Development of Biodegradable Film from Fish Processing Waste: An Environment Friendly Initiative

R.K. Gautam, A.S. Kakatkar, P.K. Mishra, V. Kumar and S. Chatterjee
Seafood Technology Group, Food Technology Division
Bhabha Atomic Research Centre, Trombay, Mumbai-400 085

Abstract

Biodegradable films were developed using fish protein gel dispersion prepared from fish processing waste with incorporation of antioxidants (BHT & Ascorbic acid). The thickness of various films namely FG (fish gel), FGs (fish gel with starch), FGB (fish gel with BHT) and FGA (fish gel with ascorbic acid) ranged between 0.08 to 0.09 mm. The physical, mechanical, barrier and colour properties of films showed no significant variations during 12 month storage at ambient temperature. However, film with combination of ascorbic acid and fish gel (FGA) showed a better tensile strength (1.23 MPa), higher elongation at break point (127.97%) and lower water solubility (10.57%) as compared to FG, FGs and FGB. These film characteristics were comparable to other biodegradable films. The study indicates feasibility of effective utilization of fish processing waste for development of suitable packaging material. The utilization of fish waste may help in significant reduction in its disposal cost generating additional revenue and thus providing cleaner environment.

Keywords: Fish waste, Protein gel dispersion, Antioxidants, Bio-degradable, Packaging

Introduction

Research in biodegradable polymeric films for food packaging is witnessing significant interest as an alternative approach to tackle widespread use of plastic and disposal of plastic materials. A biodegradable film that is eco-friendly, non-toxic and gifted with physical and chemical properties of a synthetic polymeric film is the need of the hour. Natural bio-polymers like protein, polysaccharides, lipids or their combination can be utilised for preparation of biodegradable films (Tongnuanchan et al., 2012). Amongst these, proteins have been extensively studied because of their relative abundance, film-forming ability and nutritional qualities. Generally, protein based films provide mechanical stability whereas polysaccharides are used to control oxygen and transmission of various other gases. As the protein-based films degrade, they provide a source of nitrogen acting as fertilizer, an additional benefit over other non-protein-based films. These films act as selective barrier against the transmission of gases, vapours, and solutes which improves food quality, extend shelf life and provide physical protection (Zhong and Xia, 2007).

Processing of fish generates enormous amounts of waste material, such as fish heads, skin etc. For example in case of fish fillets, 75% of the total fish weight accounts for fish waste. This fish processing waste can be useful in development of biodegradable film. The utilization of fish waste helps to generate additional revenue, with safe and low cost of disposal, providing a cleaner environment (Mathew, 2014). Few studies have been reported on fish protein based biodegradable films which can enhance the shelf life of fresh and frozen foods (Aristippos and Curtis, 1990).

Aim of the present work was to develop a biodegradable film using fish processing waste and discards and to characterize their mechanical and barrier properties, comparison of changes in mechanical and barrier properties on incorporation of soluble starch and antioxidants like Butylated hydroxy toluene (BHT) and ascorbic acid during storage at ambient temperature.

Development of biodegradable film & its stability during storage

Composition of fish protein gel & its source

Fish protein dispersion was obtained through acid gelation of myofibrillar proteins isolated from fish processing waste. Myosin is the major structural protein of vertebrate muscle including fish muscle which plays an important role in the gelation and
emulsification of muscle based food (Venugopal, 1997).

Physical & Mechanical properties

Various biodegradable films Fig. 1 were developed using fish protein gel dispersion (Kakatkar, 2004) prepared from fish processing waste with incorporation of antioxidants (BHT & Ascorbic acid) by casting method as described by Rao et al. (2010). Thickness of the FG (fish gel), FGS (fish gel with starch), FGB (fish gel with BHT) and FGA (fish gel with ascorbic acid) were 0.08 ± 0.01, 0.09 ± 0.01, 0.08 ± 0.01, and 0.08 ± 0.01 mm respectively. Evidently, there was no significant difference in thickness of the films. The thickness of the films was comparable to earlier reports with average thickness of the films from fish proteins ranging from 0.08 to 0.13 mm (Ninan, 2010).

Tensile strength (TS) and elongation at break (ELB) was measured according to ASTM method D882-00 (ASTM, 2001). Mean TS of FG, FGS, FGB and FGA ranged from 0.99 ± 0.04 to 1.44 ± 0.06MPa Fig. 2a. Mean ELB of FG, FGS, FGB and FGA ranged 93.67 ± 1.0 to 127.97 ± 1.07 (%) respectively (Fig. 2b). FGA had maximum ELB (127.97%), and TS (1.23MPa), While FGS resulted in highest TS (1.44MPa), and ELB (107.27%). The mechanical properties showed that FGA films were better than FGS, FGB and FG. There were no significant changes in physical properties of films during storage at ambient temperature over a period of 12 months. Similar edible and biodegradable packaging films based on fish myofibrillar proteins have shown TS of 17.1 MPa, ELB of 22.7%, at a thickness of 0.034 mm (Cuq et al., 1995). Kaewprachu and Rawdkuen (2014) showed that biodegradable films from giant catfish skin gelatine showed a higher TS (26.42 MPa) and ELB (128.25%). A higher TS of 5.86 MPa and 123.5 % of ELB had been reported from edible films based on Alaska Pollack (Shiku et al., 2004). Variation in the data could be due to compositional differences and the procedure employed for film preparation. FGA films showed better mechanical properties with higher tensile strength and elasticity than other films over a period of 12 months.

Barrier properties

Barrier properties of a polymer are crucial to product-package shelf-life. The specific barrier requirement of a package system depends upon the food characteristics and the intended end-use applications (Siracusa, 2012). Water vapour transmission rate was done based on ASTM E96/E96M-05 method. WVTR of the films were comparable and it ranged from 0.381 ± 0.0072 to 0.4071 ± 0.0069 g/cm²/day (Fig. 2c) with no significance variation in means. The WVTR of films remained unaffected during storage for 12 month at room temperature. WVTR of fish films were comparable and found to be lower than other similar films like gelatin-starch film (1.08 ± 0.01 g/cm²/day), albumin-starch film (0.938 ± 0.01 g/cm²/day), casein-starch film (0.892± 0.01 g/cm²/day) as reported by Jagannath et al., (2003) and surimi based edible film (1.69 ± 0.06 gm’s⁻¹Pa⁻¹) as described by Shiku et al., (2004).

Films have shown varying degree of oxygen permeability in terms of oxygen transmission rate (OTR), with FG resulting as impermeable to oxygen, while FGA and FGB were oxygen permeable in order of 153 ± 3.6 ml/m²xday, and 999 ± 3.7 ml/m²x day respectively (Fig. 2d). Oxygen permeability of FGS film could not be measured as it became brittle and tore off while measurement. Fish films showed higher rate of oxygen transmission and compared with other reported films like, Cellulose acetate phthalate film (CAP film) and Gluten film, which showed lower oxygen permeability of 22.21 ± 1.23 % ml/m²xday and 41.02 ± 0.86 % ml/m²xday respectively (Falchouri et
al., 2004). Improving oxygen barrier performance of a film helps as oxygen promotes degradation of food by oxidation and thus affects organoleptic properties of food (Siracusa, 2012).

**Water solubility of film**

Water solubility of FG, FGA and FGB was $13.97 \pm 1.22 \%$, $10.57 \pm 1.23 \%$ and $11.9 \pm 1.24 \%$ respectively, while FGS was more water soluble with $20.79 \pm 1.17 \%$ solubility (Fig. 2e). Cellulose acetate phthalate film (CAP film) and gluten film have 100% and 22.7 \pm 4.10 \% water solubility (Falchouri et al., 2004).

**Colour change**

Colour of the film was measured as per method described by Pires 2011 using Minolta CM-3600d Spectrophotometer (Konica Minolta Sensing, Inc. Osaka, Japan). The whole visible spectrum (360 to 780 nm) was recorded with $\Delta \lambda = 10$ nm and considering illuminant D65 and 10’ observer as references.

The CIELAB parameters, $L^*$ (lightness), the chromaticness coordinates, $a^*$ (red to -green component), and $b^*$ (yellow to -blue component) were analysed by JAYPAK software (Quality Control System, Version 1.2). Means of hunter $L^*, a^*$, and $b^*$ values were determined after taking average of 3 colour value parameters (each in triplicates) across each film, and the difference in colour components during storage were analysed statistically by using one-way analysis of variance (ANOVA). Changes in colour components for samples analysed during storage at ambient temperature Fig. 3. $L^*$ values [lightness or clarity, which ranged from 0 (black) to 100 (colourless)] of the samples did not change significantly ($P < 0.05$) during storage over a period of 12 months. There was a slight reduction in $a^*$ values [chromatic co-ordinates, which ranged from red (+) to green (-)] towards greenness without any significant change ($P < 0.05$). However, there was significant difference in $b^*$ values [chromatic co-ordinates, which ranged from yellow (+) to blue (-)] of the FG and FGS films. Whereas, $b^*$ values of the FGB

---

**Fig. 2:** Mechanical [Tensile Strength (TS), Elongation at Break (ELB)]; Barrier (Water Vapour Transmission Rate (WVTR), Oxygen Transmission Rate (OTR)] properties and Water Solubility Rate (WSR) of biodegradable films & their changes during 12 month of storage period. The values shown above are mean ± SD of three independent experiments, each carried out in triplicates.
and FGA films changed insignificantly (P < 0.05). Films had shown a slight yellowish discoloration, which may be due to non-enzymatic browning reactions between protein components.

**Conclusion**

Combination of fish protein, starch and antioxidants lead to successful development of clear, flexible biodegradable films. The film with combination of ascorbic acid and fish gel (FGA) showed a better tensile strength along with higher elongation at break point as compared to FG, FGS and FGB. Thus, inclusion of ascorbic acid as antioxidant has provided better protein-based biodegradable packaging film. The study shows effective use of fish protein for preparation of environment friendly biodegradable films, which can be used in food packaging industry.

**Corresponding author and email:** Smt. C. Chattarjee (suchanc@barc.gov.in)

**Acknowledgements**

We thank Mr. Shabbir Alam of Seafood Technology Group for providing technical support during entire process of research work.

**References**


7. P. Kaewprachu and S. Rawdkuen. 2014. Mechanical and physicochemical properties of biodegradable
8. A. Kakatkar, S.V. Sherekar and V. Venugopal. 2004. Fish Protein
dispersion as a coating to prevent quality loss in processed fishery
products. Fish Technol. 41, 29-36.
9. P.T. Mathew. 2014. Fishery waste management – problems and
prospects. In: Recent advances in the
development of nutraceuticals, health foods and fish feed from fish and
shellfish processing discard (Eds.) A. A. Zynudeen, J. Bindu, G. Ninan, C.O.
Mohan, & R. Venkateshwarlu. ICAR-Central Institute of Fisheries Technology.
10. G. Ninan, J. Joseph, and Z. Abubacker. 2010. Physical,
mechanical, and barrier properties of carp and mammalian skin gelatine
films. J. Food Sci. 75(9): E620-E626.
Marques. 2011. Characterization of biodegradable films prepared with
Guar gum composite films: preparation, physical, mechanical and
13. Y. Shiku, P.Y. Hamaguchi, S. Benjaku, W. Vissessanguan and M.
Tanaka. 2004. Effect of surimi quality
on properties of edible films based on
14. V. Siracusa. 2012. Food packaging permeability behaviour: A report-
https://doi.org/10.1155/2012/302029
15. P. Tongnuanchan, S. Benjakul and T. Prodpran. 2012. Properties and
antioxidant activity of fish skin gelatine film incorporated with
https://doi.org/10.1016/j.foodchem.2012.03.094
16. V. Venugopal. 1997. Functionality and potential applications of
thermostable water dispersions of fish
meat. Trends Food Sci Technol, ISSN:
0924-2244, Vol. 8, Issue: 8, Page: 271-
276 https://doi.org/10.1016/S0924-
2244(97)01038-8
17. Q.P. Zhong, W.S. Xia. 2007. Physiochemical properties of edible and
preservative film
chitosan/cassava starch/gelatine
blend plasticized with glycerol. Food