Chapter 1

Introduction

1.1 Background

Packaging has evolved dramatically over centuries—from simple containment vessels to the modern synthetic plastics that dominate today's supply chains. While current materials are durable and protective, they remain passive and environmentally persistent. Addressing the escalating food security, safety, and sustainability concerns necessitates a paradigm shift, evolving inert packaging to a more functional and responsive one.

Globally, food spoilage and microbial contamination contribute to significant postharvest losses. Over 1.3 billion tonnes of food are wasted annually, with 600 million foodborne illnesses occurring each year as a result of microbial contamination (Vasile & Baican, 2021; WHO, 2022). Simultaneously, the world is facing a silent but rising health crisis: antimicrobial resistance (AMR). Without intervention, AMR is projected to cause up to 10 million deaths annually by 2050 (Tang et al., 2023). These figures underscore the urgent need for packaging systems that can go beyond physical protection—towards actively improving food safety and extending shelf life whilst minimising reliance on synthetic preservatives and antibiotics.

Traditional food packaging materials—mainly derived from petroleum—lack antimicrobial activity and are not biodegradable (Martín Esteban González-López et al., 2023). At the same time, consumer rejection of synthetic preservatives is growing, driving demand for natural, clean-label solutions. This intersection of public health, environmental sustainability, and market demand is where active packaging enters the scene.

Active packaging incorporates functional agents—such as antimicrobials—into the packaging itself, allowing it to interact with food and its environment. One promising candidate is lemon myrtle essential oil (LMEO), derived from Backhousia citriodora, an Australian native plant rich in citral, a compound with strong antibacterial and antifungal activity (Ann Chie Lim et al., 2022). LMEO has been shown to outperform more common oils such as tea tree or clove in antimicrobial performance (Cock, 2013). However, LMEO is highly volatile and unstable when applied directly to food, limiting its effectiveness over time (Mukurumbira et al., 2022).

To harness LMEO's potential, it must be stabilised within a suitable film matrix. Biodegradable polymers, such as sodium alginate, present a viable solution. Sodium alginate is derived from brown algae, is classified as GRAS, and forms stable gels with divalent ions—making it suitable for controlled release of volatile compounds in food applications (Abka-khajouei et al., 2022; Hu et al., 2021). Unlike chitosan, which has been previously used in essential oil films but suffers from pH limitations and allergenicity concerns, alginate offers enhanced compatibility, neutrality, and safety (Zhang et al., 2024).

Despite LMEO's demonstrated antimicrobial efficacy, its behaviour in real-world food systems remains underexplored. Previous studies have largely focused on in vitro antimicrobial activity or applied LMEO to non-biodegradable or chitosan-based films (Cock, 2013; Hayes & Markovic, 2003; Sultanbawa, 2016). There is limited understanding of how LMEO performs under refrigerated storage conditions, how citral release behaves over time, and whether these films can be realistically deployed in the food industry (Tao et al., 2021).

To address these gaps, this study investigates the development and evaluation of LMEO-infused sodium alginate packaging films. Using chicken breast as a model food—a product highly susceptible to microbial spoilage—this research will test films containing 2% and 4% LMEO, examining microbial inhibition over time, and analysing the release dynamics of citral components (neral and geranial) using gas chromatography-flame ionisation detection (GC-FID) (Aslani & Armstrong, 2022; Chawla et al., 2021; Rahman et al., 2023). Chicken breast was selected as the model food matrix for this research due to its global market significance and its inherent susceptibility to microbial spoilage, making it a challenging and relevant substrate for testing the efficacy of a novel active packaging system (Soysal et al., 2015; Yusof et al., 2021).

By bridging antimicrobial testing with chemical release analysis under refrigerated storage, this research seeks to establish LMEO-alginate films as a dual-function, sustainable packaging innovation—reducing microbial contamination and food waste while advancing the practical use of essential oils in the food industry.

1.2 Objectives

1. To analyse the antimicrobial and antifungal efficacy of LMEO-incorporated sodium alginate packaging films compared to non-incorporated control films in chicken samples under refrigeration.
2. To semi-quantitatively analyse the release dynamics of citral components (neral and geranial) from 2% and 4% LMEO films using gas chromatography-flame ionisation detection (GC-FID).
3. To evaluate the performance of biodegradable active packaging films in maintaining food quality and extending shelf life during storage.

1.3 Hypothesis

H0: LMEO–incorporated active packaging does not significantly enhance antimicrobial efficacy, extend the shelf life of perishable foods, or exhibit a controlled release of citral compounds under refrigeration.

H1: LMEO–incorporated active packaging significantly enhances antimicrobial efficacy, extends the shelf life of perishable foods, and demonstrates a controlled release of antimicrobial compounds as detected by GC-FID.