Int J Adv Life Sci Res. Volume 2(4) 01-07
doi: 10.31632/ijalsr.2019v02i04.001

International Journal of Advancement in Life Sciences Research

Online ISSN: 2581-4877

journal homepage http://ijalsr.org

Review Article

Effect of Radiation Treatment on Starch Bioplastic- A Review

Nur Nadia Nasir and Siti Amira Othman[+]

Department of Physics and Chemistry, Faculty of Applied Sciences and Technology, Universiti Tun Hussein Onn Malaysia, Pagoh, Muar, Johor

**Correspondence E-mail :* sitiamira@uthm.edu.my

Abstract

Currently, there was an intensive study to used starch as raw material to produce bioplastic for a wide range of applications. However, starch-based has limited the range of applications due to their unfavorable properties such as brittleness, increase the viscosity, retrogradation and insolubility in cold water. There ionizing radiation was introduced. With the proper amount of energy and source, ionizing radiation will improve the starch-based bioplastic properties which is having mechanical and barrier properties. In this paper, the ionizing radiation source that compared with is ultraviolet (UV), electron beam, and gamma ray. Each of the rays gives a different result and gamma ray give the most promising result, however above 40kGy it will compromise the structure and properties of the starch based bioplastic. For conclude, ionizing radiation will improve the starch based bioplastic properties and will not compromise their properties within the appropriate range of energy.

Keywords: *Bioplastic, Starch –Based, Ultraviolet, Electron Beam, Gamma Ray.*

Introduction

There are rapidly increasing the production and usage of plastic because of its wide range of applications such as packaging, automotive, pharmaceutical, agriculture and more (Gadhave *et al.* 2018). According to the Solid Waste Malaysia statistic (SWM), plastic waste is the second major contributor to the average composition of solid waste in Malaysia (Faris et al. 2014). There is awareness to limit and also reduce the production and the usage of the plastic because of its environmental issues (Andrej, 2012). There are several procedures to handle the plastic waste which is recycling, land buried, burning and more. Compare to those procedures, recycling is the most eco-friendly to handle and also reduce plastic waste. However, according to (Pradeep, 2017), very minimal awareness of the recycling rate for plastic waste (Pradeep, 2017). That is why bioplastic was introduced.

A. BIOPLASTIC

According to European Bioplastic Association, bioplastic is biodegradable, bio-based or both (European bioplastic, 2017). Nowadays, bioplastic is another alternative for almost all conventional plastic (European bioplastic, 2017). Currently, bioplastic was available commercially and will constantly emerge. According to bioplastic market data for 2017, the production capacity for bioplastic was expected to increase from around 2.05 million tonnes in 2017 to approximately 2.44 million tonnes in 2022 (European bioplastic, 2017). Bioplastics also used in wide range applications, from packaging, catering products, consumer electronics, automotive, agriculture and toys to textiles and others. Packaging remains the main application, with almost 60 percent (1.2 million tonnes) of the total bioplastics market in 2017. Figure 1 shows the classification of bioplastic, bioplastic can be divided into 4 main part which is; i) directly extracted from biomass, ii) synthesized from a bio-derived monomer, iii) biodegradable polymer synthesized from petrochemicals, and iv) produced directly by natural/genetically modified organisms.

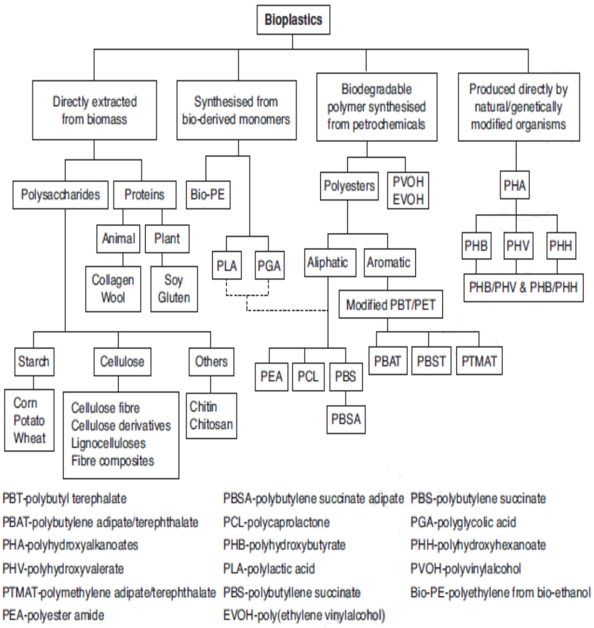

Figure 1 Classification of bioplastic (Richard *et al.* 2010)

Polylactic acid (PLA) is one of the most commercially available and exploited bioplastics (Richard *et al.* 2010). PLA has quite similar properties and the elasticity of PLA a lot like of Polypropylene (PP) (Shristi, 2016). PLA is one of the polymers that have a wide range of applications because of its ability to be stress and thermally crystallized, impact modified, filled, copolymerized and processed in most polymer processing equipment (Richard *et al.* 2010). PLA offers such many advantages such as renewability, transparency, biocompatibility, thermos plasticity and does not hazardous to humans and the environment. Despite all the advantage, PLA has a very slow degradation process, very brittle, hydrophobic and has limited gas barrier properties (Tariq, 2015). In recent years, there are rapidly research and foresee to use starch as the raw material for bioplastic. Some of the factors that influence the development of starch-based bioplastic are better product quality, abundant, inexpensive and renewable resources (Ali *et al.,* 2016).

B. STARCH

Starch is a soft, colorless, bland, odorless powder that will dissolve in warm water however it insoluble in cold water or alcohol but at a certain point it will swell then turn into a gel if the outer membrane had been broken (Gadhave *et al.* 2018). Starch was extracted from different plant resources in the form of granules. Mostly the size and shape of the granules were depend on the starch source (Gadhave *et al*. 2018). Commonly starch was found in corn, wheat, rice, potato and other plant resources (Bahram *et al.,* 2016).

Properties of Starch

Starch can be divided into two types of a macromolecule which is amylose and amylopectin (Justine *et al.* 2017). As can be seen on Figure 2, amylose is a linear polymer and amylopectin is a branched polymer.

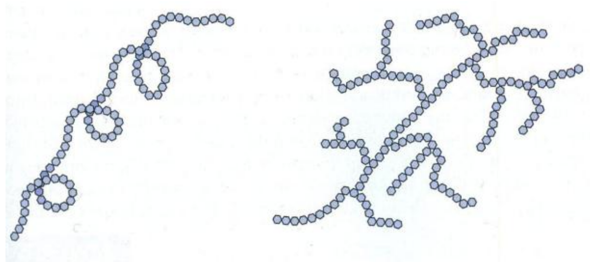

Figure 2 (a) Amylose and (b) Amylopectin (Justine *et al.* 2017)

The content of amylose and amylopectin in the starch mostly depends on the starch source and it also can be varied (Gadhave *et al.* 2018), (Justine *et al.* 2017). Table 1 shows the content of amylose and amylopectin depend on each starch types.

Table 1 Amylose and amylopectin content for each starch (Justine *et al.* 2017).

Starch	Amylose (%)	Amylopectin (%)
Wheat	30	70
Corn	28	72
Potato	20	80
Rice	20-30	80-70
Cassava	16	84

C. STARCH-BASED BIOPLASTIC

Starch- based bioplastic is usually from rice, wheat, corn and potatoes. Corn starch is the cheapest and most commonly used for starch-based plastic. According to (Shristi, 2016), starch has also been used as a source for sustainable and eco-friendly raw material. The development of starch- based bioplastic was influenced by the factor which is to produce better product quality, abundant, cheap and a renewable resource (Ali *et al.,* 2016). Starch-based bioplastic also contain additives such as plasticizers and compatibilizers to improve processability, water resistance and tear strength (Andrej, 2012), (Martien *et al.,* 2017).

Starch- based bioplastic offers so much advantage such as healthy cancer free, pollution free, do not cause death of marine animals, required less energy to be produced, light weighed which can be used for the production of plastic carry bags, reduce the dependency on fossil fuels for the production, made from renewable raw material and more (Sharon *et al.,* 2018). However, they are brittle and hydrophilic therefore it limiting their processing and application which led to a problem such as lack of water barrier, poor mechanical properties and more (Shafik *et al.,* 2014). There is numerous research that had been carrying out to improve starch- based bioplastic some of it is a plasticizer, blend with other natural polymer or artificial polymer and ionizing radiation (Gadhave *et al.* 2018), (Bahram *et al.,* 2016).

IRRADIATION TREATMENT

Irradiation is the deliberate process of exposing an item to certain types of radiation energy to bring about desirable changes (Nelida, 2016). In recent year, research has been a focus on using irradiation treatment to improve starch based bioplastic properties such as the mechanical and barrier properties that is because irradiation treatment is expected to improve and enhance the starch based bioplastic properties whether as physically or chemically (Ali *et al.,* 2016). Some of the irradiation treatment that has been extensively studied is Ultraviolet irradiation (UV), gamma irradiation and electron beam (Asyraf *et al.,* 2017). Figure (3) show the spectrum for the electromagnetic wave.

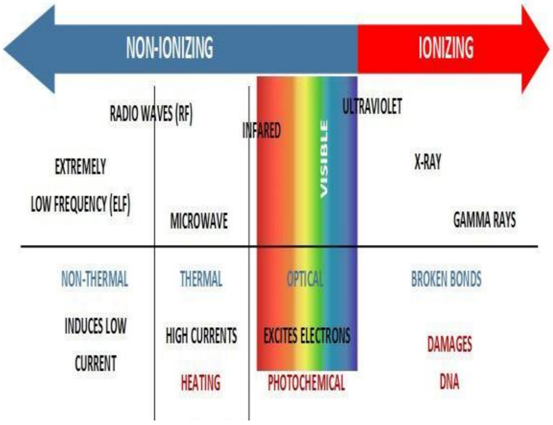

Figure (3) The electromagnetic spectrum (Nelida, 2016)

A. Ultraviolet Irradiation

In recent years, there were increasing interest in UV irradiation technology because of it's physical, cost-effective, non-thermal and also environmental friendly (Timothy & Jeffrey, 2011). UV irradiation process is photon of UV radiation energy will strike the electron then it will be induced to an excited state and resulting to unstable conformation which is due to the disruption of the stable electron (Wittaya, 2012). The current application of UV treatment is to control of microorganism and the further application that had been investigated currently using UV treatment are for water treatment (Timothy & Jeffrey, 2011).

B. Electron Beam

Electron beam irradiation is quite a simple procedure. The electron that was generated by heat, then bombard the charge atoms or particle (Wittaya, 2012). Mainly in the research area electron beam is used in technology and also in medical which is for medical application electron beam commonly used to produce X-ray, oscilloscopes and electron microscopes (Wittaya, 2012). Some of the advantages of the electron beam compared to the chemical method are the end product will have better physical properties (Kashiwagi & Hoshi, 2012). Also, electron beam irradiation is an effective and environmentally friendly approach. The electron beam irradiation process also was used to change the non-biodegradable to biodegradable product (Kashiwagi & Hoshi, 2012).

C. Gamma Irradiation

Gamma irradiation is the process where the high energy photon that was emitted from isotope source such as Cobalt-60 and then it will ionize the (Antonio *et al.,* 2018). Any substance that encounters with high energy gamma irradiation will be ionized. Compare to other irradiation treatment gamma irradiation is very penetrative (Salwa, 2010). Gamma irradiation has some advantages, such as being non-polluting, having effects at ambient temperatures, and some flexibility through process control and more (Asyraf, 2017). Gamma irradiation is not a surface treatment, since the photon energy is high enough to penetrate through materials (Asyraf, 2017). Commonly used radiation in industry was electron beam and gamma radiation (Salwa, 2010).

Methodology

In this paper, the result obtained is from the previous research which is mainly focused on mechanical and also barrier properties of starch based bioplastic that were irradiated with different types of irradiation treatment which are ultraviolet irradiation, electron beam irradiation and gamma irradiation. The exposure of each irradiation treatment depended on what result or the effect the researcher wants. Compatibility between starch and the plasticizer to irradiation treatment are also important factors that affect the effectiveness of irradiation treatment on starch based bioplastic properties. Figure 4 shown an illustration of the overall flow of the method used.

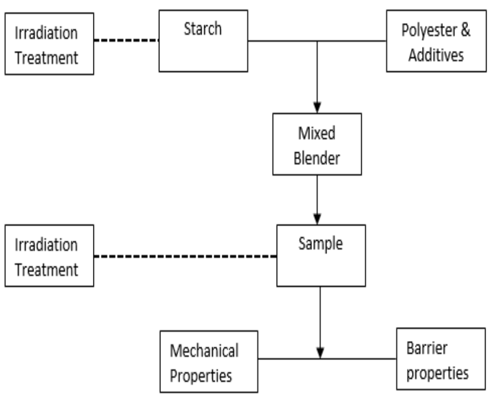

Figure 4 Overall flow chart

Result and Discussion

A. Mechanical Properties

Mechanical properties can be considered to be the most important factor for the polymer and also as the main physical properties of the polymer. Based on Table 2, overall the irradiation treatment gives a positive result which is there was an improvement on each starch based properties however when too much exposure of irradiation treatment will compromise the starch based properties.

First for UV irradiation, (Nawapat & Thawien, 2011) state that, there was an improvement on mechanical properties of starch based which is influenced by the UV irradiation. However, accord to (Nawapat & Thawien, 2013) and (Iman *et al.,* 2018), UV irradiation resulting in decreasing the mechanical properties compared to unirradiated but eventually it increases as the exposure time increased. This is because the higher energy of UV irradiation will have a high impact on starch-based properties and led to the interaction of cross-linking between the components.

Second for electron beam irradiation, according to (Abramowska et al., 2015) when the corn-based were exposed to the electron beam irradiation, the mechanical properties were decreasing however it still acceptable. In spite of that, (Abd El-Mohdy, 2006) state that electron beam irradiation led to decreasing the tensile strength of starch-based which is due to radiation induce cross-linking reaction. Electron beam irradiation causes the occurrence of a chemical reaction and results in the formation of an intact network structure in starch based. As stated by (Sharifah *et al.,* 2000) when starch-based were exposed at high doses it will compromise the starch-based properties because of excessive cross-linking occur. However, (Vanessa & Nelida, 2017) state, the tensile strength decreasing compare to unirradiated but as the doses increase the tensile strength increase and it turns to yellow color.

Last for gamma irradiation, on the result of (Antonio *et al.,* 2018), under 25kGy will not compromise the starch-based properties. Nevertheless, in the opinion of (Abramowska *et al.,* 2015), at 25kGy dose, the flexibility of starch-based were decreasing but the mechanical properties are still acceptable. This is because of gamma irradiation led to degradation and also cross-linking. According to the result of (Shafik *et al*., 2014) under the influence of gamma irradiation, the tensile strength and elongation at break were improved because of a cross-linking and chemical reaction. Gamma irradiation also improves flexibility and resistance to compression (Natalia *et al.* 2009).

Table 2 Summary of the effect of irradiation treatment on mechanical properties starch-based

Irradiation Treatment	Effect of Irradiation Treatment
Ultraviolet Irradiation	Improvement of mechanical properties (rice starch). (Nawapat & Thawien, 2011)
	Short exposure time improve mechanical properties and physical properties. (Iman *et al.,* 2018),
	Increasing the tensile strength and elongation at break when the dose increases. (Nawapat & Thawien, 2013)
Electron Beam Irradiation	Decreasing of mechanical properties but still acceptable. (Abramowska *et al*., 2015)
	Improve tensile strength and elongation at break (Abd El-Mohdy, 2006)
	15kGy enhance starch-based properties (Sharifah *et al.,* 2000)
	Decreasing of tensile strength as the doses increase and change to yellow color. (Vanessa & Nelida, 2017)
Gamma Irradiation	Under 25kGy will not compromise the structure of starch-based properties. (Antonio *et al.,* 2018)
	Increasing flexibility and resistance to compression. (Natalia *et al.* 2009)
	Increase the tensile strength and elongation at break (Shafik *et al.,* 2014)

B. Water Barrier Properties

There were important to decreasing the moisture sensitivity and enhance the water resistance because it will affect the mechanical properties of starch-based due to the nature of starch.

First for the UV irradiation, in the opinion of (Nawapat & Thawien, 2011 & 2013) starch-based that were exposed with UV irradiation show better water barrier properties compare to unirradiated starch based. This occurrence is due to decreasing of hydrophilic group (OH) when cross-linking occurs. Second, for electron beam irradiation there was an improvement of hydrophobic properties of starch-based (Abramowska *et al.,* 2015). According to (Abd El-Mohdy, 2006) and (Natalia *et al.* 2009), electron beam irradiation improves the water resistance at the high doses and it has been considered as a convenient tool for the modification of starch-based properties and may enlarge the starch-based application. Abd El-Mohdy (2006) state, the content of starch should be lower to improve the starch-based properties when it was irradiated. Last for gamma irradiation, when the gamma was applied on the starch-based, their barrier properties improve and there were increasing in terms of compatibility and homogeneity between the compounds (Natalia *et al.* 2009). Gamma irradiation led to degradation and cross-linking which is resulting in decreasing of hydrophilicity starch-based (Abramowska *et al.,* 2015).

Table 3 Summary of the effect of irradiation treatment on mechanical properties starch-based

Irradiation Treatment	Effect of Irradiation Treatment
Ultraviolet Irradiation	Improve the water barrier (Nawapat & Thawien, 2011)
	Improve the water vapor permeability (Nawapat & Thawien, 2013)

Electron Beam Irradiation	Improvement of the water resistance (Abd El-Mohdy, 2006) Decreasing the hydrophilicity (Abramowska *et al.,* 2015) Decreasing the water absorption (Natalia *et al.* 2009).
Gamma Irradiation	Improve the barrier properties (Natalia *et al.* 2009). Improvement of hydrophobic properties (Abramowska *et al.,* 2015).

Conclusion

Generally, irradiation treatment led to an improvement of starch-based bioplastic properties. Irradiation treatment is also a convenient tool to modify starch-based bioplastic properties. In spite of that, each of the irradiation treatment gives a different result. For mechanical properties, electron beam and gamma irradiation give a positive result however for UV irradiation has worsened the properties. For barrier properties, all the irradiation treatment gives a positive result. Every irradiation treatment can enhance the starch-based bioplastic properties but only within the range of doses. If there is too much of irradiation exposure on the starch-based bioplastic it can compromise their properties. The range of the doses can be vary depending on what the researcher want.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this work.

Acknowledgement

The authors would like to thank the Faculty of Applied Sciences and Technology, Universiti Tun Hussein Onn Malaysia for facilities provided and gratefully acknowledged the financial support a research grant (H074 and H417) that make the research possible.

References

Abd El-Mohdy., H. L. (2006). Synthesis of Starch-Based Plastic Films by Electron Beam Irradiation. *Journal of Applied Polymer Science*, Vol. 104, 504–513 (2007) VVC 2007 Wiley Periodicals, Inc.

Abramowska, A., Krystyna, A.C., Marek, J. B., Andrzej, N. and Wojciech, G. (2015). The influence of ionizing radiation on the properties of starch-PVA films*. NUKLEONIKA* 2015;60(3):669-677 doi: 10.1515/nuka-2015-0088

Ali, H.E. and Ghaffar, A.M. (2016). Preparation and Effect of Gamma Radiation on The Properties and Biodegradability of Poly (Styrene/Starch) Blends. *Radiation Physics and Chemistry Journal* 130 (2017) 411– 420 http://dx.doi.org/10.1016/j.radphyschem.2016.09.006

Andrej, K. (2012). Biodegradable Polymers and Plastic. Innovative value Chain Development for Sustainable Plastics in Central Europe (*PLASTiCE)*.

Antonio, J.C.B., Natalia, N., Ademar, B.L., Patricia, P. (2018). Influence of Ionizing Radiation on Biodegradable Foam Trays for Food Packaging Obtained from Irradiated Cassava Starch. *Brazilian Archives of Biology And Technology An International Journal.* Vol.61: e18160520, 2018 http://dx.doi.org/10.1590/1678-4324-2018160520

Asyraf, S.S. A., Zuraida, A., Azura, A. and Maisarah, T. (2017). Effect Gamma Irradiation on Starch-Based Biomaterials Composites for Wound Healing. *International Medical Device and Technology Conference* 2017 eISBN 978-967-0194-93-6 FBME

Bahram, K., Muhammad, B.K.N., Ghufrana, S. and Zaib, J. (2016) Thermoplastic Starch: A Possible Biodegradable Food Packaging Material—A Review. *Journal of Food Process Engineering* ISSN 1745–4530

European bioplastic. (2017). Bioplastic market data 2017. *Report European Bioplastic, nova-Institue*(2017) www.bio-based.eu/markets.

Faris, N.A., Noriman, N.Z. and Sam.S.T. (2014). Current Research in Biodegradable Plastics. *Applied Mechanics and Materials,* 2014 doi: 10.4028/www.scientific.net/AMM.679.273

Gadhave, R.V., Das, A., Mahanwar, P.A. and Gadekar, P.T. (2018). Starch Based Bio-Plastics: The Future of Sustainable Packaging. *Open Journal of Polymer Chemistry*, 8, pp. 21-33. https://doi.org/10.4236/ojpchem.2018.82003

Iman, S.G., Vahid, G. and Amin, B.G. (2018). Production of starch based biopolymer by green photochemical reaction at different UV region as a food packaging material*: Physicochemical characterization. International Journal of Biological Macromolecules* S0141-8130(18)33401-9 doi:10.1016/j.ijbiomac.2018.10.154

Justine, M., Chelo, G.M. and Amparo, C. (2017). Combination of Poly(lactic) Acid and Starch for Biodegradable Food Packaging. *Material MDPI Journal. Materials* 2017, 10, 952; doi:10.3390/ma10080952 www.mdpi.com/journal/materials

Kashiwagi, M. & Hoshi, Y. (2012). Electron beam Processing System and It's Application. *SEI Technical Review.* No 75 10-2012

Martien, V.D.O., Karin, M., Maarten, V.D.Z., Harriette, B. (2017). Bio-based and biodegradable plastics - Facts and Figures. *Wageningen Food & Biobased Research*

Natalia, N., Patricia, P. and Ademar, B.L. (2009). Gamma Irradiation Effect on Mechanical And Barrier Properties Of Foamed Articles Based on Cassava Starch. 2009 *International Nuclear Atlantic Conference* - INAC 2009 Rio de Janeiro,RJ, Brazil ABEN ISBN: 978-85-99141-03-8

Nawapat, D. and Thawien, W. (2011). Effect of UV-Treatment on Properties of Biodegradable Film From Rice Starch. *World Academy of Science, Engineering and Technology International Journal of Materials and Metallurgical Engineering* Vol:5, No:9, 2011

Nawapat, D. and Thawien, W. (2013). Effect of UV-treatment on the properties of biodegradable rice starch films. *International Food Research Journal* 20(3): 1313-1322 (2013)

Nelida, L.D.M. (2016). Radiation Influence on Edible Materials. INTECH. *Radiation Effects in Materials*. http://dx.doi.org/10.5772/62430

Pradeep, M. (2017). Feasibility Study: Bio-based Biodegradable Thermal Pallet Covers (BBTPC). *Helsinki Metropolia University of Applied Sciences*.

Richard, C., Martin, K. and Jim, S. (2010). Bioplastic. *Food and Beverage Packaging Technology* Second Edition https://www.researchgate.net/publication/229918338

Salwa, A.S.K. (2010). Effect of ionizing radiation on the properties of prepared plastic/starch blends and their applications as biodegradable materials. *National Center For Radiation Research And Technology Atomic Energy Authority.*

Shafik, S.S., Kawakib, J.M., Mohanad, I.K. (2014). Preparation of PVA/Corn Starch Blend Films and Studying the Influence of Gamma Irradiation on Mechanical Properties. *International Journal of Materials Science and Applications*. Vol. 3, No. 2, 2014, pp. 25-28. doi: 10.11648/j.ijmsa.20140302.13

Sharifah, K.S.M., Muhammad, A.H., Benchamaporn, W., Zulkafli, G. and Kamaruddin, H. (2000). Biodegradable Foam from Irradiated Sago Starch/Polyvinyl Alcohol Blend. *UPM Research Report* 1997-2000, Vol II, Section 2-Extended Abstracts

Sharon, K.V., Gayathri, R. and Vishnu, P.V. (2018). Biodegradable plastic production from corn starch. *Drug Invention Today* Vol 10 Issue 7 2018

Shristi, B. (2016). Production of Polylactic Acid in Laboratory Scale, and Characterizing The Thermal Properties. *Material Processing Technology* : Arcada

Tariq, Z.A. (2015). Physical and Chemical Investigations of Starch Based Bio-Plastics. *University of Leicester In Material Science*

Timothy, D.C. and Jeffrey, J.Z. (2011). Ultraviolet irradiation and the mechanisms underlying its inactivation of infectious agents. *Cambridge University Press 2011 Animal Health Research Reviews* 12(1); 15–23 ISSN 1466-2523 doi:10.1017/S1466252311000016

Vanessa, B.U. and Nelida, L.D.M. (2017). Characteristics of biodegradable films based on cassava starch and soy isolate protein treated by electron beam radiation. *Academia Journal of Agricultural Research* 5(4): 068-074, April 2017 DOI: 10.15413/ajar.2017.0115 ISSN: 2315-7739

Wittaya, T. (2012). Rice Starch Based Biodegradable Films: Properties Enhancement Structure & Function of Food Engineering, *INTECH* http://dx.doi.org/10.5772/47751