile Strength

The sample was cut according to the specification of length x width listed on the universal testing machine MCT 2150 with a size of 10 x 4 cm. Then the sample was observed at length initially by being placed on an analyzer (Sitompul and Zubaidah 2017). Based on Rhim and Wang (2013), the engine setting is carried out with a pull speed of 50 mm / min with an initial distance between clamps of 100 mm. The data obtained is then calculated using the formula:

$$Tensile\ Strength = \frac{F}{A}$$

Description:

Tensile Strength = Tensile strength edible

film (N/mm2)
F = Tensile strength force (N)
A = Cross-sectional area (mm^2)

The obtained data then converted to MPa unit.

Elongation

Elongation testing was obtained by the same procedure as tensile strength (Sitompul and Zubaidah, 2017). Elongation is expressed in percentages and is calculated using the formula:

$$Elongation = \frac{P2 - P1}{P1} X\ 100\%$$

Description:
Elongation = Extension of material (%)
P1 = Initial length (mm)
P2 = Final length (mm)

Thickness

The thickness of edible film was measured using a micrometer with an accuracy of 0.01 mm at five different points on the surface of the film. The data obtained were then averaged and expressed as film thicknesses with mm units (Zuwanna et al., 2017).

Data Analysis

The results of testing the physical-mechanical properties of edible films were statistically analyzed using the SPSS application to look for Analysis of Variance (ANOVA), to determine the effect of the treatment. The results of the analysis that show a significant effect will be analyzed by further testing using the Duncan's Multiple Range Test (DMRT) test at a 95% confidence level.

RESULTS AND DISCUSSION

From its physical appearance, edible film with the addition of PEG plasticizer was stiffer, harder and not transparent compared to edible film with sorbitol and glycerol plasticizer added. Edible film with the addition of sorbitol plasticizer had a smoother surface appearance compared to edible film with the addition of glycerol and PEG plasticizers. When compared with control edible films, edible films with the addition of the plasticizer sorbitol had a transparent film surface like the film from the control. The surface of the film with the addition of glycerol plasticizer tended to be transparent with a slightly thin yellow color, while the film with the addition of PEG plasticizer is white like matte (Figure 1). Physically, edible film with the addition of sorbitol and PEG plasticizer was not stiff and dry, so it did not stick to paper or other objects when in contact. While the edible film with the addition of glycerol plasticizer had elastic properties, soft, and moist, so it was easy to stick and difficult to remove.

The response of edible film analysis to the type and concentration of plasticizers can be seen in Table 2.

The water vapor transmission test results from Table 2 showed that the increased concentration of the plasticizer could increase the transmission value of *edible film* water vapor. Based on the results of the research conducted, the range of water vapor transmission values of sorbitol plasticizers, glycerol and PEG was successively 0.1210 - 0.1317 g / m^2h, 0.1750 - 0.2046 g / m^2h, and 0.1242 - 0.1732 g / m^2h. The largest water vapor transmission value in the study was produced by a 5% glycerol sample and the smallest water vapor transmission value was produced by a 1% sorbitol sample. Analysis of variance showed that the interaction between the type and concentration of plasticizer did not have a significant effect on the response of water vapor transmission. The best water vapor transmission value was obtained in sample 1% sorbitol, but this value was not significantly different from the other samples.

The transmission of moisture depends on the properties of the constituent materials used in the production of edible film. *Edible film* that has a high vapor transmission value is generally made of polysaccharide and protein materials. Proteins can absorb high water moisture because they are included in polar polyners (Herliany *et al.*, 2013). Water vapor transmission that has the ability to absorb the smallest moisture is the best packaging. This is due to the smaller the product that is packaged to be exposed to water and experience damage caused by air. The main role *of edible film* as a packer is to inhibit moisture, light, oxygen, lipids and solutes (Dwimayasanti and Kumayanjati, 2019).

The value of water vapor transmission of edible film according to the Japanese Industrial Standard (JIS) is a maximum of 7 g/m^2h. In this study, the highest water vapor transmission of edible film was 0.2046 g/m^2h, which means it has met the JIS standard. In the research of Pangesti et al. (2014), the water vapor transmission of the taro starch edible film was 5.75 g/m^2h, which means that the water vapor transmission value of the taro starch edible film was lower than previous studies.

The results of the solubility test in water from Table 2 showed that an increase in the concentration of plasticizers in the type of sorbitol plasticizer could increase the solubility value in edible film water, while in the PEG type of plasticizer, the addition of a plasticizer decreased the solubility value of edible film the resulting. Based on the results of the research conducted, the range of solubility values in sorbitol, glycerol and PEG plasticizer water was 62.8 –74.8 %, 77.53 – 91.57%, and 41.94 – 49%, respectively. The largest solubility value in water in the study was produced by a 5% glycerol sample and the smallest solubility value was produced by a 5% PEG sample. Analysis of variance showed that the interaction between the type and concentration of plasticizer had a significant effect on the solubility in water response. The best value from the analysis of solubility in water was obtained in sample 5% glycerol with analysis letters that were not the same as other samples

The high solubility of the film indicates the ease with which the film is dissolved in water and the poor resistance to water. The solubility of the film is influenced by the nature of the film-forming compounds. Plasticizers interact with matrix film by facilitating the migration of water into the film and increasing the space between the film chains, so that the solubility of the film can be improved (Lagos et al., 2015). Edible film with high solubility is good to use for ready-to-eat products due to its easily soluble properties (Dwimayasanti and Kumayanjati, 2019).

The tensile strength test results from Table 2 showed that an increase in the concentration of the plasticizer cannot always raise the tensile strength value of edible film. Based on the results of the research conducted, the range of tensile strength values of sorbitol, glycerol and PEG plasticizers was 10.8660 - 17.7567 MPa, 8.7533 - 11.9967 MPa, and 8.3100 - 9.2100 MPa. The largest tensile strength value in this study was generated by a 3% sorbitol sample and the smallest tensile strength value was generated by a 5% PEG sample. Analysis of variance showed that the interaction between the type and concentration of plasticizer had a significant effect on the tensile strength response. The best value of the tensile strength analysis is obtained in the 1% sorbitol sample with the analysis letter that is not the same as the other samples

In general, the higher the concentration of plasticizers added will make the tensile strength value of edible film decrease. However, in this study there were several treatments that showed the opposite trend where the tensile strength increased higher (Dwimayasanti and Kumayanjati, 2019). The higher the concentration of the added plasticizer will reduce the tensile strength value. The cause of this is the nature of the plasticizer which will reduce the internal hydrogen bond in the intermolecular bond, as a result of which the resulting edible film will have weak physical properties and can reduce the tensile strength value of a film (Sitompul and Zubaidah, 2017).

The tensile strength of edible film according to the Japanese Industrial Standard (JIS) is a minimum of 0.39 MPa. In this study, the value of the lowest edible film tensile strength was 7.4867 MPa, which means that all edible film treatments had met the JIS standard. In the research of Putri et al. (2021), the tensile strength of the kimpul taro starch edible film was 0.361 MPa, while in Handayani and Nurzanah (2018), the tensile strength of the taro starch edible film was 1.198 MPa, which means that the tensile strength value of the taro starch edible film is higher than previous studies.

The elongation test results from Table 2 show that an increase in the concentration of plasticizers can increase the elongation value of edible film. Based on the results of the research conducted, the range of elongation values of sorbitol, glycerol and PEG plasticizers was 5.18 - 11.02 %, 8.33 - 13.86 %, and 2.78 - 5.01 %. The largest elongation value in this study was generated by a 5% glycerol sample and the smallest elongation value was generated by a 1% PEG sample. Analysis of variance showed that the interaction between the type and concentration of plasticizer had a significant effect on the elongation response. The best value from the results of the elongation analysis was obtained in the 5% glycerol sample with analysis letters that were not the same as the other samples.

The increase in the concentration of plasticizers will affect the elongation value obtained, the higher the plasticizer added, the higher the percent value of the resulting lengthening. This can be attributed to the treatment of increasing the concentration of plasticizers. According to Nandika et al. (2021) with the increasing concentration of plasticizers added, it will cause a reduction in the intermolecular hydrogen bonds and the intramolecular polymer chains adjacent to it will be weak, so that the resulting film will be more flexible and the percentage of elongation will increase.

The elongation of the edible film according to the Japanese Industrial Standard (JIS) is minimal 70%. In this study, the highest edible film elongation is 13.8600%, which means that it does not meet the JIS standard. In the research of Putri et al. (2021), the elongation of the taro kimpul starch edible film was 76.70%, while in Handayani and Nurzanah (2018), the elongation of the taro starch edible film was 55.13%, which means that the elongation value of the taro starch edible film was lower than previous studies.

The thickness test results from Table 2 show that the increase in the concentration of the plasticizer increases the thickness of the edible film produced. Based on the results of the research conducted, the range of thickness values of sorbitol, glycerol and PEG *plasticizers* was 0.0403 – 0.1027 mm, 0.0590 – 0.0843 mm, and 0.0673 – 0.0904 mm respectively. The thickest edible film value in this study was produced by a 5% sorbitol sample and the smallest thickness value was produced by a 1% sorbitol sample. Analysis of variance showed that the interaction between the type and concentration of plasticizer had a significant effect on the thickness response. The best value from the thickness analysis was obtained in the 5% sorbitol sample with the analysis letters that were not the same as the other samples

The thickness of edible film increased along with the increase in the concentration of plasticizers. This could be happened because the plasticizer has properties that can increase the viscosity of edible film solutions. The thickness of edible film is influenced by several factors such as the length of time the film is dried, the size of the film container, and the properties of the constituent materials used. If there are many materials used in making edible film, the resulting film will be thicker because the constituent components are diverse (Maharani et al., 2017).

The thickness of the edible film according to the Japanese Industrial Standard (JIS) is a maximum of 0,25 mm. In this study, the highest thickness of edible film was 0,1027 mm so that it met the JIS standard. In the research of Putri et al. (2021), the thickness of the taro kimpul starch edible film is 0,22-0,26 mm, while in Handayani and Nurzanah (2018), the thickness of the taro starch edible film is 0,3 mm, which means the thickness of the taro starch edible film is thinner than in previous studies.

The effectiveness of beneng taro as food packaging is not yet known, because until now there has been no research that discusses the use of taro beneng starch as a basic material for making edible films, edible coatings and microencapsulations. Further research is needed regarding the use and application of taro beng starch edible film as food packaging.

CONCLUSION

Based on the research that has been done, it can be concluded that the treatment of type and concentration of plasticizer had a significant effect on the characteristics of tensile strength, elongation, thickness, water vapor transmission, and water solubility of edible film. The interaction had a significant effect on the characteristics of tensile strength, elongation, thickness, and water solubility of the edible film, but had no significant effect on the value of the water vapor transmission rate. The best edible film in this study was the edible film with the addition of the plasticizer sorbitol with a concentration of 3%. The test value of the water vapor transmission rate was 0.1214 g/m2-hour, 67.7205% water solubility, 17.7567 MPa tensile strength, 9.0367% elongation, and 0.0683 mm thick. The edible film produced in this study met the JIS standard on the variable rate of water vapor transmission, tensile strength, and thickness, but did not meet the JIS standard on the elongation variable.

REFERENCES

Afifah, N., Sholichah, E., Indrianti, N., and Darmajana, D.A. 2018. Effect of Plasticizer Combination on *Edible Film* Characteristics of Carrageenan and Beeswax. Biopropal Industry. Vol. 9(1): 49-60.

Ariska, R.E and Suyatno. 2015. Effect of Carrageenan Concentration on Physical and Mechanical Properties of *Edible film* Of Banana Weevil Starch and Carrageenan with Glycerol *Plasticizer*. Proceedings of the National Seminar on Chemistry: Department of Chemistry FMIPA State University Surabaya. Pp 34-40. ISBN: 978-602-0951-05-8.

Budiarto, M.S. and Rahayuingsih, Y. 2017. Potential Economic Value of Taro Beneng (*Xanthosoma undipes* K.Koch) Based on its Nutritional Content. Journal of Regional Development Policy. Vol. 1(1): 1-12.

Dwimayasanti, R., and Kumayanjati, B. 2019. Characterization *edible film* d ar Carrageenan dan Chitosan withLayer Method by Layer. JPB Marine and Fisheries. Vol. 14(2): 141-150.

Handayani, R. and Nurzanah, H. 2018. Characteristics of Edible Film of Taro Starch with Antimicrobial Addition of Galangal Essential Oil. Journal of

Engineering Competition. Vol. 10(1): 1-11.

Herliany, N. E., Santoso, J., and Salamah, E. 2013. Characteristics of bio*films* based on carrageenan. Journal of Aquaculture. Vol. 4(1): 10-20.

Jacoeb, A.M., Nugraha, R., and Utari, S.P.S.D. 2014. Making *Edible Film* from Starch Fruit Lindur With the Addition Of Glycerol And Carrageenan. Journal of Land Acquisitionof Indonesian Fishery Products. Vol. 17(1): 14-21.

Kusumasari, S., Eris, F.R., Mulyati, S., and Pamela, V.Y. 2019. Characterization of the Physicochemical Properties of Beneng Taro Flour as a Typical Food of Pandeglang Regency. Journal of Agroecotech. Vol. 11(2): 227-234.

Lagos, J.B., Vicentini, N.M., Santos, R.M.C. Dos, Bittante, A.M. Q.B., and Sobral, P. J. A. 2015. *Mechanical Properties of Cassava Starch Films as Affected by Different Plasticizers and Different Relative Humidity Conditions*. International Journal of Food Studies. Vol. 4: 116-125. doi:10.7455/ijfs/4.1.2015.a10.

Lismawati. 2017. Pengaruh Penambahan Plasticizer Gliserol Terhadap Karakteristik Edible film Dari Pati Kentang (Solanum tuberosum L.). Skripsi. Fakultas Sains dan Teknologi, UIN Alauddin Makassar. Makassar. 79 hal.

Maharani, Y., Hamzah, F., Rahmayuni, R. 2017. Effect of Sodium Tripolyphosphate (Stpp) Treatment On Modified Sago Starch On Thickness, Transparency And Rate Of Transfer Of Edible Water Vapor *Film*. JOM Faperta. Vol. 4(2): 1-11.

Marpongahtun, C.F.Z. 2013. *Physical-Mechanical Properties and Microstructure Of Breadfruit Starch Edible films With Various Plasticizer*. Exact. Vol. 13(1-2): 56-62.

Marpongahtun, C.F.Z. 2013. *Physical-Mechanical Properties and Microstructure Of Breadfruit Starch Edible films With Various Plasticizer*. Exact. Vol. 13(1-2): 56-62.

Nandika, A., Harsojuwono, B.A., Arnata, I.W. 2021. Effect of Type and Concentration of Plasticizing Material on Glucomannan Bioplastics. Journal of Agro-Industrial Engineering and Management. Vol. 9(1): 75-84.

Pangesti, A.D., Rahim, A., Hutomo, G.S. 2014. Physical, Mechanical and Sensory Characteristics of Edible Film from Taro Starch at Various Concentrations of Palmitic Acid. agrotechnical. Vol. 2(6): 604-610.

Putri, M.D.Y., Fradela, Z.A., Wahyudi, B. 2021. Preparation and Characterization of Edible Film from Pati Talas Kimpul and Chitosan. SNAST proceedings. ISSN: 1979-911X.

Rhim, J.W dan Wang L.F. 2013. Mechanical and Water Barrier Properties Of Agar/-Carrageenan/Konjac Glucomannan Ternary Blend Biohydrogel Films. Elsevier. Hal 71-81. DOI: 10.1016/j.carbpol.2013.03.083.

Rostianti, T., D.N. Hakiki, A. Ariska, and Sumantri. 2018. Characterization of the Physicochemical Properties of Taro Beneng Flour as Local Food Biodiversity of Pandeglang Regency. *Gorontalo Agriculture Technology Journal*. Vol. 1(2): 1-7.

Salamah, P. 2018. Edible Film Properties with theAddition of Pepaya Leaf Extract (*Carica papaya* L.). Thesis. Faculty of Agriculture, Sriwijaya University. Palembang. 86 p.

Saleh, F.H.M., Arni Y.N., and M. Ridho J. 2017. Edible *Film* Making of Cassava Starch as Makanan Packer. Journal of Industrial Technology. Vol. 23(1): 43-48.

Sitompul, A.J.W.S. and Zubaidah, E. 2017. Effect of Plasticizer Type and Concentration on Edible Physical Properties of Kolang Kaling (*Arenga pinnata) film*. Journal of Food and Agroindustry.Vol. 5(1): 13-25.

Wattimena, D., La Ega, F.J. Polnaya. 2016. Edible Characteristics of Natural Sago Starch-based film and Sago Starch Phosphate withn Addition of Glycerol. Agritech. Vol. 36(3): 247-252.

Zuwanna, I., Fitriani, dan Hesti, M. 2017. Pengemas Makanan Ramah Lingkungan, Berbasis Limbah Cair Tahu (Whey) Sebagai Edible film. Prosiding Seminar Nasional Pascasarjana (SNP) Unsyiah. Hal 77-87.

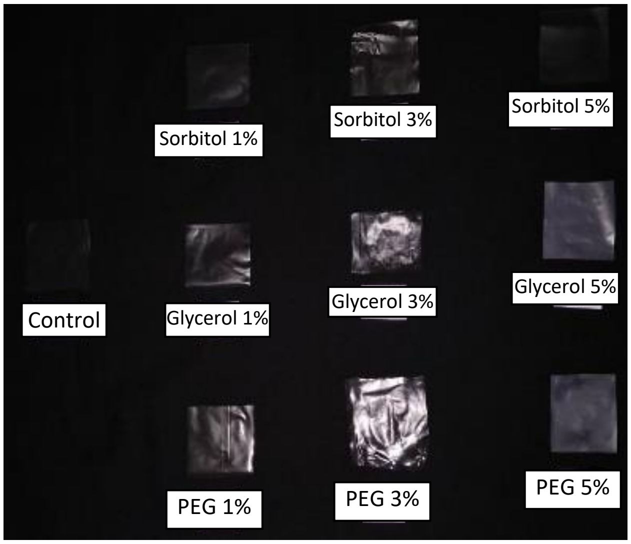

Figure 1. Edible Film appearence

Table 1. Edible Film Formulation

Formulation per 150 ml			
Plasticizer type	Beneng starch (grams)	Carrag-eenan (grams)	Plasticizer concentra-tion (v/v)
Sorbitol	5,25	1,75	1%
Glycerol	5,25	1,75	3%
PEG	5,25	1,75	5%

Table 2. Results of analysis

Types of Plasticizers	Plasticizer Concentration	Analysis of physical and mechanical properties				
		Water Vapor Transmission	Solubility in Water	Tensile Stength	Elongation	Thickness
	%	g/m^{2}h	%	MPa	%	Mm
Control		0,1248	37.8794	19,9200	1,4400	0,0900
Sorbitol	1	0,1210^{a}	62.8047^{f}	10.8660^{b}	5.1867^{d}	0.0403^{e}
	3	0,1214^{a}	67.7205^{e}	17.7567^{a}	9.0367^{c}	0.0683^{cde}
	5	0,1317^{a}	74.8029^{d}	11,1700^{b}	11.0233^{b}	0.1027^{a}
Glycerol	1	0,1750^{a}	77.5366^{c}	8.7533^{c}	8.3300^{c}	0.0590^{de}
	3	0,2022^{a}	85.0058^{b}	11.9967^{b}	10.4867^{b}	0.0700^{cde}
	5	0,2046^{a}	91.5766^{a}	8.9467^{c}	13.8600^{a}	0.0843^{bc}
PEG	1	0,1242^{a}	49.7507^{g}	8.3100^{cd}	2.7867^{e}	0.0673^{cde}
	3	0,1550^{a}	48.2629^{g}	9.2100^{c}	3.7167^{e}	0.0743^{cd}
	5	0,1732^{a}	41.9469^{h}	7.4867^{d}	5.0100d	0.0904^{b}