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O_2 and CO_2 permeability apparatus for edible casing of sausage: design and performance test

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KEYWORDS

Edible Casing
Permeability
O_2
CO_2
Water Vapour

ABSTRACT

Edible casing which has good mechanical properties can substitute synthetic packaging to protect products from the evapouration of water, O_2 and CO_2 transmission, extend shelf life of product and prevent environmental pollution and it can be consumed along with product which packed in it. Therefore, it is important to evaluate permeability of edible casing in order to determine the value of water vapour transmission, O_2 and CO_2 gas transmission and thickness. The aims of this research were to determine the amount of water vapour transmission by following ASTM Standard E-96 and and evaluate gas permeability. The gas barrier properties of the casing films were analysed using manometric method (ASTM D 1434). The experimental design used in this research was Randomized Block Design with 2 factors; plasticiser type (glycerol, sorbitol, sucrose) and garlic concentration (2.5%, 5%, 10%) with three replicates. The properties evaluated were thickness and value of O_2 and CO_2 gas transmission. The results showed that type of plasticiser and concentration of garlic affect significantly on thickness, water vapour transmission, O_2 and CO_2 gas transmission. The interaction of two factors has also significantly affected on thickness, water vapour transmission, O_2 and CO_2 gas transmission. The best combination according to Zeleny method was obtained on sucrose plasticiser and garlic 5% with thickness 0.073 mm, water vapour transmission 0.56 $g/m^2/h$, O_2 gas transmission 1.6 × 10^{-4} $cc.mm/m^2.24h.kPa$ and CO_2 gas transmission 3.4 × 10^{-4} $cc.mm/m^2.24h.kPa$.

Introduction

Edible casing is a thin layer on a material that can be consumed and serves as a barrier to mass transfer (moisture, oxygen, light, lipid, solute) as well as excellent moisture barrier and the exchange barrier of O_2 and CO_2 (Paylath, 2009). Edible casing is widely used for coating frozen meat products, semi-moist food (intermediate moisture foods), confectionery products, frozen chicken, seafood, sausage, fruit and medicine, especially for coating the capsules (Sari et al., 2015).

The materials of edible casing according to Sumarto (2008) can be classified into three groups: hydrocolloid (proteins and polysaccharides), fats (fatty acids and wax), and mixed (hydrocolloid and fat). The protein is used as the base material include soy protein, corn, casein, collagen, gelatin, and fish protein. Some of the ingredients are edible gelatin casing made of flesh, skin and bones of animals, and one of them comes from chicken claw.

Tests on the permeability of edible casing are conducted to determine its capabilities in passing water vapour and gas. The amount of water vapour transmission rate and gas through the edible casing is affected by driving force, materials and environmental conditions. Vapour transmission test of edible casing can use plate method by following ASTM E-96 standard (Rizvi and Rizvi, 1992), while the gas barrier properties can be tested by manometric method (ASTM D 1434) and isostatic method (ASTM D 3985) (Brown, 1992). According to Santoso et al. (2007) standard manufacture of edible casing refers to JIS Z 1707: 1975 are WVTR (Water Vapour Transmission Rate) value up to 10 $g/m^2/day$, compressive strength at least 50 gf, and elongation value at least 70%.

The aims of this study were to design an edible casing permeability test apparatus and evaluate the

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permeability values of edible casing to water vapour, O_2 and CO_2 gas using WVTR test.

Research Methods

This research was carried out at the Laboratory of Agriculture Product and Food Process Engineering, Department of Agricultural Engineering, Faculty of Agricultural Technology, the UB.

Methods

This study used a randomized block design with 2 factors. The first factor was the type of plasticiser (glycerol, sorbitol, sucrose) and the second factor was the concentration of garlic extract (2.5%; 5%; 10%). Water vapour permeability test was conducted by gravimetric method while gas permeability test was conducted by manometric method.

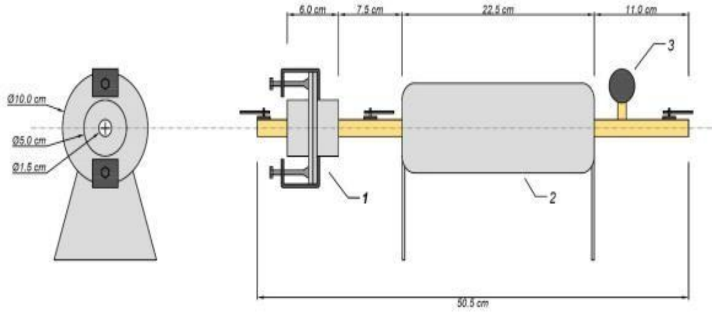

Figure 1. Design of O_2 and CO_2 permeability apparatus

Water Vapour Permeability Test

Water vapour permeability test was carried out for all treatment, water vapour transmission rate through a film was determined by the gravimetric method according to Xu et al. (2005) with modification. Film samples to be tested was inserted in plate which contains 20 g of silica gel, and placed in container that contains solution of NaCl 40% w/v (RH=75% at 25ºC). Water diffused through the film was absorbed by the silica gel thus adding weight. Weight of the plate were recorded per hour for 6 hours. Obtained data was analyzed using linier regression for rate calculation. WVTR was determined by equation (1).

$$\text{WVTR} = \frac{\text{the slope of the straight line (g/h)}}{\text{the exposed film area (m}^2\text{)}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

O_2 and CO_2 permeability test

Permeability was determined by the amount of gas that passes through a given material from wide and thickness of the unit under pressure gradient at the determined time. Manometric method was described in the standard specification of ASTM and ISO. The quantity of gas that has been permeated through test piece within determined time was measured as the change of pressure and volume. Constant high pressure (usually 1 atm) was maintained in one chamber and the low pressure (usually vacuum) was built in other chamber. Part of the high pressure test was supported by the porous substrate. Mercury manometer was attached to low pressure chamber to measure variations of pressure and volume during the specified test time (Brown, 1992).

In this study, manometric method is applied to test oxygen and carbon dioxide permeability. This test was carried out using permeability test apparatus by cutting the edible film with diameter of 7 cm. Then, it was inserted into an edible film container. The operation of the permeability test apparatus began with vacuum process. After the vacuum has reached stable value, the vacuum valve was closed then opened gas inlet valves and the gas was flowed until the pressure returns to normal at the certain time. The gas transmission rate can be calculated by equation (2) (Brown, 1992).

$$\frac{C}{GTR}\int_{\Delta P0}^{\Delta Pt} \Delta P^{-1}\, \partial P = \int_0^t \partial t \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

From equation (2), the relation between ln ∂P and t, where ln ∂P is $P_0 - P_t$ can be obtained. The relation would produce a value which would produce slope value as $\frac{C}{GTR}$ value and can be used to calculate permeability value by using equation (3).

$$P = GTR \times \Delta L \ldots\ldots\ldots\ldots\ldots\ldots\ldots(3)$$

Results and Discussion

Design of O_2 and CO_2 permeability apparatus

The structural design of O_2 and CO_2 permeability test apparatus is shown in Fig. 2. The chamber was made of stainless steel with length x width of 50.5 cm x 12 cm. This test apparatus has a tube with 22.5 cm length where gas flows through, a round plate with diameter of 10 cm as container of edible coating, and valves which include valve for vacuum, valve for and O_2 and CO_2. This permeability test could work optimally if the device did not leak. The indicator that there was no leakage in the device is that when tested using non-permeable materials such as polypropylene (PP), the manometer will show a stable pressure value.

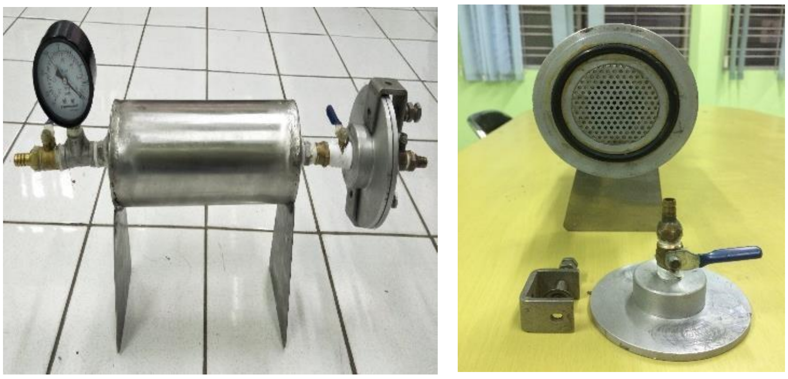

Figure 2. Result design of O_2 and CO_2 permeability apparatus

The experimental method of this test apparatus was initiated by cutting edible film with a diameter of 7 cm, then the edible container was opened by loosening its clamp and then edible casing was inserted into container and closed by tightening the clamp. The operation of the permeability test apparatus began with vacuuming process. After stable vacuum pressure has been achieved, the vacuum valve was closed and then gas inlet valves opened. The gas was flowed until the pressure returns to normal for the determined time.

Edible film thickness

Measurement result of edible film thickness from several kind of plasticiser is shown in Fig. 3. Thickness value obtained ranged from 0.07 mm to 0.15 mm. The highest thickness value was obtained from the treatment of sorbitol plasticisers with addition of 5% garlic with value 0.15 mm. The lowest thickness value was from the treatment of glycerol plasticiser with addition of 5% garlic with value of 0.07 mm.

Glycerol plasticiser has properties that can bind water up to very high level. Glycerol plasticiser can also increase the total solids in the solution which will cause more polymers that make up the matrix of edible film so that the thickness of the edible casing will increase (Nugroho et al., 2013). The thickness of edible film is very closely related to permeability, mechanical properties and its appearance when applied to the product. The thicker the edible casing produced, the lower the gas and water vapour transmission rate (Santoso et al., 2007). Wirawan et al. (2012) states that the thickness of edible casing is influenced by the nature and constituent components of the edible casing, water content and dissolved solids concentration.

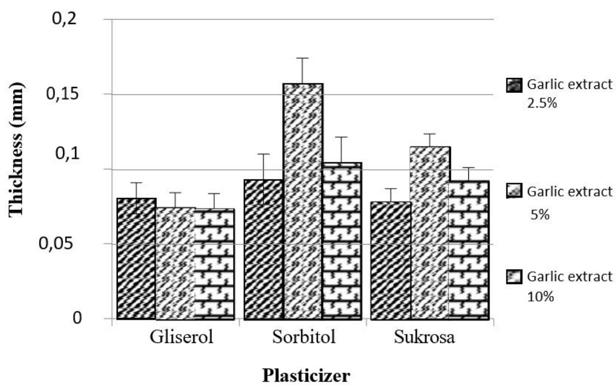

Figure 3. Thickness of edible film from some kind plasticiser

Beside of plasticisers, the thickness of edible casing is also influenced by several factors, Wirawan et al. (2012) revealed that the thickness of edible casing is influenced by the properties and constituent components of the edible casing, water content and dissolved solids concentration. In this study the thickness of edible casing is also influenced by gelatin which is hydrophilic, fat content which is hydrophobic, use of alginate which is hydrophilic, and use of garlic extract.

The addition of garlic extract did not significantly affect the thickness of the edible casing. However, from the data obtained that the higher concentration of garlic used, the thickness of edible casing will be increased. The addition of garlic concentration will increase the composition of the film matrix along with the increase in total dissolved solids and viscosity of the edible casing solution, so that the thickness of the edible casing will increase.

Water vapour transmission

The value of WVTR from several types of plasticisers is shown in Fig. 4.

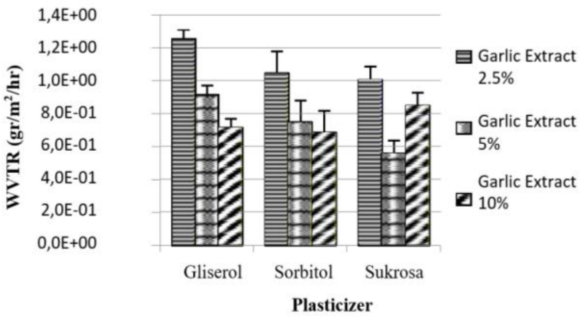

Figure 4. Water vapour transmission rate of edible film from several kind of plasticiser

The value of WVTR obtained ranged from 15 to 35 g/m^2/hour. The highest value was in the treatment of glycerol plasticisers with addition of 2.5% garlic with value 1.258 g/m^2/hour and the lowest value was in the treatment of glucose plasticisers with addition of 5% garlic with value 0.559 g/m^2/hour. In the control treatment (edible casing using 2.5% garlic extract without addition of plasticisers) The WVTR value was 1,970 gs/m^2 hour. This is in accordance with Maizura et al. (2007) study which states that edible casing without plasticisers produces high water vapour transmission compared to edible casing that uses plasticisers. This happens because of the formation of small cracks in the edible casing without using of plasticisers, whereas in the edible casing that using plasticisers are less permeable so that the resulting transmission value of water vapour is low. Gontard et al. (1993) revealed that the factors that influence the value of the water vapour transmission rate are the structure of the forming material, and the concentration of the plasticiser. The addition of hydrophilic plasticisers will reduce water vapour transmission. Water vapour transmission is also influenced by the thickness of the edible casing, Yulianti and Ginting (2012) revealed that the thicker edible casing produced, can lead the higher the ability of edible casing to inhibit the rate of gas and water vapour, so that the storage period will be longer.

O_2 and CO_2 permeability

The value of O_2 and CO_2 permeability from several types of plasticisers is shown in Fig. 5 and 6. The results of the gas transmission calculation indicate that the thickness factor also has an effect on permeability. The greater the thickness of the film edible, can lead the greater the value of gas transmission. But the results of this study are not in line with the results of Kusumawati (2007) study which revealed that the greater the thickness of the edible film, the gas permeability will be smaller and the protective effect on packaged food products will be better. This may be caused by the number of bubbles in the film, so that it will facilitate the transmission of gas in the edible film. According to Katili et al. (2013), gas permeability is affected by several factors such as natural gas, storage time, temperature, RH, addition of plasticisers and types of products packed. Result of this study showed that glycerol plasticisers gave the lowest permeability compared to other plasticisers. This is because glycerol is hydrophilic (has many -OH bonds) where -OH bonds themselves are known to have low permeability (Irawan, 2010).

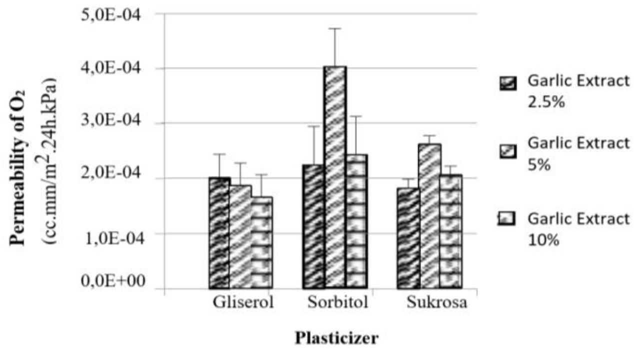

Figure 5. O_2 permeability from several types of plasticisers

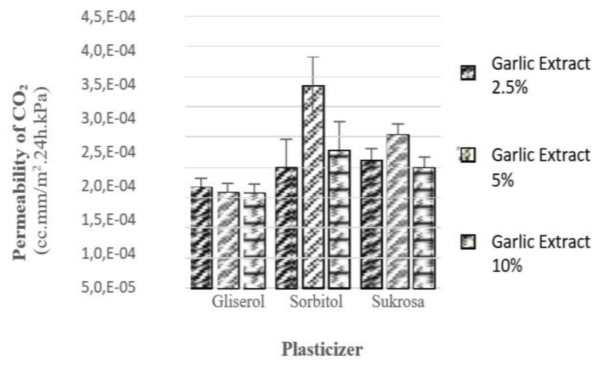

Figure 6. CO_2 permeability from several types of plasticisers

Conclusions

This study develops permeability test apparatus for sausage edible casings. The value of the expected water vapour transmission was the smallest value. Addition of plasticisers and garlic to edible casing has a significant effect on the value of water vapour transmission, in which the smallest value was produced by sucrose plasticisers and 5% garlic extract with a value 0.559 g/m^2/hour. The addition of plasticiser to edible casing has a significant effect on the value of the transmission rate of O_2 and CO_2 which the best or lowest yield was produced by glycerol plasticiser and 10% garlic extract with a value of 1.6×10^{-4} cc.mm/m^2.24h.kPa on O_2 gas transmission and 3.4×10^{-4} cc.mm/m^2.24h.kPa on CO_2 gas transmission.

Conflict of interest

The authors declare that there is no conflict of interest in this publication.

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