

Corn Hominy, a Potential Material for Biodegradable Foam

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ABSTRACT. Our dependence on styrofoam for single used food packaging is very high due to its high strength, low density and low cost. However, despite of all the advantages, there are some problems caused by styrofoam such as environmental issued and health problems. Agromaterials such as corn hominy, a by-product of dry-milling industry, is a potential source to be used as raw material for biodegradable foam production due to its composition that contains starch, fiber, protein and lipid which are necessary for producing biofoam. Fibers can act as reinforcement fillers, meanwhile starch needed for expansion and also as a binder. Protein as natural polymer can synergized with starch to perform strength matrix. Fat will acts as lubricant for demolding process and also as plasticizer to improve mechanical properties of the foam. Some additional materials such as tapioca and synthetic polymer such as poly vinyl alcohol (PVOH) still needed to improve physical and mechanical properties of biofoam. There are many techniques that can be used for producing biodegradable foam such as thermopressing, extrusion, and microwave assisted moulded. Different techniques resulted different shape and function of biofoam such as peanut foam, tray biofoam or molded biofoam. Utilization of corn hominy for producing biodegradable foam, can increase added value of corn hominy, decreasing enviromental problem such as pollution caused by styrofoam and also improve the level of public health.

Keywords: biodegradable foam, corn hominy, tapioca, polyvinyl alcohol, thermopressing

Introduction

Our dependence on plastic in our daily life is very high, almost 100 million tons annually (Anonymous 2010). Meanwhile, most of the plastic derived from petroleum that is related to environmental issues such as the low degradability and biodegradability, scarce availability, and the emissions generated during incineration. Polystyrene foam is one of the most common used plastic due to its high strength, low density and low cost (Glenn and Orts 2001). However, the migration of styrene monomers from polystyrene foam packaging on a long term may cause health problems such as fatigue, sleep difficulty, anaemia, chromosome trouble and carcinogenic effect (Dowly *et al.* 1976). This condition motivated an extensive research on environmentally friendly materials and significant progress has been achieved in the development of biodegradable products that is based on agricultural materials (Curvello *et al.* 2001; Herrmann *et al.* 1998).

One option for the replacement of petroleum-based polymers is agrobased materials such as starch and lignocellulose. Some studies have shown that it is possible to obtain food containers from the mixture of starch, fiber and water (Glenn and Orts 2001; Schmidt 2006; Shey *et al.* 2006, Cinelli *et al.* 2006 and Vercelheze *et al.* 2012). Starch-based foam can be produced by using thermopressing like wafer technology (Xu *et al.*, 2005). Foam baking process

includes two main steps, the first one is starch gelatinization and water evaporation, expanding the mixture and forming foam, and the second one is the foam dried up to a final moisture content of 2–4% (Shogren *et al.* 1998; Salgado *et al.* 2007).

The disadvantages of starch-based foams is their fragility and high affinity for water (Glenn *et al.* 2001). There are many approaches that can be done to improve these properties like blending with synthetic polymer (de Carvalho *et al.* 2001; Sarazin *et al.* 2008; Ma *et al.* 2008), using modified starch (Shogren *et al.* 2002), blending with fiber or by using nanocomposites that can help in the development of new low-cost products with better performances (Yu *et al.* 2006)

Fiber-reinforced composites can improve mechanical properties of bioplastic materials according to some research (Lawton *et al.* 2004; Salgado *et al.* 2008; Cinneli *et al.* 2006). According to Glen *et al.* (2001), natural fibers can improve foam mechanical properties, degradability and lower cost to the final product.

One kind of lignocellulosic material that have promising potency as material to produce biodegradable is corn hominy. Corn hominy is an industrial name given to the pericarp fraction of the corn kernel. Because of the inefficiency in the milling process during removal of the

pericarp, some of the kernel endosperm is also removed. Corn hominy consists of not only fiber from the pericarp, but also starch, protein and fat from the endosperm and germ. According to Sharma *et al.* (2007), corn hominy composition are 56.9% starch, 25.2% neutral detergent fiber, 11.1% protein and 5.3% fat. Corn hominy is a fibrous material and usually used as animal feeds. The wet corn fibers are about \$15/ton, and the dried ground fibers (about 10 mesh) are about us \$50/ton marketed (Cinelli *et al.* 2006)

The starch and fibre content in corn hominy is still quite high which allows it to be used as raw materials for biodegradable foam. The fibre in corn hominy can be utilized as a filler to improve the properties of foam product. Thus, in addition to being inexpensive, non-toxic, and easily recycled, the use of this material contributes to environmental protection (Lawton *et al.* 2004). The presence of fibers during biodegradation will induce the fast breakdown of foam due to the action of microorganisms attracted by its lignocellulosic components.

Utilization of corn by-product such as corn hominy for biodegradable polymer, will provide greater added value and also decrease the environmental problem. The objective of this research is to improve hydrophobicity and mechanical properties of biodegradable foam by addition of corn hominy and PVOH.

Material and Methods

Material and Equipment

The main material in this research is corn hominy which was supplied from PT Kediri Matahari Prima, a corn flour milling company in East-Java, and cassava starch starch obtained from PT Budi Makmur Perkasa, a local cassava starch industry in Subang. Polyvinyl alcohol purchased from PT Tirta Martha, Cikupa Tangerang. Magnesium stearate was purchased from Sigma Aldrich. The equipments used in this research were thermo press, texture analyzer Brookfield CT 3, Chromameter, digital scale, erlenmeyer, and other laboratory sets.

Biodegradable Foam Production

Cassava starch, corn hominy, PVA and magnesium stearate were first mixed using a high speed mixer with a wire whisk attachment for 10 minutes. Magnesium stearate acts as a mold release agent, preventing sticking of starch to the mold. For batters containing no PVA, guar gum (1% by weight of starch) was also added to prevent settling of the starch. Water was added to give the solid content of

50%. Starch-based foam trays were prepared using a baking machine. This equipment consists of two heated steel molds, the top of which can be hydraulically lowered to mate with the bottom half for a set amount of time. Dimensions of the mold were 198 mm long, 121 mm wide, 20 mm deep and thickness 3 mm (plate separation). Baking temperatures were set at 150–170°C and baking times were the minimum required to avoid a soft or bubbled tray and varied from about 150-210 seconds.

Biodegradable Foam Characterization

Density: Density was calculated as the relationship between weight and volume (Shogren *et al.* 1998). Reported values are averages of three determinations for each formulation.

Water absorption of samples during immersion: Samples measuring 3 cm x 3 cm were weighted and soaked in distilled water for 60 seconds. After removing the water excess using tissue paper, samples were weighted again. The quantity of absorbed water was calculated as the weight difference and expressed as mass of absorbed water per mass of original sample (ABNT NBR NM ISO 535, 1999). Reported values were the mean of three determinations for each formulation.

Color: Foams color was determined using a (CR 300, Minolta Chromameter Co., Osaka, Japan). A CIE Lab color scale was used to measure the degree of lightness (L^* ; black=0; white=100), red ($a^*=+60$) or green ($a^*=-60$), and yellow ($b^*=+60$) or blue ($b^*=-60$) of the foams. The instrument was calibrated using a set of three Minolta calibration plates. Values were expressed as the mean of five measurements for each sample, using five samples for each formulation.

Mechanical properties: A texture analyser Brookfield CT3, with a 2.5 N load cell was used to determine the mechanical properties of foam samples by means of tension and puncture tests. Tensile Tests were performed using foam strips measuring 100 mm by 25 mm, an initial grip separation of 80 mm and a crosshead speed set at 2 mm/s. Stress-strain curves were recorded during extension, and tensile strength at break (r_{break}) was determined. Each formulation was assayed 5 times, reported values being an average of such assays. Compression tests were performed using material samples of 10 cm by 10 cm. Force vs. distance were recorded during tests using a spherical probe with a diameter of 18 mm. Samples were broken at a speed rate of 1 mm/s with a 0.5 N load. Relative deformation (d) was calculated as the ratio between the vertical distance travelled by the probe from sample contact until rupture

and the sample diameter that coincides with the hole of the measuring device (80 mm).

Result and Discussion

Biodegradable Foam Production

The foaming process of starch batter inside a hot mold depend on moisture content, condition process such as temperature, time and composition of the batter. The amount of batter determines wheter a complete tray is formed. In contrast, when the batter were to liittle, no foaming will takes place and the foam tray not formed. But when too much batter is added then a foam tray is made but large amount of waste batter will produce and also some cracked tray founded (Figure 1).

Characteristics of Biodegradable Foam

Biodegradable caharacteristics were determined by batter composition and condition process during the foam production. Addition of corn hominy will increase fiber content in the batter and also protein and fat content. Addition of corn hominy ratio between 0-75% will increase fiber content in the batter varied from 0-This condition will affected foaming process and foam characteristics produced. Compared to styrofoam, biofoam still have



Figure 1. Tray biofoam.

higher water absorption index and density as showed at Table 1.

Density of corn hominy based foam was influenced by corn hominy addition and PVOH concentration and also interaction between corn hominy and PVA. Figure 2 showed that density of starch-based foam was around 0,26-0.47 g/cm³ and slightly increased by increasing of corn hominy ratio and PVOH concentration. Even tough, the density of starch-based foam in this research was higher than polystyrene foam 0.035 g/cm³ but when compared to Salgado *et al.* (2007), the foam density were lower. Salgado use a raw material mixture of starch, cellulose and protein isolates from sunflower to produce a foam with a density ranging from 0.45 to 0.58 g/cm³. Other researche, Schmidt (2006) also use a feedstock starch, cellulose fiber and CaCO₃ and produced foam with a density of 0.63 to 1.3 g/cm³.

Increasing corn hominy ratio will decrease starch content in the batter and affected starch ability to expand due to the fact that fiber tend to resistant to swelling and expansion compared to starch (Glenn *et al.* 2001; Carr *et al.* 2006). The presence of fibers are also responsible for increasing the viscosity of the batter, that will decreases the foaming ability and resulted in denser foam (Cinelli *et al.* 2006; Shogren *et al.* 1998).

Starch-based foam density were also affected by raw materials composition. According to Mali *et al.* (2010), foam's density affected by starch, fiber, polymer synthetic and interaction between the materals. This experiment were contrast with Benezet *et al.* (2011) and Glenn *et al.* (2001) results which said that the fiber addition contributes to reduction of foam density. This situation can be explained by Nabar *et al.* (2005), who said that processing the starches with other materials that produced stiff materials will not support air cell growth. Addition of polymer synthetic (PVA) can also reduced the expansion ability of starch due to the fact that PVA can increase the viscosity of the batter. Increasing PVA propotion in the batter will decrease starch propotion caused reducing cell grow ability to expand.

Table 1. Characteristics comparison between corn hominy based foam and styrofoam.

Characteristics	Corn hominy tray foam	Styrofoam
Moisture (%)	7.07	0.86
Water absorption index (%)	38.66	23.96
Density (g/cm ³)	0.477	0.035
Brightness	85.36	89.83
Compressibility (KPa)	19.11	29.11
Tensile strength (KPa)	48.72	28.69

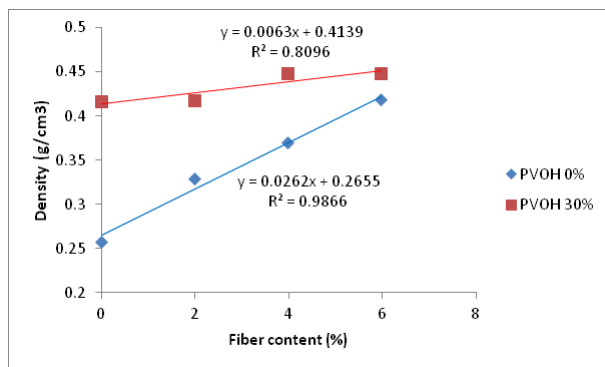


Figure 2. Correlation between fiber content and foam's density.

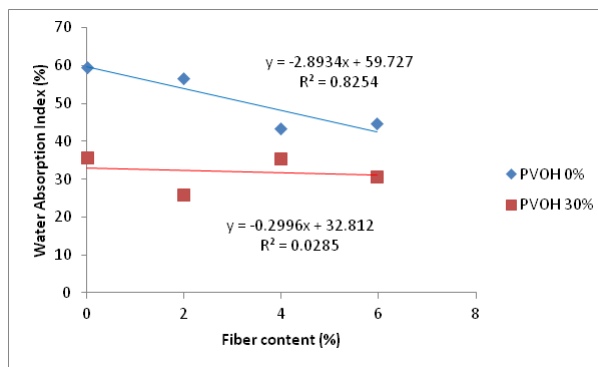


Figure 3. Correlation between fiber content and water absorption index of biofoam.

Water absorption

The result showed at Figure 3, indicate that the increasing corn hominy ratio will decrease water absorption index of biofoam without PVOH. This result was in line with Katsangsri *et al.* (2011), who said that addition of fiber to cassava-based foam will decrease water absorption index of starch-based foam. Meanwhile, increasing corn hominy proportion on foams with PVOH 30% addition were not affected WAI of the biofoam. This condition was probably caused by the fiber were covered by melted starch and PVA, so bonding with water molecules was prevented (Bourtoom and Chinnan 2008).

Observation on colour parameter is committed with using chromameter to know the addition of influence of corn hominy addition which has pigment yellow colour to biofoam produced. The result of observation on colour covers level of brightness. The results showed at Figure 4 showed that PVOH concentration and corn hominy fiber content affected on the color of cassava starch-based foam. The addition of corn hominy and PVA into the cassava starch-based foam resulted in decreased L* values caused by yellowish pigment found on corn hominy.

Foam made from higher corn hominy proportion present a "burned" aspect when pressed at temperatures above 180°C. According to Poovarodom (2006), mixture that contain protein more than 5 wt % causes the shaped of foam bodies to become brittle, charred and burnt before the starch in the mixer becomes fully gelatinized thus causes the failure in manufacturing process.

Foam made from starch is usually brittle and has poor mechanical properties so it requires other materials such as fiber, synthetic polymer etc to improve their properties. In Fig 4 showed that increasing PVOH concentration on mixture consist of 25% of corn hominy fiber, will increase the foam tensile strength. On the other hand, increasing



Figure 4. Foam's brightness with increasing of corn hominy proportion.

PVOH concentration on higher level of corn hominy (50%) will decrease foam tensile strength. According to some previous research, the addition of lignocelulose soft fibre, fibre flax and aspen and jute could improve foam tensile strength (Glenn *et al.* 2001; Lawton *et al.* 2004; Shogren *et al.* 2002; Soykeabkaew *et al.* 2004). According to Herald *et al.* (2002), higher filler content may lead to poor distribution of filler across the matrix which caused the stress in the continuous phase to increase and promote poor tensile strength. Meanwhile Buzarovska *et al.* (2008) said that the decrease in tensile strength was caused by the imperfect

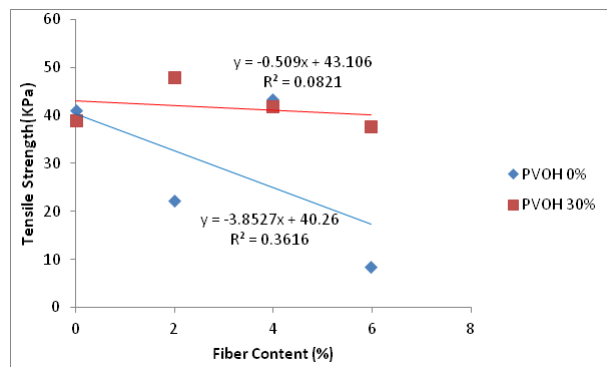


Figure 5. Correlation between fiber content with foam’s tensile strength.

distribution as well as very poor adhesion between the matrix and filler.

PVOH addition (10-30%) into potato starch batter is known to improve strength, flexibility and water resistance of the finished foam trays (Cinelli *et al.* 2006). PVOH addition to the trays containing corn fiber also provided some additional foaming ability. Shogren *et al.* (2002). showed that PVOH was a good choice for providing tray flexibility. As corn fiber was increased the flexibility of trays also decreased. The addition of PVOH to the formulations mitigates the reduction in tensile properties that can be seen when corn fiber was added alone. Increasing the fibers content increases batter viscosity, thus increasing baking time. The fiber also interferes with foaming so additional batter volume is needed as corn fiber increases to form complete trays.

Conclusion

1. Corn hominy, a by product of dry milling industry, is a potential source to be used as fiber reinforcement on starch-based foam production.
2. Corn hominy addition into cassava starch batter can improve hydrophobicity of biofoam by reducing water absorption index of biofoam.
3. Increasing corn hominy proportion increase foam’s density and decrease foam’s brightness.
4. PVOH addition can improve hydrophobicity and mechanical properties of the foam.
5. Utilization of corn hominy can increase value added of corn waste and also provide alternative packaging to reduce styrofoam usage

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