Abstract

Valorisation of oilseed meals for development of biopolymeric films and biodegradable plates using natural gums and plant fibres

Abstract

The Thesis

The thesis is divided into six chapters that are discussed below:

Chapter 1 includes the general introduction of the overall work of present research considering the major details about the oilseed meals and its contribution to waste increment, limitations in various sectors and potentials in biodegradable film development. The chapter also discusses the role of emulsifiers and plasticisers, natural gums and crosslinkers in the development of biodegradable films. The plant fibres contributions in the film development along with research gap has been added in this chapter.

Chapter 2 comprises of the review of literature cited related to the research objectives. The chapter covers the thorough analysis of various oilseed meal kinds, their extraction processes, the ingredients included in the oilseed meals, and the oilseed production rate across different geographic regions. The chapter also includes the review on biopolymeric films fabrication with different polysaccharides, protein, lipids or synthetic polymers and natural polymer used in combination with each other. The hydrocolloids such as Acacia gum and Xanthan gum behavior has been reviewed along with their structural components helpful in film development. Crosslinkers such as citric acid and glutaraldehyde as additives are also been reported in literatures and its benefits in improving the structural and barrier properties of the films. The literature on various fibre kinds, how to handle and extract them, and the advantages of utilising them in various ways are covered in the chapter. The review of literature comprises the research on biodegradable plate applications that has been gathered during the previous five to six decades, together with information on the development and purpose of biodegradable plates and the many techniques for their creation as well.

Chapter 3 deals with optimization of the levels of mustard, soybean and flaxseed meal for the development of biopolymeric films. Mustard and soybean seeds are most commonly known for their edible oilseeds whereas flaxseed, a non-edible oil category is known for its health benefits. The oilseeds cake has high content of fibre and protein, are usually seen as mass waste after the extraction of oils. The study was conducted to evaluate functional properties of oilseed cakes and meals. Water absorption capacity and oil absorption capacity was more in defatted seed meal compared to cake of mustard and soybean seed meal. However, the results were

revered in case of flaxseed meal. Water absorption capacity was higher for defatted soybean seed meal (24.67%) compared to defatted mustard and flaxseed meal. Among three oilseed cake samples, oil absorption capacity was higher in flaxseed cake (14.33%). Foaming capacity was higher for soybean seed cake (21.19%) followed by flaxseed cake (11.95%) and mustard seed cake (3.10%). Emulsion capacity was ranged from 40.69–51.38% and 47.26–57.18%; whereas emulsion stability was ranged from 107.52–107.52% and 108.15–119.89% in seed cake and defatted seed meal respectively. Results indicated that the removal of fat from oilseed meal helps to increase their functional properties. This shows that oilseed meals are useful in food application, fortification and packaging instead of being leftover as waste. The current research work demonstrates the valorisation of oilseed meals by transforming them into biopolymeric films with tuneable properties for stringent food packaging applications. The oilseed meals are by-products obtained as considered waste materials after oil extraction having a large potential in the food industry.

Further, the biopolymeric films fabricated using defatted oilseed meals of mustard, flaxseed, and soybean each in range of (1–100%) using the mixture design. The films were developed using solvent casting method with the addition of a glycerol (75%) as plasticizer and soy lecithin (2%) as emulsifier. The effectiveness of the various proportions of the selected oilseed meals on water vapour permeability, water solubility, swelling property and tensile strength has been studied. The optimized films were obtained with the combination of 20.50% mustard seed meal, 67.15% flaxseed meal, and 12.33% soybean seed meal. The result obtained after investigation of selected responses were found as 47.67% solubility, 1.01 MPa tensile strength, elongation at break at 8.31%, and water vapour permeability with 1.36×10^{-10} g/Pa h m g. The oilseed meals were found significant on the properties of the biopolymeric films. The thermal, morphological, and functional analysis results improved in the optimized biopolymeric films. The formulation obtained had improved mechanical as were as barrier properties of biopolymeric film.

Chapter 4 deals with determining the influence of natural gums and crosslinkers on the properties of oilseed meal based biopolymeric films. In continuation to the study, the three widely accessible oilseed meals viz. flaxseed, soybean, and mustard were gathered, ground,sieved and de-oiled oilseedmeals were used to create biopolymeric films. A film forming suspension of defatted meals along with natural gums (acacia and xanthan gum) and crosslinkers (citric acid and glutaraldehyde) were formed. The suspension was cast into petri dishes and dried to produce smooth and even films. The physical, functional, color, thermal

and morphological properties of the oilseed meals-gums crosslinked biopolymeric films were evaluated and statistical analysis was performed. The use of natural gums enhanced the blended oilseed meal film's composition. Optimizing the amount of natural gums required to be added to the oilseed meals-gum film forming suspension involved the use of a full factorial design. It was determined that the ideal blend ratio for biopolymeric film formulation was 0.5:1.5 AG: XG, based on the independent variables (acacia gum and xanthan gum) interaction with the responses. The optimized film formulation resulted in 41.84% solubility, 0.98 MPa tensile strength, 9.21% elongation at break, and 4.43×10^{-10} g/Pa h m g water vapour permeability following investigation of selected responses. To validate to actual results v/s the predicted values, the film formulation was tested in triplicate. This implies that the developed (0.5:1.5 AG: XG) oilseed meals-gums biopolymeric film had an acceptable barrier, physical and mechanical properties that can be applied for further practical utilisation. The production of a successful biopolymeric film requires minimal solubility, minimum water vapour permeability, minimum elongation at break and maximum tensile strength.

The oilseed meals-gums crosslinked films were also successfully developed after incorporation of crosslinkers into the best obtained oilseed meals-gums suspension. It was found that the films crosslinked with 10% Citric acid (CA-film 10) was found to have better results in comparison to the films crosslinked with 10% Glutaraldehyde (GL-film 10). The response data recorded were 35.83 % solubility, 1.15 MPa tensile strength, 10.68 % elongation at break and 3.8×10^{-10} g/Pa h m g water vapour permeability for the optimized film with 10 % Citric acid (CA-film 10). The solubility was found to decrease and increase in tensile strength with the addition of citric acid. There was significant difference observed in the values of elongation at break after the addition of citric acid as crosslinker. The research shows how oilseed meals enriched with natural gums and crosslinkers are converted into biopolymeric films, which can be used in food packaging to lessen reliance on petroleum-based, non-biodegradable plastics.

Chapter 5 deals with the effect of plant fibres reinforcement on mechanical properties of oilseed meals- gums crosslinked biopolymeric films and biodegradable plates and their function with various density food models. In this chapter, the plant fibres (banana pseudo-stem, coconut coir and sugarcane bagasse) were mercerized and characterized prior to enforce into film suspension. The plant fibres were studied on the basis of physicochemical, morphological, thermal and functional properties. All the three fibres of banana pseudo-stem, coconut coir and sugarcane bagasse were used for the development of biocomposite films to

study the effect of addition of fibres on the biopolymeric films. The fibres were taken in 1-5% w/w of the oilseed meals. The films were compared based on physical, morphological, thermal and functional properties. The tensile strength, as well as thermal properties of the biocomposite film, increased whereas, the elongation and moisture content decreased after the addition of plant fibres in comparison to the biopolymeric films without fibres. The water vapour permeability, solubility and the thickness also increased after incorporation of fibres. Among all the fibre incorporated films, the banana, coconut and sugarcane films with 5% addition had the best results. The responses recorded for the percent solubility; tensile strength; percent elongation and water vapor permeability were 37.98%, 45.06% & 45.12%; 1.96MPa, 1.30 MPa & 1.28 MPa; 7.11%, 5.61% & 6.19% and 6.25×10^{-10} g/Pa h m g; 5.37×10^{-10} g/Pa h m g & 5.56×10^{-10} g/Pa h m g for banana, coconut & sugarcane fibres reinforced films respectively.

The biodegradable plates composition was kept similar to the 5% fibre incorporated biocomposite films. The fabrication of the biodegradable plates was done by hot compression molding machine at 107 ºC for 2 min compression. The biodegradable plates of all the three different fibres (banana, coconut and sugarcane) were analyzed in triplicate. The moisture content lowest in coconut coir with 7.28% in comparison to banana pseudostem (11.58%) and sugarcane bagasse (11.68%). The mechanical properties studied for hardness and fracturability of the biodegradable plates were analyzed by Compression Test (at 10%, 30%, 50% and 70%) strains. The fracturability of the biodegradable plates ranged from 33.71 N to 144.54 N whereas, the hardness of the biodegradable plates ranged from 40.05 N to 155.96 N. The study of water holding capacity was found highest in coconut coir (29.82%) than banana pseudosten (26.89%) and sugarcane bagasse (21.69%) fibre biodegradable plates. The leak test of the biodegradable plates with different food models like ketchup, honey, syrup, oil and water was analyzed within 15 min. The absorption of cold water occurred within 5 min whereas, there was no spreadability was observed on the surface of the biodegradable plates with other food models like ketchup, honey, syrup or oil. The contact angle found highest in banana pseudostem fibre incorporated biodegradable plates (69.8º) than coconut (42.8º) and sugarcane (49.3º). The biodegradability of the biodegradable plates were observed to break into bits within the interval of 20 days.

Chapter 6 summarizes the conclusion, summary and future scope of the present research study. The purpose of the research work was to utilize the whole oilseed cakes that not only contributes to the waste utilization of the oilseed cakes as well as to the economical

development of small-scale industries. Research work concluded on the development of the biodegradable plates developed with oilseed meals incorporated with natural gums (Gum Acacia & Gum Xanthan) as binders, citric acid as crosslinker and plant fibres (Banana pseudo-stem, coconut coir and sugarcane bagasse) as mechanical support. The presence of Glycerol as a plasticizer and Soy Lecithin as an emulsifier, played an important role in the biodegradable plates development. The biodegradable plates can be used for various purposes as single-use food plates. For future scope, agricultural by-products as well as wastes other than oilseeds and plant fibres can also be used to develop such biodegradable plates that can satisfy environmental concerns. Using various molds for smooth Teflon surfaced molding machines or injection molding machines, biodegradable plate shapes and textures may be altered. However, the developed oilseed meals-gum crosslinked biodegradable plates incorporated with fibres are reasonably strong, and biodegradable and would also work well as single-use food containers.