Chapter 1

Introduction

1.1. Introduction

The utilization of waste material from available natural sources have been trending research in the field of food sectors (Abdel-Shafy and Mansour, 2018). The importance of waste management has received a considerable attention all over the world for economic, social, and environmental wellbeing (Wilson et al., 2006). Since every industry produces a wide amount of dispose eventually after processing of food processing, therefore, attention is needed to treat the disposed materials to create "waste to wealth". Wastes resulting from farming operations are categorized as- crop residues, leftover trimming material from trees and plants, land and water weeds, food and poultry processing residues (Ezejiofor et al., 2014). Additionally, the waste management is needed in parallel to the rest sectors of food industry for reducing the effect of waste on health and environment. The waste management includes various methods such as processing/extraction of wastes, incineration into biogas production, pre-treatment, hydrolysis, and anaerobic digestion into fertilizers as well as direct addition into food production (Abdel-Shafy and Mansour, 2018). Utilization of waste or waste valorisation consist of the process of reusing, recycling, or composting waste materials where, the waste are more converted to new useful products and less heading to landfills contributing to environmental pollution (Roughan, 2021).

Development of a biodegradable packaging material out of waste can provide us an opportunity to replace non-biodegradable petroleum-based plastics. In addition to solving the issues of sustainability, disposal, and biodegradability, proteins, lipids, and starches, or their blends, have been identified as runners in the creation of biopolymeric film (Schettini et al., 2013). Selection and utilization of natural food grade materials as food packaging can protect human health along with environmental worries. Such biodegradable films extend shelf life of food by acting as selective barriers against moisture and oxygen. They also reduce volatile compounds and controls oxygen transmission which results in undesired odour and flavour through oxidation in foods (Kopeček and Yang, 2007). One of the most common materials that we come across in our daily life are the plastics. It has become a serious issue since it contributes into environmental pollution. To find an alternative to this problem, biopolymeric film production is the first thing that comes in our mind which can be renewed, found in abundance, should be eco-friendly as well as biodegradable through natural means and inexpensive in nature (Bastioli, 2005; Farris et al., 2009; Wretfors et al., 2009).

The best natural forms of biodegradable packaging and containers are found in seed shells and fruit rinds and peels. Biodegradability is an eco-friendly concept that benefits from both user and eco-friendliness. The commonly known natural components used in the fabrication of biopolymeric films are polysaccharides, protein, lipids or synthetic polymers and natural polymer used in combination with each other (Shit and Shah, 2014). From the very early days, there have been several research going on across the world over the development of biodegradable films from waste, however, the biodegradable film provides inferior mechanical strength and barrier properties compared to fossil derived films (Platt, 2006). Considering this, the modification of biopolymeric films or exploring the waste materials to tailor the biopolymeric films is a noteworthy choice (Ortega et al., 2022).

Recycling these byproducts can minimise pollution and maximise the preservation of natural resources while upholding safety and environmental friendliness. Biodegradable plastics are found in nursery pots used in agriculture, foam packaging for industrial items, and fast-food flatware and food containers (Mohareb and Mittal, 2007). Moulded pulp products have been widely used in the disposable goods market because of its affordability, biodegradability, and ease of disposal. Moulded pulp products are replacing plastics in the food business as consumer expectations demands for sustainable and eco-friendly products (Zhang et al., 2022). The market for single-use cutlery and tableware may be divided into product categories such as straws, chopsticks, glasses, spoons, forks, sporks, cups, and so on (Dybka-Stępień et al., 2021). Hot compression, induction moulding, extrusion, solvent casting and hot mold baking procedure are some of the common technologies used for the development of rigid containers such as trays, cutleries, etc. from plant fibres, fruit and vegetable wastes incorporated with polysaccharides (Kaisangsri et al., 2012).

Agriculture is the backbone of the Indian economy. A generous amount of by-products and waste are produced from agriculture which can also be beneficial for Indian farmers. India comes forth in the production rate of oilseeds across the world after USA, China and, with average yield of 25 million tons annually (Reddy and Immanuelraj, 2017). Oilseed production is one of the major industrial crops for the production of oil all over the world. The extraction of oils from major oilseed sources such as soybean, mustard seed etc. produces a substantial amount of de-oiled meals as by-product, considered unfit for human or animal consumption due to the presence of anti-nutritional compounds. Due to high moisture content and high-water activity in oilseed cakes promotes the growth of fungi and production of aflatoxins. This problem mainly happen is tropical and subtropical regions where oilseed crops are grown. They mostly have fear of infections with *Aspergillus flavus* or *A. parasiticus* during the storage period (Pettersson, 2012). A regulatory structure is necessary since 33% of oilseed meals are still disposed of in the open, even after being composted, land filled, burned, fermented, recycled into fertilizers, or fed to cattle (Kaza et al., 2018). About 2.26 million tonnes are exported and 4.33 million tonnes of oilseed cake treated by solvent extraction plants from which approximately 2.31 million tonnes of oilseed cake are fed to cattle in India (Shukla et al., 1992).

Other than oilseed meals, plant fibre are one of the agricultural waste that can be valorized for the production of packaging materials in replacing plastics. As per data released by the Food and Agriculture Organisation of the United Nations, 11,864,344 hectares of land are covered by coconut trees, yielding 61,708,358 tonnes of coconuts at a yield of 5.20 tonnes per hectare. In 2020, globally around 1869.71 million metric tons of sugarcane was produced and generally, 1 tonne of sugarcane yields approximately 280 kg of bagasse (Singha et al., 2023b). Whereas, China alone produce banana waste estimating around 29.0 million tonnes of banana stalk residue annually. The outer sheath of banana pseudostems make around 1.5 million tonnes of dry banana fibres per year, indicates that they can be turned into useful products instead of wastage (Vigneswaran et al., 2015). In terms of coconut output, India comes in at number three out of the top 90 nations, accounting for 16.4% of global coconut production. In India, coconut trees cover around 1.93 million hectares of land and yield 21 million nuts annually, or 10,122 nuts per hectare.

Oilseed meals are not commonly used in the area of rigid packaging (Mohareb and Mittal, 2007). Proteins that can be extracted from oilseed cake and utilised to create films with desirable properties, such as barrier and adhesive qualities and resistance to organic and oily solvents, are available at a reasonable cost (Popović et al., 2020). Many uses of proteins have been investigated, including its usage as a thermoplastic for non-food purposes. A thermoplastic polymer was initially made using oilseed meal. Since the majority of biopolymeric films are known to have lower mechanical qualities than petroleum-based plastics, the use of biopolymeric films and natural composite packaging materials with enhanced mechanical properties is required in a wider variety of applications.

Plants containing fibres of interest for the manufacture of engineering materials include coconut coir, sugarcane bagasse, banana pseudo stem etc. Banana pseudostem, coconut coir and sugarcane bagasse fibres are popularly being used to enhance mechanical strength of engineering materials and also in other sectors. The main advantages of using plant fibre are renewability, high strength and elastic modulus, low density, non-abrasiveness and biodegradability. There is a growing trend to use such fibres as fillers and/or reinforcers in plastics composite (Teh et al., 2014; Koushki et al., 2015; Mohan et al., 2010). Scientists are working on development of new packaging materials by treating the fibres in various ways to increase their strength that can compete in the market with poly-oriented packaging materials and in their availability, quality and selection of any fibres, geographic location plays major role (Muneer et al., 2014). The field of moulded fibre technologies and products is experiencing rapid evolution. To fully realise the potential of moulded fibre products for a range of packaging applications, scientific knowledge and engineering design/practices are essential. The benefits of moulded fibre products include cost-effectiveness and environmental advantages. The food industry must comply with certain standards because of stringent guidelines (Zhang et al., 2022).

Effective formation of film using only oilseed meal is challenging task. During development of oilseed meals based biodegradable films, the oilseed meal particles in the suspension tend to settle down quickly which affect film formation. The possible solution is to use emulsifiers which can improve the emulsion stability of particles. The nature of compounds of hydrocolloids depends on its chemical structure. The hydrocolloids with highly branched structure tends to form gels more easily and are more stable in nature in comparison to linear structured hydrocolloids as their possibility of extension along the structural chains are less (Jani et al., 2009). The uses of natural gums in film formation have property to bind, stabilize, and suspend the agents and works excellent as emulsifiers and thickening agents.

Hydrocolloids like gums and resins, as well as crosslinkers like citric acid & glutaraldehyde, have long been significant players in the production of films. There is availability of synthetic as well as natural based crosslinkers that are found successful in interconnecting starch and protein molecules by modifying and thermosetting thus, enhancing mechanical properties and molecular weight, water solubility, thermal stability as well as resistance to quick degradation (Mustafa and Temel, 2018). The most common gums which can be used are Arabic gum and Xanthan gum (Desplanques et al., 2012).

The use of a good plasticizer such as glycerol and soy lecithin as emulsifier can improve the packaging properties significantly. Plasticizer plays an important role making the film smooth and emulsifier with its amphiphilic property form a mechanical barrier around the droplets of oilseed meals protecting them against destabilization phenomena such as coalescence or flocculation (Klang et al., 2019). Lee et al., (2015) explains that when protein films are added with plasticizers, it makes the films more flexible as well as decrease the glass transition temperature whereas, when comes to the crosslinkers, it enhances the barrier and mechanical properties when added with the protein films (Friesen et al., 2015).

The novelty of the present study relies on the valorisation of agricultural by-products such as oilseed meals and plant fibres. The research work has market potential for boosting the economy of farmers as well as small scale industries and provides an opportunity to decrease the dependency on petroleum based plastics. Thus, this work aimed to utilize the oilseed meals and plant fibres for the development of biopolymeric films and biodegradable plates. The oilseed meals and plant fibres were characterized and their suitability in film and plate development. The oilseed meals were introduced with gums and crosslinkers to study the effect on barrier properties and reinforcing plant fibres to study the mechanical properties of oilseed based biopolymeric films. The study also includes the development and characterization of the biocomposites and biodegradable plates by direct utilization of oilseed meals and plant fibres. It also paves the way for future research projects that will evaluate the unique functions, applications and qualities of food packaging.

Research Gap/Justification

The following research gaps were observed.

- The studies related to development of blended oilseed meals based biopolymeric films are very limited.
- The literatures for combine effects of natural gums and crosslinkers on oilseed meals based biopolymeric films are rarely available.
- The effect of reinforcement of plant fibres into oilseed meals based biopolymeric films are not much explored.

Objectives of the current study

1) **To optimize the levels of mustard, soybean, and flaxseed meal for the development of biopolymeric films**

    a) To characterize the oilseed cake and defatted oilseed meals

    b) To optimize and develop biopolymeric films using combination of oilseed meals

2) **To determine the influence of natural gums and crosslinkers on the properties of oilseed meal based biopolymeric films**

    a) To study the effect of acacia and xanthan gums on the properties of the biopolymeric films

    b) To study the effect of crosslinkers (citric acid and glutaraldehyde) on the properties of the biopolymeric films

3) **To investigate the effect of plant fibres reinforcement on properties of oilseed meal based biocomposite films and biodegradable plates**

    a) To characterize the properties of plant fibres (banana pseudostem, coconut coir & sugarcane bagasse) and its effects on the developed biocomposite films

    b) To develop biodegradable plates and study its characteristics

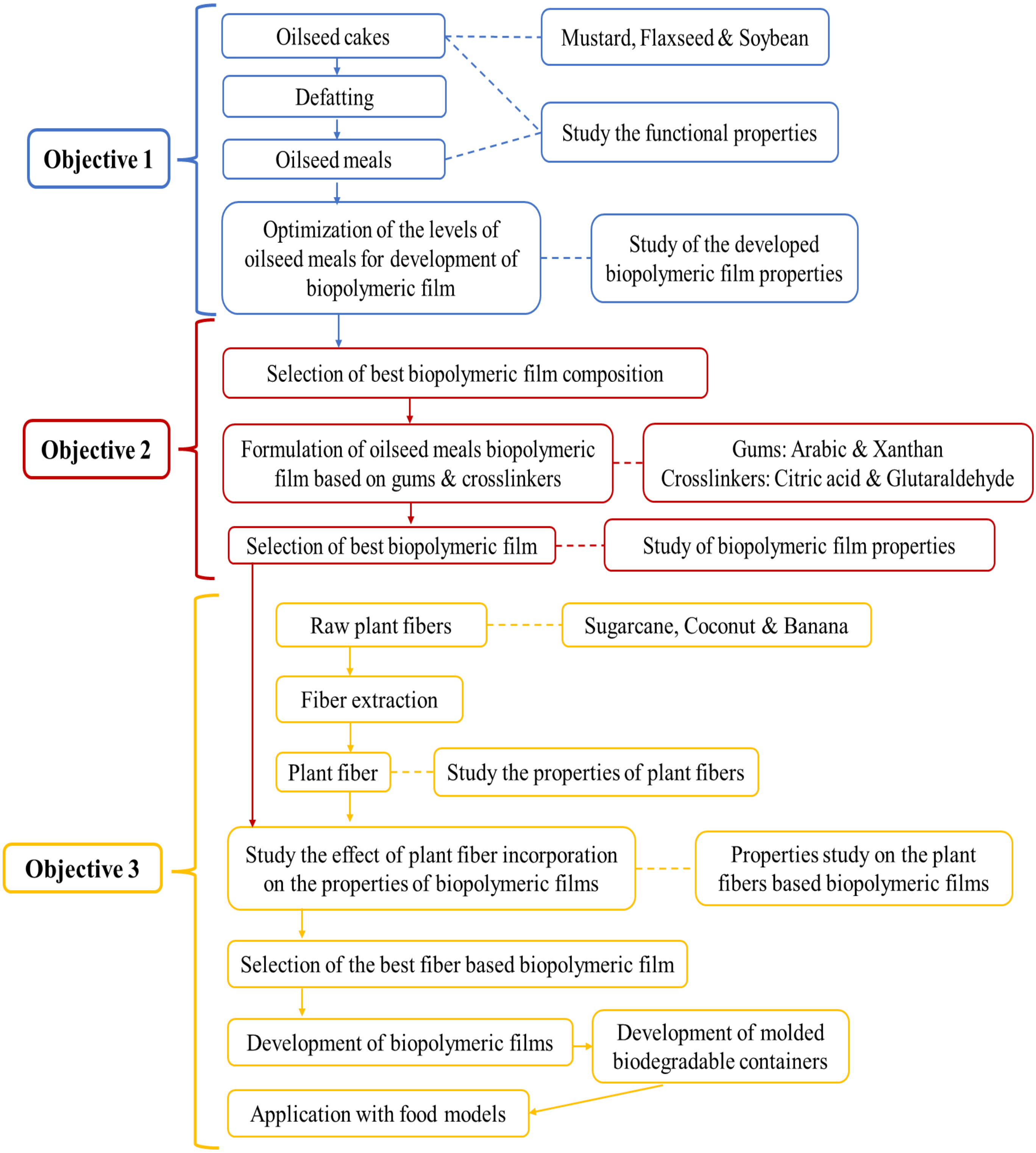

Fig. 1.1. The Outline of the overall research work plan