UNIVERSITI PUTRA MALAYSIA

DEVELOPMENT AND CHARACTERIZATION OF SUGAR PALM [Arenga pinnata (Wurmb.) Merr.] STARCH/NANOCELLULOSE BIOCOMPOSITES FILMS INCORPORATED WITH ESSENTIAL OILS

MOHAMAD OMAR SYAFIQ BIN RAZALI

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By

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Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfillment of the Requirements for the Degree of Doctor of Philosophy

March 2022

DEDICATION

To Al-Quran, the greatest source of knowledge

Bring me sheets of iron" - until, when he had leveled [them] between the two mountain walls, he said, "Blow [with bellows]," until when he had made it [like] fire, he said, "Bring me, that I may pour over it molten copper." (Al-Kahf:Verse 96)

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To my beloved father and mother for their invaluable sacrifices, encouragements and support throughout my life

&

To my beloved family for their love, patience and understanding

&

To my beloved Teachers

&

To my awesome team members

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfillment of the requirement for the degree of Doctor of Philosophy

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March 2022

Chairman : Mohd Sapuan bin Salit, PhD
Institute : Tropical Forestry and Forest Product

The demand of antibacterial active packaging is escalating due to the needs of improving quality and shelf life of food. Furthermore, plastic waste is one of the world's concern to human health. Biocomposite have attracted attentions among the researchers, due to their environmental friendliness and sustainable nature. Starch is an alternative to substitute the petroleum based plastic film. There are several limiting factors as using starch, which are fragile and brittle. Plasticizers were added to the starch film-forming solutions to help overcome the unplasticized starch films' fragile and brittle nature. Besides, cinnamon essential oil was incorporated as antibacterial agent in the biocomposite films to form antibacterial active packaging. In order to transform into high performance of the antibacterial active packaging, cinnamon essential oil incorporated sugar palm nanocellulose reinforced sugar palm starch biopolymer composites were casted by using solution-casting method to investigate the properties of biocomposite films. The characterizations of biocomposite films was performed using Field Emission Scanning Electron Microscopic (FESEM), Thermal Gravimetric Analysis (TGA), Fourier Transform Infrared Spectroscopic (FTIR), density, antibacterial activity, seal and tear strength. The effect of various types of plasticizer with different concentrations (glycerol, sorbitol and (glycerol + sorbitol) at 0 - 4.5 %wt) on the mechanical, physical, water barrier and biodegradable properties were evaluated. It shows water absorption were increase respective to the plasticizer concentration. Besides, water vapour permeability (WVP) and solubility of the different concentration plasticizer used in the biopolymer shows increasing trend due to high water content. Water content for sample glycerol (G-plasticized), sorbitol (S-plasticized) and mixture of glycerol and sorbitol (GS-plasticized) were shown increasing trend, which were from 14.86-30.30%, 12.36-15.00% and 13.58-35.04% respective to their concentration. Increasing plasticizer contents resulted in increments in film thickness and moisture contents. On the contrary, the increase in plasticizer concentrations resulted in the decrease of the densities of the plasticized films. Three types of essential oil, i.e. cinnamon, eucalyptus and rosemary oils were tested for antibacterial activity, cinnamon essential oil (EO) showed the highest inhibition zone. Cinnamon EO had been chosen as antibacterial agent in the

biocomposite films. The effect of various concentration of cinnamon EO (0 - 2.0 wt %) on the mechanical, morphological, flammability, thermal and antibacterial activity were evaluated. The effectiveness of antibacterial packing is determined by the diameter of the zone of inhibition; the wider the diameter, the more sensitive the bacterium to the packaging. The antibacterial test was carried out by agar disc method (ADM) to evaluate the inhibition effect of the films on the gram positive bacteria, gram negative bacteria and yeast. The result suggested that the optimum amount of EO used (2.0 wt %) for positive result of inhibition activity. Tested film incorporated with 2.0 wt % EO showed the inhibition zone for *B. subtilis*, *S. aereus* and *E. coli*, which were 7.85, 6.63, and 7.43 mm respectively. From scanning electron microscopy analysis, the cross-sections of the cinnamon EO-containing films showed appearance of micro-porous spots as micro-porous holes because of the occurrence of partial evaporation on the cryo-fractured surface as a result of the vacuum condition. Increment in cinnamon EO concentration resulted in increasing trend of the number and size of the micro-porous holes. Significant increase was observed in the thermal stability with the cinnamon EO loading. The thermal stability of the CEO/SPNCC/SPS biopolymer composites was remarkably improved with increasing CEO loadings (sample 5, T_{max}=296.25°C) compared to the thermal stability of the unfilled compound (sample 1, T_{max}=289.18°C). FESEM micrograph show the films was slightly yellowish and transparent films. Overall, cinnamon essential oil/sugar palm nanocellulose/starch biocomposite films have good potential for active food packaging applications.

Abstrak tesis yang dikemukan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk Ijazah Doktor Falsafah

PEMBANGUNAN DAN PENCIRIAN FILEM BIOKOMPOSIT KANJI/NANOSELULOSA ENAU [*Arenga Pinnata* (Wurmb.) Merr.] YANG DIGABUNGKAN DENGAN PELBAGAI JENIS PATI MINYAK

Oleh

MOHAMAD OMAR SYAFIQ BIN RAZALI

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Permintaan pembungkusan aktif antibakteria semakin meningkat kerana keperluannya untuk meningkatkan kualiti dan jangka hayat makanan. Tambahan pula, sampah berpunca daripada plastik adalah salah satu faktor kerisauan dunia terhadap kesihatan manusia. Biokomposit telah menarik perhatian para penyelidik, kerana sifatnya yang mesra alam, lestari alam sekitar, dan mempunyai kekuatan yang sesuai. Kanji adalah salah satu alternatif untuk menggantikan filem plastik berasaskan petroleum. Terdapat beberapa faktor yang membatasi dalam menggunakan kanji, iaitu rapuh dan mudah pecah. Pemplastik ditambahkan ke dalam bancuhan pembuatan filem berasaskan kanji untuk membantu mengatasi sifat rapuh dan dan mudah pecah tersebut. Selain itu, pati minyak kayu manis ditambah dan digabungkan sebagai agen antibakteria dalam filem biokomposit. Untuk menghasilkan pembungkusan aktif antibakteria yang berprestasi tinggi, pati minyak kayu manis yang digabungkan ke dalam komposit biopolimer kanji/nanoselulosa enau telah dibuat menggunakan kaedah penuangan cairan akan diuji terhadap sifat filem bionanokomposit. Pencirian filem bionanokomposit dilakukan adalah terdiri daripada mikroskopi elektron pengimbasan emisi lapangan (FESEM), analisis gravimetrik termal (TGA), spektroskopi inframerah transformasi Fourier (FTIR), ketumpatan, aktiviti antibakteria, kekuatan lekatan termal dan kekuatan untuk mengoyak. Kesan daripada pelbagai jenis pemplastik dengan isi padu yang berbeza (gliserol, sorbitol dan (gliserol + sorbitol) pada 0 – 4.5 wt %) terhadap sifat mekanikal, fizikal, penghalang air dan biodegradasi telah dinilai. Keputusan menunjukkan penyerapan air meningkat bergantung kepada kepekatan pemplastik. Selain itu, kebolehtelapan wap air (WVP) dan kelarutan menunjukkan arah aliran yang meningkat bergantung kepada perbezaan kadar kepekatan pemplastik yang digunakan dalam biopolimer kerana kandungan air yang tinggi. Kandungan air untuk sampel G-, S- dan GS-plastik menunjukkan peningkatan dari (14.86-30.30%), (12.36-15.00%) dan (13.58-35.04%) bergantung kepada kepekatannya. Peningkatan kandungan pemplastik mengakibatkan peningkatan ketebalan filem dan kandungan lembapan. Sebaliknya, peningkatan kepekatan pemplastik mengakibatkan penurunan kepadatan filem plastik. Tiga jenis pati minyak daripada kayu manis, kayu putih dan rosemari diuji untuk

mengetahui aktiviti antibakteria dan pati minyak kayu manis telah menunjukkan zon penghadangan tertinggi. Pati minyak kayu manis telah dipilih untuk digunakan sebagai agen antibakteria dalam filem bionanokomposit. Pelbagai kepekatan pati minyak kayu manis (0 - 2.0 wt %) dinilai terhadap aktiviti mekanikal, morfologi, mudah terbakar, termal dan antibakteria. Keberkesanan pembungkusan antibakteria ditentukan oleh diameter zon penghadangan; lebih lebar diameter, lebih sensitif bakteria kepada pembungkusan. Ujian antibakteria dilakukan dengan kaedah ADM untuk menilai kesan penghadangan bagi filem terhadap bakteria gram positif, bakteria gram negatif dan yis. Keputusan menunjukkan bahawa kandungan pati minyak yang paling tinggi (2.0 wt %) di dalam kandungan filem menghasilkan zon penghadangan tertingggi iaitu, 7.85, 6.63, dan 7.43 mm untuk *B. subtilis*, *S. aereus* dan *E. coli*. Dalam keadaan vakum, analisis imbasan mikroskopi electron bagi filem yang mengandungi pati minyak kayu manis menunjukkan kemunculan bintik-bintik mikro-poros sebagai lubang mikro-berpori kerana berlakunya penyejatan separa pada permukaan fraktur krio. Peningkatan kepekatan pati minyak kayu manis menghasilkan tren peningkatan bagi bilangan dan saiz lubang berliang mikro. Peningkatan ketara dilihat pada kestabilan terma dengan penambahan pati minyak kayu manis. Kestabilan terma bagi komposit biopolimer CEO/SPNCC/SPS meningkat dengan ketara bergantung kepada peningkatan kandungan CEO (sampel 5, T_{max}=296.25°C) berbanding dengan (sampel 1, T_{max}=289.18°C) Mikrograf FESEM menunjukkan filem yang agak baik dengan ciri-ciri yang sedikit kekuningan dan lut sinar. Secara keseluruhan, filem bionanokomposit yang diperbuat daripada gabungan kanji/nanoselulosa enau serta ditambah dengan pati minyak kayu manis berpotensi untuk meningkatkan kesesuaiannya dalam aplikasi pembungkusan makanan.

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Jazakumullahu Khairan!

This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfillment of the requirement for the degree of Doctor of Philosophy. The members of the Supervisory Committee were as follows:

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Declaration by Members of Supervisory Committee

This is to confirm that:

- the research conducted and the writing of this thesis was under our supervision;
- supervision responsibilities as stated in the Universiti Putra Malaysia (Graduate Studies) Rules 2003 (Revision 2012-2013) are adhered to.

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LIST OF SYMBOLS

A	Area of film exposed (m^2)
cm^3	Centimeter cube
^{o}	Degree
^oC	Degree celcius
ρ	Density
t	Duration for permeation (s)
W_i	Initial weight
W_f	Final weight
d	Film thickness (mm)
g	Gram
h	Hour
mm	millimeter
MPa	Mega pascal
T_{Onset}	Onset temperature
P	Water vapor partial pressure across the films (Pa)
%	Percentage
M_f	Mass final
M_i	Mass initial
W_L	Weight loss
Wo	Weight before being buries
Wt	Weight after being buried
wt %	Weight percentage
T_{max}	Temperature max

LIST OF ABBREVIATIONS

ADM	Agar disc method
ANOVA	Analysis of Variance
ASTM	American Society for Testing and Materials
DDM	Disk diffusion method
DSC	Differential Scanning Calorimetry
DTG	Derivative thermogravimetry
EN ISO	European Union-International Organisation for Standardisation
EO	Essential oil
EOCs	Essential oil constituents
FESEM	Field scanning electron microscope
FTIR	Fourier Transform Infrared
IEC	International Electrotechnical Commission
MIC	Minimum inhibitory concentration
PVA	polyvinyl alcohol
SEM	Scanning Electron Microscopy
SPF	Sugar palm fibre
SPNCC	Sugar palm nanocrystalline celluloses
SPS	Sugar palm starch
TGA	Thermal-gravimetric analysis
TPS	Thermoplastic Starch
TS	Tensile strength
WA	Water absorption
WC	Water content
WS	Water solubility
WVP	Water vapour permeability

CHAPTER 1

INTRODUCTION

1.1 Background

Food quality and freshness products may change by numerous unwanted physical and chemical properties change before, during or after processing stages. The biodegradable film keeps food quality and an environmentally friendly packaging (Ilyas et al, (2018a); Ilyas et al., (2018b); Resianingrum et al. (2016); Sanyang et al., (2018)). Packaging plays an important role in ensuring food safety and quality, and the development of active packaging, especially antibacterial packaging, enables actively inhibiting/killing the microorganisms causing food spoilage and thus extending the product's shelf life. Antibacterial active packaging is one of the favourable concepts that can prolong the shelf life of food by inhibiting the growth of microbial. Starch-based polymers are potential as feedstock for the huge scale manufacture of bio-plastic film.

The essential oil has a lengthy history of use as a current antibacterial Cox et al. (2000). In current times, it has enlarged its reputation as a harmless, natural and active antibacterial substance. This has directed to a reappearance in popularity and presently it is incorporated as the principal antibacterial or as a natural preservative in many pharmaceutical and cosmetic products proposed for external use Ishak et al., (2011). Test of *Escherichia coli* cells or other microbes using electron microscopy after contact with essential oil discovered a damage of cellular electron-dense material and coagulation of cytoplasmic parts, although it was apparent that these effects were secondary actions that happened after cell death Cox et al. (2000). In addition, various antibacterial additive type of essential oils (EO) and concentration were implemented into the nanocomposite films to defeat microbial activities in the films. An edible film with antibacterial characteristics has potential to prevent contamination in food product Resianingrum et al., (2016). The researcher targeted small amounts of EO used to minimise costs while having higher mechanical properties that allow the film to maintain its structure for a long time. Antibacterial activity was observed to be more active against the bacteria tested than the control film to extend product shelf life (Restrepo et al., 2018). Thus, biocomposite polymer based materials for food packaging is explored to address environmental pollution from non-biodegradable food packaging materials. The main driving factor for the commercialization of biodegradable plastics in many countries is government laws related to environmentally products.

Starch is not meltable in its pure form and thus cannot be processed as thermoplastic. Hence, products made from native starches easily crumble into bits when dried in ambient conditions. The process of curing the brittleness of native starches is known as plasticization of starch. Therefore, plasticization is repeatedly employed for the modification of starches to further upgrade their processability and other properties. Plasticizers are non-volatile compounds with low molecular weight. The ultimate role of

plasticizers is to enhance the flexibility and processibility of starch by reducing strong intermolecular interactions between starch molecules Sanyang et al. (2015).

1.2 Problem Statements

Recently many scientists and polymer engineers focus on developing sustainable eco-friendly packaging based on renewable natural biopolymers. When looking at the issue from a bigger picture, i.e. the whole food chain, packaging plays a key role in reducing food losses. Biodegradable films for packaging still have been reported not to have antibacterial agent. Such drawback strongly limits their wide application, especially for food packaging purposes. This is because foods served on our tables are subjected to various risks, including physical damage, physicochemical deterioration, microbial spoilage, and particularly, contamination/cross-contamination of pathogens could cause severe threats to human health. It is believed that the amount of packaging wastes generated in industrialized countries in a single day is sufficient to fill up a space equivalent to the Sears Tower, Chicago, USA, which was once the tallest building in the world Rosa et al. (2010). To minimize food losses, a number of practical measures have been proposed to consumers, for example, planning before shopping, avoiding the temptation of special offers coming with large quantity packs, decreasing the cooking/warming proportions in one's diet Günkaya & Banar, (2016).

Sugar palm is a multipurpose tree found in most South East Asian countries and it is regarded as a potential source of natural fibre and biopolymer. However, such a bio-source is still underutilized and, thus, very limited studies have been reported related to their development as a green packaging material. Hence, sugar palm starch (SPS) incorporated with cinnamon essential oil was modified and employed in the current study to develop fully biodegradable films and nanocomposite films as environmentally friendly packaging material for the food industry. This study focused on the SPS based films incorporated with cinnamon essential oil for food packaging industries to prolong the shelf life of products and reduce the risk of pathogenic bacteria growth on food surfaces. Biodegradable composite films with antibacterial properties can be made up of three groups of substances: biopolymers (polysaccharides, proteins, fats), additives (plasticizers, emulsifiers), and synthetic or natural antibacterial. The introduction of essential oils into food packaging films form strong prevention of bacterial and fungi properties, positively affecting the storage of food products. The reinforcement of natural biopolymers with nanocellulose has been shown to be beneficial for reducing water transmission properties of biodegradable film.

The major challenges for the development of starches as packaging films are the shortcomings related to brittleness, processability, high moisture sensitivity, quick retrogradation, poor mechanical and barrier properties. Pure sugar palm starch (SPS) cannot be directly used as thermoplastic materials for film preparation without addition of plasticizer. It is like most other biopolymers, which is hydrophilic in nature due to either their hydroxyl or polar groups. The addition of different types and concentrations of plasticizer(s) into the starch matrix and the reinforcement of nanocellulose fibre would help to transform native SPS into high performance thermoplastic starch for food packaging application.

1.3 Research objectives

The principal aim of this study is to develop and characterize totally biodegradable and sustainable materials based on natural resources to be utilized in antibacterial active packaging applications The research objectives can be specified into:

1. To determine the antibacterial activity, physical, mechanical and barrier properties of sugar palm based nanocellulose/starch biocomposite films incorporated with different concentrations of cinnamon essential oil based on fixed amount of plasticizer and nanocellulose.

2. To evaluate the thermal, morphological and flammability properties of sugar palm based nanocellulose/starch biocomposite films incorporated with different concentrations of cinnamon essential oil based on fixed amount of plasticizer and nanocellulose.

3. To characterize the effect of plasticizer type and concentration on selected properties of sugar palm nanocellulose reinforced sugar palm starch composites incorporated with cinnamon essential oil.

4. To develop and characterize the effect of sugar palm nanocellulose/ essential oil (SPNCC/EO) loading on the physical, water barrier properties, biodegradability and morphological properties of sugar palm nanocrystalline cellulose reinforced sugar palm starch incorporated with cinnamon EO composites for packaging purposes.

1.4 Significance of study

1. The current study's findings are likely to contribute to the development of high performance antibacterial biodegradable polymers generated from sugar palm starch reinforced nanocellulose incorporated cinnamon EO for food packaging applications.

2. The development of biodegradable antibacterial polymers with better qualities in this work is intended to aid in addressing environmental issues related to replacement materials for petroleum-based polymers.

3. In term of waste management issue, this research provides platform for utilizing wastes from agricultural products into nanofibres and biopolymers, which these biocomposites are low-cost, biodegradable, environmentally friendly, and renewable.

4. The successful development of such green materials from sugar palm tree would provide opportunities to improve the standard of living of the sugar palm tree farmers in Malaysia by generating non-food source of economic development for rural areas.

5. This research may also add to the effort to uncover the potential of using sugar palm starch in developing green products with antibacterial properties; else, such abundant bioresources may be underutilized.

1.5 Scope of Study

In this study, sugar palm fibre (SPF) and sugar palm starch (SPS) were manually extracted from the sugar palm tree. Then, the sugar palm cellulose (SPC) were extracted from sugar palm fibres and the yield was optimized using delignification and mercerization process. The best properties of the obtained cellulose were subsequently hydrolyzed (sulphuric acid solution) and mechanically homogenised (high pressurise homogenization) to isolate sugar palm nanocrystalline cellulose (SPNCC).

Thermoplastic sugar palm starch was developed by using solution casting method with the addition of glycerol, sorbitol and essential oil. The characterized biocomposite film of SPNCC and cinnamon EO were used as reinforcement for SPS films to improve the matrix and antibacterial properties. The optimal loading ratio of the obtained composite films was then selected based on the physical and tensile properties supported by morphological, structural, antibacterial properties and thermal properties. Thus, the effect of various concentration of cinnamon EO (0.8, 1.2, 1.6, 2.0 wt %) also types (sorbitol, glycerol and sorbitol + glycerol) and concentrations (1.5, 3.0 and 4.5 wt %) of plasticizer on the physical, mechanical, water barrier, thermal and biodegradable properties of SPS based composite films was carried out. The criteria for selection were mainly based on the best physical and tensile properties as well as good antibacterial activity.

1.6 Structure of thesis

The structure of this thesis is in accordance with the alternative thesis format of Universiti Putra Malaysia which is based on the publications of this study. Each research chapter represents a separate study that has its own: 'Introduction', 'Materials and method', 'Results and discussion', and 'Conclusions'. The details structure of the thesis are presented below.

Chapter 1

The concerns that prompted this research, as well as the research objectives, were clearly stated in this chapter. This chapter further elaborated on the significance of this work and the scope of study.

Chapter 2

This chapter offers a comprehensive literature review on previous research works related to the current study. Furthermore, the research gaps identified throughout the review were clarified inside this chapter.

Chapter 3

This chapter describes the methods utilised in this study for material preparation, testing procedures, and data collection.

Chapter 4

This chapter presents the first article entitled "Antibacterial activity, physical, mechanical and barrier properties of sugar palm based nanocellulose/starch biocomposite films incorporated with cinnamon essential oil". In this article, the antibacterial activity of biocomposite were investigated.

Chapter 5

This chapter presents the second article entitled "Thermal, flammability, and morphological properties of nanocellulose fibre reinforced starch biopolymer composites incorporated with cinnamon essential oil". In this article, the thermal, flammability, and morphological properties were investigated.

Chapter 6

This chapter present the third article entitled "Effect of plasticiser on properties of sugar palm nanocellulose/cinnamon essential oil reinforced starch biocomposite films". In this article, the effect of various plasticizer types and concentrations were investigated.

Chapter 7

This chapter presents the forth article entitled "Water barrier and biodegradable properties of cinnamon essential oil/sugar palm nanocellulose/starch biopolymer composites". In this article, the biodegradable characteristics of the biocomposite film were investigated.

Chapter 8

This chapter covers the overall findings and conclusion of the study, as well as future recommendations for improving the study.

References

Ahmad, M., Benjakul, S., Prodpran, T., & Agustini, T. W. (2012). Physico-mechanical and antimicrobial properties of gelatin film from the skin of unicorn leatherjacket incorporated with essential oils. *Food Hydrocolloids*, *28*(1), 189–199. https://doi.org/10.1016/j.foodhyd.2011.12.003

Ahmad, M., Hani, N. M., Nirmal, N. P., Fazial, F. F., Mohtar, N. F., & Romli, S. R. (2015). Optical and thermo-mechanical properties of composite films based on fish gelatin/rice flour fabricated by casting technique. *Progress in Organic Coatings*, *84*, 115–127. https://doi.org/10.1016/j.porgcoat.2015.02.016

Altiok, D., Altiok, E., & Tihminlioglu, F. (2010). Physical, antibacterial and antioxidant properties of chitosan films incorporated with thyme oil for potential wound healing applications. *Journal of Materials Science: Materials in Medicine*, *21*(7), 2227–2236. https://doi.org/10.1007/s10856-010-4065-x

ASTM 570. (1998). Standard Test Method for Water Absorption of Plastics. In *ASTM International*. West Conshohocken, PA.

ASTM D 664. (2002). Standard test method for moisture content of paper and paperboard by oven drying. In *ASTM International*. West Conshohocken, PA.

ASTM D1103. (1977). Method of Test for Alpha-Cellulose in Wood. In *ASTM International*. West Conshohocken, PA.

ASTM D1104. (1978). Method of Test for Holocellulose in Wood. In *ASTM International*. West Conshohocken, PA.

ASTM D882-02. (2002). Standard Test Method for Tensile Properties of Thin Plastic Sheeting. In *ASTM International*. West Conshohocken, PA.

Atikah, M. S. N., Ilyas, R. A., Sapuan, S. M., Ishak, M. R., Zainudin, E. S., Ibrahim, R., Jumaidin, R. (2019). Degradation and physical properties of sugar palm starch / sugar palm nanofibrillated cellulose bionanocomposite. *Polimery*, *64*(10), 27–36. https://doi.org/10.14314/polimery.2019.10.5

Chouhan, S., Sharma, K., & Guleria, S. (2017). Antimicrobial Activity of Some Essential Oils—Present Status and Future Perspectives. *Medicines*, *4*(3), 58. https://doi.org/10.3390/medicines4030058

Dassanayake, R. S., Wansapura, P. T., Tran, P., Hamood, A., & Abidi, N. (2019). Cotton cellulose-CdTe quantum dots composite films with inhibition of biofilm-forming S. aureus. *Fibers*, *7*(6). https://doi.org/10.3390/fib7060057

Han, J. H., & Krochta, J. M. (1999). (1999). Water vapor permeability and wetting properties of whey protein coating on paper. In *Am Soc Agricul Eng* (pp. 1375–1382).

Hoque, M. S., Benjakul, S., & Prodpran, T. (2011). Properties of film from cuttlefish (Sepia pharaonis) skin gelatin incorporated with cinnamon, clove and star anise extracts. *Food Hydrocolloids*, *25*(5), 1085–1097. https://doi.org/10.1016/j.foodhyd.2010.10.005

Ilyas, R. A., Sapuan, S. M., Ibrahim, R., Abral, H., Ishak, M. R., Zainudin, E. S., Jumaidin, R. (2019a). Effect of sugar palm nanofibrillated cellulose concentrations on morphological, mechanical and physical properties of biodegradable films based on agro-waste sugar palm (Arenga pinnata (Wurmb.) Merr) starch. *Journal of Materials Research and Technology*, *8*(5), 4819–4830. https://doi.org/10.1016/j.jmrt.2019.08.028

Ilyas, R. A., Sapuan, S. M., Ibrahim, R., Abral, H., Ishak, M. R., Zainudin, E. S., Jumaidin, R. (2019b). Effect of sugar palm nanofibrillated celluloseconcentrations on morphological, mechanical andphysical properties of biodegradable films basedon agro-waste sugar palm (Arenga pinnata (Wurmb.) Merr) starch. *Journal of Materials Research and Technology*, *8*(5), 4819–4830. https://doi.org/10.1016/j.jmrt.2019.08.028

Ilyas, R. A., Sapuan, S. M., & Ishak, M. R. (2018). Isolation and characterization of nanocrystalline cellulose from sugar palm fibres (Arenga Pinnata). *Carbohydrate Polymers*, *181*(November 2017), 1038–1051. https://doi.org/10.1016/j.carbpol.2017.11.045

Ilyas, R. A., Sapuan, S. M., Ishak, M. R., & Zainudin, E. S. (2018). Development and characterization of sugar palm nanocrystalline cellulose reinforced sugar palm starch bionanocomposites. *Carbohydrate Polymers*, *202*(September), 186–202. https://doi.org/10.1016/j.carbpol.2018.09.002

Ilyas, R. A., Sapuan, S. M., Ishak, M. R., Zainudin, E. S., & Products, F. (2018). Sugar Palm Nanofibrillated Cellulose Fibre Reinforced Sugar Palm Starch Nanocomposite . Part 1 : Morphological , Mechanical and Physical Properties, (September), 1–30. https://doi.org/10.20944/preprints201809.0140.v1

Jamróz, E., Juszczak, L., & Kucharek, M. (2018). Investigation of the physical properties, antioxidant and antimicrobial activity of ternary potato starch-furcellaran-gelatin films incorporated with lavender essential oil. *International Journal of Biological Macromolecules*, *114*(2017), 1094–1101. https://doi.org/10.1016/j.ijbiomac.2018.04.014

Khalid Haddi, Lêda R.A. Faroni, and E. E. O. (2017). Cinnamon Oil. *Green Pesticides Handbook Essential Oils for Pest Control*, 117–150. https://doi.org/10.32388/AGZ578

Li, S., Yi, J., Yu, X., Wang, Z., & Wang, L. (2020). Preparation and characterization of pullulan derivative/chitosan composite film for potential antimicrobial

applications. *International Journal of Biological Macromolecules*, *148*, 258–264. https://doi.org/10.1016/j.ijbiomac.2020.01.08

Liu, X., Xu, Y., Zhan, X., Xie, W., Yang, X., Cui, S. W., & Xia, W. (2020). Development and properties of new kojic acid and chitosan composite biodegradable films for active packaging materials. *International Journal of Biological Macromolecules*, *144*, 483–490. https://doi.org/10.1016/j.ijbiomac.2019.12.126

Lu, Y., Weng, L., & Cao, X. (2005). Biocomposites of plasticized starch reinforced with cellulose crystallites from cottonseed linter. *Macromolecular Bioscience*, *5*(11), 1101–1107. https://doi.org/10.1002/mabi.200500094

Luque-Alcaraz, A. G., Cortez-Rocha, M. O., Velázquez-Contreras, C. A., Acosta-Silva, A. L., Santacruz-Ortega, H. D. C., Burgos-Hernández, A., Plascencia-Jatomea, M. (2016). Enhanced Antifungal Effect of Chitosan/Pepper Tree (Schinus molle) Essential Oil Bionanocomposites on the Viability of Aspergillus parasiticus Spores. *Journal of Nanomaterials*, *2016*. https://doi.org/10.1155/2016/6060137

Mousavi Khaneghah, A., Hashemi, S. M. B., & Limbo, S. (2018). Antimicrobial agents and packaging systems in antimicrobial active food packaging: An overview of approaches and interactions. *Food and Bioproducts Processing*, *111*, 1–19. https://doi.org/10.1016/j.fbp.2018.05.001

N. Jain, K. S. Somvanshi, P. C. G. and V. K. S. (2019). Mechanical characterization and machining performance evaluation of rice husk/epoxy an agricultural waste based composite material. *Journal of the Mechanical Behavior of Materials*, *28*(1), 29–38.

Nazzaro, F., Fratianni, F., De Martino, L., Coppola, R., & De Feo, V. (2013). Effect of essential oils on pathogenic bacteria. *Pharmaceuticals*, *6*(12), 1451–1474. https://doi.org/10.3390/ph6121451

Nguyen, V., Ohemeng, K. A., & Barrett, J. F. (1995). Antimicrobial Resistance: A Crisis in Health Care. *Plenum Press*, 59–60.

Nielsen, P. V., & Rios, R. (2000). Inhibition of fungal growth on bread by volatile components from spices and herbs, and the possible application in active packaging, with special emphasis on mustard essential oil. *International Journal of Food Microbiology*, *60*(2–3), 219–229. https://doi.org/10.1016/S0168-1605(00)00343-3

Ojagh, S. M., Rezaei, M., Razavi, S. H., & Hosseini, S. M. H. (2010). Development and evaluation of a novel biodegradable film made from chitosan and cinnamon essential oil with low affinity toward water. *Food Chemistry*, *122*(1), 161–166. https://doi.org/10.1016/j.foodchem.2010.02.033

Oussalah, M., Caillet, S., Saucier, L., & Lacroix, M. (2006). Antimicrobial effects of selected plant essential oils on the growth of a Pseudomonas putida strain isolated from meat. *Meat Science*, *73*(2), 236–244. https://doi.org/10.1016/j.meatsci.2005.11.019

Oussalah, M., Caillet, S., Saucier, L., & Lacroix, M. (2007). Inhibitory effects of selected plant essential oils on the growth of four pathogenic bacteria: E. coli O157:H7, Salmonella Typhimurium, Staphylococcus aureus and Listeria monocytogenes. *Food Control*, *18*(5), 414–420. https://doi.org/10.1016/j.foodcont.2005.11.009

Peng, Y., & Li, Y. (2014). Combined effects of two kinds of essential oils on physical, mechanical and structural properties of chitosan films. *Food Hydrocolloids*, *36*, 287–293. https://doi.org/10.1016/j.foodhyd.2013.10.013

Rattaya, S., Benjakul, S., & Prodpran, T. (2009). Properties of fish skin gelatin film incorporated with seaweed extract. *Journal of Food Engineering*, *95*(1), 151–157. https://doi.org/10.1016/j.jfoodeng.2009.04.022

Raucci, G. L., Lanna, R., Silveira, F. da, & Capitani, H. D. (2019). Developtment of wheater derivatives: evidence from the Brazilian soybean market. *Italian Review of Agricultural Economics*, *74*, 17–28. https://doi.org/10.13128/rea-10850

Sahari, J., Sapuan, S. M., Zainudin, E. S., & Maleque, M. A. (2012). Sugar palm tree: A versatile plant and novel source for biofibres, biomatrices, and biocomposites. *Polymers from Renewable Resources*, *3*(2), 61–78. https://doi.org/10.1016/j.matdes.2013.01.048

Sahari, J., Sapuan, S. M., Zainudin, E. S., & Maleque, M. A. (2013a). Effect of water absorption on mechanical properties of sugar palm fibre reinforced sugar palm starch (SPF/SPS) biocomposites. *Journal of Biobased Materials and Bioenergy*. https://doi.org/10.1166/jbmb.2013.1267

Sahari, J., Sapuan, S. M., Zainudin, E. S., & Maleque, M. A. (2013b). Thermo-mechanical behaviors of thermoplastic starch derived from sugar palm tree (Arenga pinnata). *Carbohydrate Polymers*, *92*(2), 1711–1716. https://doi.org/10.1016/j.carbpol.2012.11.031

Salzer, U. J., & Furia, T. E. (1977). The Analysis of Essential Oils and Extracts (Oleoresins) from Seasonings - A Critical Review. *C R C Critical Reviews in Food Science and Nutrition*, *9*(4), 345–373. https://doi.org/10.1080/10408397709527239

Sánchez-González, L., González-Martínez, C., Chiralt, A., & Cháfer, M. (2010). Physical and antimicrobial properties of chitosan-tea tree essential oil composite films. *Journal of Food Engineering*, *98*(4), 443–452. https://doi.org/10.1016/j.jfoodeng.2010.01.026

Sanyang, M. L., Sapuan, S. M., Jawaid, M., Ishak, M. R., & Sahari, J. (2016a). Development and characterization of sugar palm starch and poly(lactic acid) bilayer films. *Carbohydrate Polymers*, *146*(4), 36–45. https://doi.org/10.1016/j.carbpol.2016.03.051

Sanyang, M. L., Sapuan, S. M., Jawaid, M., Ishak, M. R., & Sahari, J. (2016b). Effect of sugar palm-derived cellulose reinforcement on the mechanical and water barrier properties of sugar palm starch biocomposite films. *BioResources*, *11*(2), 4134–4145. https://doi.org/10.15376/biores.11.2.4134-4145

Shankaranarayana, M. L., Raghavan, B., Abraham, K. O., & Natarajan, C. P. (1981). Titrimetric Determination of Total Aldehydes in Cinnamon Bark and Leaf Oils Using Chloramine-T Reagent. *Journal of Food Quality*, *4*(1), 35–41. https://doi.org/10.1111/j.1745-4557.1981.tb00710.x

Song, X., Zuo, G., & Chen, F. (2018a). Effect of essential oil and surfactant on the physical and antimicrobial properties of corn and wheat starch films. *International Journal of Biological Macromolecules*, *107*(PartA), 1302–1309. https://doi.org/10.1016/j.ijbiomac.2017.09.114

Song, X., Zuo, G., & Chen, F. (2018b). Effect of essential oil and surfactant on the physical and antimicrobial properties of corn and wheat starch films. *International Journal of Biological Macromolecules*, *107*, 1302–1309. https://doi.org/10.1016/j.ijbiomac.2017.09.114

Souza, A. C., Goto, G. E. O., Mainardi, J. A., Coelho, A. C. V., & Tadini, C. C. (2013). Cassava starch composite films incorporated with cinnamon essential oil: Antimicrobial activity, microstructure, mechanical and barrier properties. *LWT - Food Science and Technology*, *54*(2), 346–352. https://doi.org/10.1016/j.lwt.2013.06.017

Tongnuanchan, P., & Benjakul, S. (2014). Essential Oils: Extraction, Bioactivities, and Their Uses for Food Preservation. *Journal of Food Science*, *79*(7), 1231–1249. https://doi.org/10.1111/1750-3841.12492

Vilay, V., Mariatti, M., Mat Taib, R., & Todo, M. (2008). Effect of fiber surface treatment and fiber loading on the properties of bagasse fiber-reinforced unsaturated polyester composites. *Composites Science and Technology*, *68*(3–4), 631–638. https://doi.org/10.1016/j.compscitech.2007.10.005

Xu, Y. X., Kim, K. M., Hanna, M. A., & Nag, D. (2005). Chitosan-starch composite film: Preparation and characterization. *Industrial Crops and Products*, *21*(2), 185–192. https://doi.org/10.1016/j.indcrop.2004.03.002

References

Acosta, S., Jiménez, A., Cháfer, M., González-Martínez, C., & Chiralt, A. (2015). Physical properties and stability of starch-gelatin based films as affected by the addition of esters of fatty acids. *Food Hydrocolloids*, *49*, 135–143. https://doi.org/10.1016/j.foodhyd.2015.03.015

Aitboulahsen, M., El Galiou, O., Laglaoui, A., Bakkali, M., & Hassani Zerrouk, M. (2020). Effect of plasticizer type and essential oils on mechanical, physicochemical, and antimicrobial characteristics of gelatin, starch, and pectin-based films. *Journal of Food Processing and Preservation*, *44*(6), 1–10. https://doi.org/10.1111/jfpp.14480

Atarés, L., & Chiralt, A. (2016). Essential oils as additives in biodegradable films and coatings for active food packaging. *Trends in Food Science and Technology*, *48*, 51–62. https://doi.org/10.1016/j.tifs.2015.12.001

Atikah, M. S. N., Ilyas, R. A., Sapuan, S. M., Ishak, M. R., Zainudin, E. S., Ibrahim, R., Jumaidin, R. (2019). Degradation and physical properties of sugar palm starch / sugar palm nanofibrillated cellulose bionanocomposite. *Polimery*, *64*(10), 27–36. https://doi.org/10.14314/polimery.2019.10.5

Avila-Sosa, R., Hernández-Zamoran, E., López-Mendoza, I., Palou, E., Munguía, M. T. J., Nevárez-Moorillón, G. V., & López-Malo, A. (2010). Fungal inactivation by mexican oregano (lippia berlandieri schauer) essential oil added to amaranth, chitosan, or starch edible films. *Journal of Food Science*, *75*(3), M127–M133. https://doi.org/10.1111/j.1750-3841.2010.01524.x

Bhavaniramya, S., Vishnupriya, S., Al-Aboody, M. S., Vijayakumar, R., & Baskaran, D. (2019). Role of essential oils in food safety: Antimicrobial and antioxidant applications. *Grain & Oil Science and Technology*, 49–55. https://doi.org/10.1016/j.gaost.2019.03.001

Cano, A., Cháfer, M., Chiralt, A., & González-Martínez, C. (2015). Physical and Antimicrobial Properties of Starch-PVA Blend Films as Affected by the Incorporation of Natural Antimicrobial Agents. *Foods*, *5*(1), 3. https://doi.org/10.3390/foods5010003

Cardoso-Ugarte, G. A., López-Malo, A., & Sosa-Morales, M. E. (2016). Cinnamon (Cinnamomum zeylanicum) essential oils. *Essential Oils in Food Preservation, Flavor and Safety*, 339–347. https://doi.org/10.1016/B978-0-12-416641-7.00038-9

Choi, W. S., Singh, S., & Lee, Y. S. (2016). Characterization of edible film containing essential oils in hydroxypropyl methylcellulose and its effect on quality attributes of 'Formosa' plum (Prunus salicina L.). *LWT*, *70*, 213–222. https://doi.org/10.1016/j.lwt.2016.02.036

Dashipour, A., Razavilar, V., Hosseini, H., Shojaee-Aliabadi, S., German, J. B., Ghanati, K., Khaksar, R. (2015). Antioxidant and antimicrobial carboxymethyl

cellulose films containing Zataria multiflora essential oil. *International Journal of Biological Macromolecules*, *72*, 606–613. https://doi.org/10.1016/j.ijbiomac.2014.09.006

Donsì, F., & Ferrari, G. (2016). Essential oil nanoemulsions as antimicrobial agents in food. *Journal of Biotechnology*, *233*, 106–120. https://doi.org/10.1016/j.jbiotec.2016.07.005

El Atki, Y., Aouam, I., El Kamari, F., Taroq, A., Nayme, K., Timinouni, M., … Abdellaoui, A. (2019). Antibacterial activity of cinnamon essential oils and their synergistic potential with antibiotics. *Journal of Advanced Pharmaceutical Technology and Research*, *10*(2), 63–67. https://doi.org/10.4103/japtr.JAPTR_366_18

Hazrol, M. D., Sapuan, S. M., Ilyas, R. A., Othman, M. L., & Sherwani, S. F. K. (2020). Electrical properties of sugar palm nanocrystalline cellulose reinforced sugar palm starch nanocomposites. *Polimery*, *65*(05), 363–370. https://doi.org/10.14314/polimery.2020.5.4

Hosseini, S. F., Rezaei, M., Zandi, M., & Farahmandghavi, F. (2015). Bio-based composite edible films containing Origanum vulgare L. essential oil. *Industrial Crops and Products*, *67*, 403–413. https://doi.org/10.1016/j.indcrop.2015.01.062

Hosseini, S. F., Rezaei, M., Zandi, M., & Farahmandghavi, F. (2016). Development of bioactive fish gelatin/chitosan nanoparticles composite films with antimicrobial properties. *Food Chemistry*, *194*, 1266–1274. https://doi.org/10.1016/j.foodchem.2015.09.004

Iamareerat, B., Singh, M., Sadiq, M. B., & Anal, A. K. (2018). Reinforced cassava starch based edible film incorporated with essential oil and sodium bentonite nanoclay as food packaging material. *Journal of Food Science and Technology*, *55*(5), 1953–1959. https://doi.org/10.1007/s13197-018-3100-7

Ilyas, R. A., Sapuan, S. M., Atiqah, A., Ibrahim, R., Abral, H., Ishak, M. R., … Ya, H. (2020). Sugar palm (Arenga pinnata [Wurmb .] Merr) starch films containing sugar palm nanofibrillated cellulose as reinforcement: Water barrier properties. *Polymer Composites*, *41*(2), 459–467. https://doi.org/10.1002/pc.25379

Ilyas, R. A., Sapuan, S. M., Ibrahim, R., Abral, H., Ishak, M. R., Zainudin, E. S., … Jumaidin, R. (2019). Effect of sugar palm nanofibrillated celluloseconcentrations on morphological, mechanical andphysical properties of biodegradable films basedon agro-waste sugar palm (Arenga pinnata(Wurmb.) Merr) starch. *Journal of Materials Research and Technology*, *8*(5), 4819–4830. https://doi.org/10.1016/j.jmrt.2019.08.028

Ilyas, R. A., Sapuan, S. M., & Ishak, M. R. (2018). Isolation and characterization of nanocrystalline cellulose from sugar palm fibres (Arenga Pinnata). *Carbohydrate Polymers*, *181*(November 2017), 1038–1051. https://doi.org/10.1016/j.carbpol.2017.11.045

Ilyas, R. A., Sapuan, S. M., Ishak, M. R., & Zainudin, E. S. (2018a). Development and characterization of sugar palm nanocrystalline cellulose reinforced sugar palm starch bionanocomposites. *Carbohydrate Polymers*, *202*(September), 186–202. https://doi.org/10.1016/j.carbpol.2018.09.002

Ilyas, R. A., Sapuan, S. M., Ishak, M. R., & Zainudin, E. S. (2018b). Water transport properties of bio-nanocomposites reinforced by sugar palm (*Arenga Pinnata*) nanofibrillated cellulose. *Journal of Advanced Research in Fluid Mechanics and Thermal Sciences Journal*, *51*(2), 234–246.

Ilyas, R., Sapuan, S., Atikah, M., Asyraf, M., Rafiqah, S. A., Aisyah, H., Norrrahim, M. (2020). Effect of hydrolysis time on the morphological, physical, chemical, and thermal behavior of sugar palm nanocrystalline cellulose (*Arenga pinnata (Wurmb.) Merr*). *Textile Research Journal*, 004051752093239. https://doi.org/10.1177/0040517520932393

Ilyas, R.A., Sapuan, S. M., Ibrahim, R., Abral, H., Ishak, M. R., Zainudin, E. S., Jumaidin, R. (2019a). Effect of sugar palm nanofibrillated cellulose concentrations on morphological, mechanical and physical properties of biodegradable films based on agro-waste sugar palm (Arenga pinnata (Wurmb.) Merr) starch. *Journal of Materials Research and Technology*, *8*(5), 4819–4830. https://doi.org/10.1016/j.jmrt.2019.08.028

Ilyas, R.A., Sapuan, S. M., Ishak, M. R., & Zainudin, E. S. (2018). Sugar palm nanofibrillated cellulose (*Arenga pinnata (Wurmb.) Merr*): Effect of cycles on their yield, physic-chemical, morphological and thermal behavior. *International Journal of Biological Macromolecules*, *123*, 379–388. https://doi.org/10.1016/j.ijbiomac.2018.11.124

Ilyas, R.A., Sapuan, S. M., Ishak, M. R., Zainudin, E. S., & Atikah, M. S. N. (2018a). Characterization of Sugar Palm Nanocellulose and Its Potential for Reinforcement with a Starch-Based Composite. In *Sugar Palm Biofibers, Biopolymers, & Biocomposites* (1st ed., pp. 190–212). Boca Raton: CRC Press/Taylor & Francis Group.

Ilyas, R.A., Sapuan, S. M., Kadier, A., Kalil, M. S., Ibrahim, R., Atikah, M. S. N., Ibrahim, M. I. J. (2020). Properties and Characterization of PLA, PHA, and Other Types of Biopolymer Composites. In F. Al-Oqla & S. M. Sapuan (Eds.), *Advanced Processing, Properties, and Applications of Starch and Other Bio-Based Polymers* (1st ed., pp. 111–138). Elsevier. https://doi.org/10.1016/B978-0-12-819661-8.00008-1

Ilyas, R.A., Sapuan, S. M., Kadier, A., Krishnan, S., Atikah, M. S. N., Ibrahim, R., Hazrol, M. D. (2020). Mechanical Testing of Sugar Palm Fiber Reinforced Sugar Palm Biopolymer Composites. In F. Al-Oqla & S. M. Sapuan (Eds.), *Advanced Processing, Properties, and Applications of Starch and Other Bio-Based Polymers* (1st ed., pp. 89–110). Elsevier. https://doi.org/10.1016/B978-0-12-819661-8.00007-X

Ilyas, R A, Sapuan, S. M., Ibrahim, R., Abral, H., Ishak, M. R., Zainudin, E. S., Jumaidin, R. (2020). Thermal, Biodegradability and Water Barrier Properties of Bio-

Nanocomposites Based on Plasticised Sugar Palm Starch and Nanofibrillated Celluloses from Sugar Palm Fibres. *Journal of Biobased Materials and Bioenergy*, *14*, 1–13. https://doi.org/10.1166/jbmb.2020.1951

Ilyas, Rushdan Ahmad, Sapuan, S. M., Ibrahim, R., Abral, H., Ishak, M. R., Zainudin, E. S., Jumaidin, R. (2019). Sugar palm (*Arenga pinnata (Wurmb.) Merr*) cellulosic fibre hierarchy: a comprehensive approach from macro to nano scale. *Journal of Materials Research and Technology*, *8*(3), 2753–2766. https://doi.org/10.1016/j.jmrt.2019.04.011

Jamróz, E., Juszczak, L., & Kucharek, M. (2018). Investigation of the physical properties, antioxidant and antimicrobial activity of ternary potato starch-furcellaran-gelatin films incorporated with lavender essential oil. *International Journal of Biological Macromolecules*, *114*(2017), 1094–1101. https://doi.org/10.1016/j.ijbiomac.2018.04.014

Ju, J., Chen, X., Xie, Y., Yu, H., Guo, Y., Cheng, Y., Yao, W. (2019). Application of essential oil as a sustained release preparation in food packaging. *Trends in Food Science & Technology*, *92*, 22–32. https://doi.org/10.1016/j.tifs.2019.08.005

Kamaliroosta L. (2012). Extraction of cinnamon essential oil and identification of its chemical compounds. *Journal of Medicinal Plants Research*, *6*(4), 609–614. https://doi.org/10.5897/JMPR11.1215

Kechichian, V., Ditchfield, C., Veiga-Santos, P., & Tadini, C. C. (2010). Natural antimicrobial ingredients incorporated in biodegradable films based on cassava starch. *LWT - Food Science and Technology*, *43*(7), 1088–1094. https://doi.org/10.1016/j.lwt.2010.02.014

Khalid Haddi, Lêda R.A. Faroni, and E. E. O. (2017). Cinnamon Oil. *Green Pesticides Handbook Essential Oils for Pest Control*, 117–150. https://doi.org/10.32388/AGZ578

Lee, C. H., Sapuan, S. M., Ilyas, R. A., Lee, S. H., & Khalina, A. (2020). Development and Processing of PLA, PHA, and Other Biopolymers. In F. Al-Oqla & S. M. Sapuan (Eds.), *Advanced Processing, Properties, and Applications of Starch and Other Bio-Based Polymers* (1st ed., pp. 47–63). Elsevier. https://doi.org/10.1016/B978-0-12-819661-8.00005-6

Liakos, I., Rizzello, L., Scurr, D. J., Pompa, P. P., Bayer, I. S., & Athanassiou, A. (2014). All-natural composite wound dressing films of essential oils encapsulated in sodium alginate with antimicrobial properties. *International Journal of Pharmaceutics*, *463*(2), 137–145. https://doi.org/10.1016/j.ijpharm.2013.10.046

Liang, R., Xu, S., Shoemaker, C. F., Li, Y., Zhong, F., & Huang, Q. (2012). Physical and antimicrobial properties of peppermint oil nanoemulsions. *Journal of Agricultural and Food Chemistry*. https://doi.org/10.1021/jf301129k

Ma, W., Tang, C.-H., Yin, S.-W., Yang, X.-Q., Wang, Q., Liu, F., & Wei, Z.-H. (2012). Characterization of gelatin-based edible films incorporated with olive oil. *Food Research International*, *49*(1), 572–579. https://doi.org/10.1016/j.foodres.2012.07.037

Murbach Teles Andrade, B. F., Nunes Barbosa, L., da Silva Probst, I., & Fernandes Júnior, A. (2014). Antimicrobial activity of essential oils. *Journal of Essential Oil Research*, *26*(1), 34–40. https://doi.org/10.1080/10412905.2013.860409

Mustapha, F. A., Jai, J., Nik Raikhan, N. H., Sharif, Z. I. M., & Yusof, N. M. (2019). Response surface methodology analysis towards biodegradability and antimicrobial activity of biopolymer film containing turmeric oil against Aspergillus niger. *Food Control*, *99*(December 2018), 106–113. https://doi.org/10.1016/j.foodcont.2018.12.042

Nazari, M., Majdi, H., Milani, M., Abbaspour-Ravasjani, S., Hamishehkar, H., & Lim, L. T. (2019). Cinnamon nanophytosomes embedded electrospun nanofiber: Its effects on microbial quality and shelf-life of shrimp as a novel packaging. *Food Packaging and Shelf Life*, *21*(June), 100349. https://doi.org/10.1016/j.fpsl.2019.100349

Nielsen, P. V., & Rios, R. (2000). Inhibition of fungal growth on bread by volatile components from spices and herbs, and the possible application in active packaging, with special emphasis on mustard essential oil. *International Journal of Food Microbiology*, *60*(2–3), 219–229. https://doi.org/10.1016/S0168-1605(00)00343-3

Noshirvani, N., Ghanbarzadeh, B., Gardrat, C., Rezaei, M. R., Hashemi, M., Le Coz, C., & Coma, V. (2017). Cinnamon and ginger essential oils to improve antifungal, physical and mechanical properties of chitosan-carboxymethyl cellulose films. *Food Hydrocolloids*, *70*, 36–45. https://doi.org/10.1016/j.foodhyd.2017.03.015

Ojagh, S. M., Rezaei, M., Razavi, S. H., & Hosseini, S. M. H. (2010). Development and evaluation of a novel biodegradable film made from chitosan and cinnamon essential oil with low affinity toward water. *Food Chemistry*, *122*(1), 161–166. https://doi.org/10.1016/j.foodchem.2010.02.033

Oussalah, M., Caillet, S., Saucier, L., & Lacroix, M. (2006). Antimicrobial effects of selected plant essential oils on the growth of a Pseudomonas putida strain isolated from meat. *Meat Science*, *73*(2), 236–244. https://doi.org/10.1016/j.meatsci.2005.11.019

Oussalah, M., Caillet, S., Saucier, L., & Lacroix, M. (2007). Inhibitory effects of selected plant essential oils on the growth of four pathogenic bacteria: E. coli O157:H7, Salmonella Typhimurium, Staphylococcus aureus and Listeria monocytogenes. *Food Control*, *18*(5), 414–420. https://doi.org/10.1016/j.foodcont.2005.11.009

Peng, Y., & Li, Y. (2014). Combined effects of two kinds of essential oils on physical, mechanical and structural properties of chitosan films. *Food Hydrocolloids*, *36*, 287–293. https://doi.org/10.1016/j.foodhyd.2013.10.013

Resianingrum R, Atmaka W, Khasanah LU, Kawiji, Utami R, P. D. (2016). Characterization of cassava starch-based edible film enriched with lemongrass oil (Cymbopogon citratus). *Nusantara Bioscience*, *8*(2), 278–282. https://doi.org/10.13057/nusbiosci/n080223

Rojas-Graü, M. A., Avena-Bustillos, R. J., Olsen, C., Friedman, M., Henika, P. R., Martín-Belloso, O., McHugh, T. H. (2007). Effects of plant essential oils and oil compounds on mechanical, barrier and antimicrobial properties of alginate-apple puree edible films. *Journal of Food Engineering*, *81*(3), 634–641. https://doi.org/10.1016/j.jfoodeng.2007.01.007

Sahari, J., Sapuan, S. M., Zainudin, E. S., & Maleque, M. A. (2013). Thermo-mechanical behaviors of thermoplastic starch derived from sugar palm tree (Arenga pinnata). *Carbohydrate Polymers*, *92*(2), 1711–1716. https://doi.org/10.1016/j.carbpol.2012.11.031

Sánchez-González, L., Pastor, C., Vargas, M., Chiralt, A., González-Martínez, C., & Cháfer, M. (2011). Effect of hydroxypropylmethylcellulose and chitosan coatings with and without bergamot essential oil on quality and safety of cold-stored grapes. *Postharvest Biology and Technology*, *60*(1), 57–63. https://doi.org/10.1016/j.postharvbio.2010.11.004

Sánchez Aldana, D., Andrade-Ochoa, S., Aguilar, C. N., Contreras-Esquivel, J. C., & Nevárez-Moorillón, G. V. (2015). Antibacterial activity of pectic-based edible films incorporated with Mexican lime essential oil. *Food Control*, *50*, 907–912. https://doi.org/10.1016/j.foodcont.2014.10.044

Sanyang, M. L., Ilyas, R. A., Sapuan, S. M., & Jumaidin, R. (2018). Sugar Palm Starch-Based Composites for Packaging Applications. In *Bionanocomposites for Packaging Applications* (pp. 125–147). Cham: Springer International Publishing. https://doi.org/10.1007/978-3-319-67319-6_7

Sanyang, M. L., Sapuan, S. M., Jawaid, M., Ishak, M. R., & Sahari, J. (2016). Effect of sugar palm-derived cellulose reinforcement on the mechanical and water barrier properties of sugar palm starch biocomposite films. *BioResources*, *11*(2), 4134–4145. https://doi.org/10.15376/biores.11.2.4134-4145

Shahbazi, Y. (2017). The properties of chitosan and gelatin films incorporated with ethanolic red grape seed extract and Ziziphora clinopodioides essential oil as biodegradable materials for active food packaging. *International Journal of Biological Macromolecules*, *99*, 746–753. https://doi.org/10.1016/j.ijbiomac.2017.03.065

Silveira, M. P., Silva, H. C., Pimentel, I. C., Poitevin, C. G., da Costa Stuart, A. K., Carpiné, D., Jorge, R. M. M. (2019). Development of active cassava starch cellulose nanofiber-based films incorporated with natural antimicrobial tea

tree essential oil. *Journal of Applied Polymer Science*, *48726*(21), 1–11. https://doi.org/10.1002/app.48726

Song, X., Zuo, G., & Chen, F. (2018). Effect of essential oil and surfactant on the physical and antimicrobial properties of corn and wheat starch films. *International Journal of Biological Macromolecules*, *107*(Part A), 1302–1309. https://doi.org/10.1016/j.ijbiomac.2017.09.114

Souza, A. C., Goto, G. E. O., Mainardi, J. A., Coelho, A. C. V., & Tadini, C. C. (2013). Cassava starch composite films incorporated with cinnamon essential oil: Antimicrobial activity, microstructure, mechanical and barrier properties. *LWT - Food Science and Technology*, *54*(2), 346–352. https://doi.org/10.1016/j.lwt.2013.06.017

Sun, L., Sun, J., Chen, L., Niu, P., Yang, X., & Guo, Y. (2017). Preparation and characterization of chitosan film incorporated with thinned young apple polyphenols as an active packaging material. *Carbohydrate Polymers*, *163*, 81–91. https://doi.org/10.1016/j.carbpol.2017.01.016

Taghizadeh, M., Sabouri, N., & Ghanbarzadeh, B. (2013). Polyvinyl alcohol:starch:carboxymethyl cellulose containing sodium montmorillonite clay blends; mechanical properties and biodegradation behavior. *SpringerPlus*, *2*(1), 376. https://doi.org/10.1186/2193-1801-2-376

Tongnuanchan, P., Benjakul, S., Prodpran, T., Pisuchpen, S., & Osako, K. (2016). Mechanical, thermal and heat sealing properties of fish skin gelatin film containing palm oil and basil essential oil with different surfactants. *Food Hydrocolloids*, *56*, 93–107. https://doi.org/10.1016/j.foodhyd.2015.12.005

Turek, C., & Stintzing, F. C. (2013). Stability of essential oils: A review. *Comprehensive Reviews in Food Science and Food Safety*, *12*(1), 40–53. https://doi.org/10.1111/1541-4337.12006

Utami, R., Khasanah, L. U., Manuhara, G. J., & Ayuningrum, Z. K. (2019). Effects of cinnamon bark essential oil (cinnamomum burmannii) on characteristics of edible film and quality of fresh beef. *Pertanika Journal of Tropical Agricultural Science*, *42*(4), 1173–1184.

Wong, Y., Ahmad-Mudzaqqir, M., & Wan-Nurdiyana, W. (2014). Extraction of Essential Oil from Cinnamon (Cinnamomum zeylanicum). *Oriental Journal of Chemistry*, *30*(1), 37–47. https://doi.org/10.13005/ojc/300105

References

A. Nazrin, S.M. Sapuan, M.Y.M. Zuhri, R.A. Ilyas, R. Syafiq, S. F. K. S. (2020). Nanocellulose Reinforced Thermoplastic Starch (TPS), Polylactic Acid (PLA), and Polybutylene Succinate (PBS) for Food Packaging Applications. *Frontier in Chemistry*. https://doi.org/10.3389/fchem.2020.00213

Abral, H., Atmajaya, A., Mahardika, M., Hafizulhaq, F., Kadriadi, Handayani, D., Ilyas, R. A. (2020). Effect of ultrasonication duration of polyvinyl alcohol (PVA) gel on characterizations of PVA film. *Journal of Materials Research and Technology*, *9*(2), 2477–2486. https://doi.org/10.1016/j.jmrt.2019.12.078

Adawiyah, D. R., Sasaki, T., & Kohyama, K. (2013). Characterization of arenga starch in comparison with sago starch. *Carbohydrate Polymers*, *92*(2), 2306–2313. https://doi.org/10.1016/j.carbpol.2012.12.014

Adhikari, B., Chaudhary, D. S., & Clerfeuille, E. (2010). Effect of plasticizers on the moisture migration behavior of low-amylose starch films during drying. *Drying Technology*, *28*(4), 468–480. https://doi.org/10.1080/07373931003613593

Aguirre, A., Borneo, R., & León, A. E. (2013). Properties of triticale protein films and their relation to plasticizing-antiplasticizing effects of glycerol and sorbitol. *Industrial Crops and Products*, *50*, 297–303. https://doi.org/10.1016/j.indcrop.2013.07.043

Aisyah, H. A., Paridah, M. T., Sapuan, S. M., Ilyas, R. A., Khalina, A., Nurazzi, N. M., … Lee, C. H. (2021). A Comprehensive Review on Advanced Sustainable Woven Natural Fibre Polymer Composites. *Polymers*, *13*(3), 471. https://doi.org/10.3390/polym13030471

Aitboulahsen, M., El Galiou, O., Laglaoui, A., Bakkali, M., & Hassani Zerrouk, M. (2020). Effect of plasticizer type and essential oils on mechanical, physicochemical, and antimicrobial characteristics of gelatin, starch, and pectin-based films. *Journal of Food Processing and Preservation*, *44*(6), 1–10. https://doi.org/10.1111/jfpp.14480

Alsubari, S., Zuhri, M. Y. M., Sapuan, S. M., Ishak, M. R., Ilyas, R. A., & Asyraf, M. R. M. (2021). Potential of natural fiber reinforced polymer composites in sandwich structures: A review on its mechanical properties. *Polymers*, *13*(3). https://doi.org/10.3390/polym13030423

ASTM D 664. (2002). Standard test method for moisture content of paper and paperboard by oven drying. In *ASTM International*. West Conshohocken, PA.

ASTM D882-02. (2002). Standard Test Method for Tensile Properties of Thin Plastic Sheeting. In *ASTM International*. West Conshohocken, PA.

Ayu, R. S., Khalina, A., Harmaen, A. S., Zaman, K., Isma, T., Liu, Q., Lee, C. H. (2020). Characterization Study of Empty Fruit Bunch (EFB) Fibers Reinforcement in

Poly(Butylene) Succinate (PBS)/Starch/Glycerol Composite Sheet. *Polymers*, *12*(7), 1571. https://doi.org/10.3390/polym12071571

Calo, J. R., Crandall, P. G., O'Bryan, C. A., & Ricke, S. C. (2015). Essential oils as antimicrobials in food systems - A review. *Food Control*, *54*, 111–119. https://doi.org/10.1016/j.foodcont.2014.12.040

Cao, L., Liu, W., & Wang, L. (2018). Developing a green and edible film from Cassia gum: The effects of glycerol and sorbitol. *Journal of Cleaner Production*, *175*, 276–282. https://doi.org/10.1016/j.jclepro.2017.12.064

Cerqueira, M. A., Souza, B. W. S., Teixeira, J. A., & Vicente, A. A. (2012). Effect of glycerol and corn oil on physicochemical properties of polysaccharide films - A comparative study. *Food Hydrocolloids*, *27*(1), 175–184. https://doi.org/10.1016/j.foodhyd.2011.07.007

Chouhan, S., Sharma, K., & Guleria, S. (2017). Antimicrobial Activity of Some Essential Oils—Present Status and Future Perspectives. *Medicines*, *4*(3), 58. https://doi.org/10.3390/medicines4030058

Diyana, Z. N., Jumaidin, R., Selamat, M. Z., Ghazali, I., Julmohammad, N., Huda, N., & Ilyas, R. A. (2021). Physical Properties of Thermoplastic Starch Derived from Natural Resources and Its Blends: A Review. *Polymers*, *13*(9), 1–20. https://doi.org/10.3390/polym13091396

Edhirej, A., Sapuan, S. M., Jawaid, M., & Zahari, N. I. (2017). Effect of various plasticizers and concentration on the physical, thermal, mechanical, and structural properties of cassava-starch-based films. *Starch/Staerke*, *69*(1–2), 1–11. https://doi.org/10.1002/star.201500366

El Fawal, G. F., Omer, A. M., & Tamer, T. M. (2019). Evaluation of antimicrobial and antioxidant activities for cellulose acetate films incorporated with Rosemary and Aloe Vera essential oils. *Journal of Food Science and Technology*, *56*(3), 1510–1518. https://doi.org/10.1007/s13197-019-03642-8

Ghasemlou, M., Khodaiyan, F., & Oromiehie, A. (2011). Physical, mechanical, barrier, and thermal properties of polyol-plasticized biodegradable edible film made from kefiran. *Carbohydrate Polymers*, *84*(1), 477–483. https://doi.org/10.1016/j.carbpol.2010.12.010

Ghoshal, G., & Singh, D. (2020). Synthesis and characterization of starch nanocellulosic films incorporated with Eucalyptus globulus leaf extract. *International Journal of Food Microbiology*, *332*(June), 108765. https://doi.org/10.1016/j.ijfoodmicro.2020.108765

Hassan, B., Chatha, S. A. S., Hussain, A. I., Zia, K. M., & Akhtar, N. (2018). Recent advances on polysaccharides, lipids and protein based edible films and coatings: A review. *International Journal of Biological Macromolecules*, *109*, 1095–1107. https://doi.org/10.1016/j.ijbiomac.2017.11.097

Hazrati, K. Z., Sapuan, S. M., Zuhri, M. Y. M., & Jumaidin, R. (2021). Effect of plasticizers on physical, thermal, and tensile properties of thermoplastic films based on Dioscorea hispida starch. *International Journal of Biological Macromolecules*, *185*(January), 219–228. https://doi.org/10.1016/j.ijbiomac.2021.06.099

Hazrol, M. D., Sapuan, S. M., Ilyas, R. A., Othman, M. L., & Sherwani, S. F. K. (2020). Electrical properties of sugar palm nanocrystalline cellulose reinforced sugar palm starch nanocomposites. *Polimery*, *65*(05), 363–370. https://doi.org/10.14314/polimery.2020.5.4

Hazrol, M. D., Sapuan, S. M., Zainudin, E. S., Zuhri, M. Y. M., & Wahab, N. I. A. (2021). Corn starch (Zea mays) biopolymer plastic reaction in combination with sorbitol and glycerol. *Polymers*, *13*(2), 1–22. https://doi.org/10.3390/polym13020242

Ilyas, R. A., & Sapuan, S. M. (2020). Biopolymers and Biocomposites: Chemistry and Technology. *Current Analytical Chemistry*, *16*(5), 500–503. https://doi.org/10.2174/1573411016052006030953l1

Ilyas, R. A., Sapuan, S. M., Harussani, M. M., Hakimi, M. Y. A. Y., Haziq, M. Z. M., Atikah, M. S. N., … Asrofi, M. (2021). Polylactic Acid (PLA) Biocomposite: Processing, Additive Manufacturing and Advanced Applications. *Polymers*, *13*(8), 1326. https://doi.org/10.3390/polym13081326

Ilyas, R. A., Sapuan, S. M., Ibrahim, R., Abral, H., Ishak, M. R., Zainudin, E. S., … Jumaidin, R. (2019). Effect of sugar palm nanofibrillated celluloseconcentrations on morphological, mechanical andphysical properties of biodegradable films basedon agro-waste sugar palm (Arenga pinnata(Wurmb.) Merr) starch. *Journal of Materials Research and Technology*, *8*(5), 4819–4830. https://doi.org/10.1016/j.jmrt.2019.08.028

Ilyas, R. A., Sapuan, S. M., & Ishak, M. R. (2018). Isolation and characterization of nanocrystalline cellulose from sugar palm fibres (Arenga Pinnata). *Carbohydrate Polymers*, *181*(November 2017), 1038–1051. https://doi.org/10.1016/j.carbpol.2017.11.045

Ilyas, R. A., Sapuan, S. M., Ishak, M. R., & Zainudin, E. S. (2018). Development and characterization of sugar palm nanocrystalline cellulose reinforced sugar palm starch bionanocomposites. *Carbohydrate Polymers*, *202*(September), 186–202. https://doi.org/10.1016/j.carbpol.2018.09.002

Ilyas, R. A., Sapuan, S. M., Ishak, M. R., Zainudin, E. S., & Atikah, M. S. N. (2018). Characterization of Sugar Palm Nanocellulose and Its Potential for Reinforcement with a Starch-Based Composite. In *Sugar Palm Biofibers, Biopolymers, & Biocomposites* (1st ed., pp. 190–212). Boca Raton: CRC Press/Taylor & Francis Group.

Ilyas, R. A., Sapuan, S. M., Sanyang, M. L., Ishak, M. R., & Zainudin, E. S. (2018). Nanocrystalline Cellulose as Reinforcement for Polymeric Matrix Nanocomposites and its Potential Applications: A Review. *Current Analytical*

Chemistry, *14*(3), 203–225. https://doi.org/10.2174/1573411013666171003155624

Ivanič, F., Jochec-Mošková, D., Janigová, I., & Chodák, I. (2017). Physical properties of starch plasticized by a mixture of plasticizers. *European Polymer Journal*, *93*, 843–849. https://doi.org/10.1016/j.eurpolymj.2017.04.006

Jouki, M., Khazaei, N., Ghasemlou, M., & Hadinezhad, M. (2013). Effect of glycerol concentration on edible film production from cress seed carbohydrate gum. *Carbohydrate Polymers*, *96*(1), 39–46. https://doi.org/10.1016/j.carbpol.2013.03.077

Kurt, A., & Kahyaoglu, T. (2014). Characterization of a new biodegradable edible film made from salep glucomannan. *Carbohydrate Polymers*, *104*(1), 50–58. https://doi.org/10.1016/j.carbpol.2014.01.003

Lu, F., Ding, Y. C., Ye, X. Q., & Ding, Y. T. (2011). Antibacterial effect of cinnamon oil combined with thyme or clove oil. *Agricultural Sciences in China*, *10*(9), 1482–1487. https://doi.org/10.1016/S1671-2927(11)60142-9

M. O. Syafiq, R., Sapuan, S. M., & Zuhri, M. R. M. (2020). Effect of cinnamon essential oil on morphological, flammability and thermal properties of nanocellulose fibre–reinforced starch biopolymer composites. *Nanotechnology Reviews*, *9*(1), 1147–1159. https://doi.org/10.1515/ntrev-2020-0087

Maniglia, B. C., Tessaro, L., Ramos, A. P., & Tapia-Blácido, D. R. (2019). Which plasticizer is suitable for films based on babassu starch isolated by different methods? *Food Hydrocolloids*, *89*(October 2018), 143–152. https://doi.org/10.1016/j.foodhyd.2018.10.038

Mith, H., Duré, R., Delcenserie, V., Zhiri, A., Daube, G., & Clinquart, A. (2014). Antimicrobial activities of commercial essential oils and their components against food-borne pathogens and food spoilage bacteria. *Food Science & Nutrition*, *2*(4), 403–416. https://doi.org/10.1002/fsn3.116

Mohd Nurazzi, N., Asyraf, M. R. M., Khalina, A., Abdullah, N., Sabaruddin, F. A., Kamarudin, S. H., Sapuan, S. M. (2021). Fabrication, Functionalization, and Application of Carbon Nanotube-Reinforced Polymer Composite: An Overview. *Polymers*, *13*(7), 1047. https://doi.org/10.3390/polym13071047

Muscat, D., Adhikari, B., Adhikari, R., & Chaudhary, D. S. (2012). Comparative study of film forming behaviour of low and high amylose starches using glycerol and xylitol as plasticizers. *Journal of Food Engineering*, *109*(2), 189–201. https://doi.org/10.1016/j.jfoodeng.2011.10.019

Nazrin, A., Sapuan, S. M., & Zuhri, M. Y. M. (2020). Mechanical, physical and thermal properties of sugar palm nanocellulose reinforced thermoplastic starch (Tps)/poly (lactic acid) (pla) blend bionanocomposites. *Polymers*, *12*(10), 1–18. https://doi.org/10.3390/polym12102216

Nazrin, Asmawi, Sapuan, S. M., Zuhri, M. Y. M., Tawakkal, I. S. M. A., & Ilyas, R. A. (2021). Water barrier and mechanical properties of sugar palm crystalline nanocellulose reinforced thermoplastic sugar palm starch (TPS)/poly(lactic acid) (PLA) blend bionanocomposites. *Nanotechnology Reviews*, *10*(1), 431–442. https://doi.org/10.1515/ntrev-2021-0033

Nurazzi, N. M., Asyraf, M. R. M., Khalina, A., Abdullah, N., Aisyah, H. A., Rafiqah, S. A., Sapuan, S. M. (2021). A Review on Natural Fiber Reinforced Polymer Composite for Bullet Proof and Ballistic Applications. *Polymers*, *13*(4), 646. https://doi.org/10.3390/polym13040646

Omran, A. A. B., Mohammed, A. A. B. A., Sapuan, S. M., Ilyas, R. A., Asyraf, M. R. M., Koloor, S. S. R., & Petrů, M. (2021). Micro- and Nanocellulose in Polymer Composite Materials: A Review. *Polymers*, *13*(2), 231. https://doi.org/10.3390/polym13020231

Perdana, M. I., Ruamcharoen, J., Panphon, S., & Leelakriangsak, M. (2021). Antimicrobial activity and physical properties of starch/chitosan film incorporated with lemongrass essential oil and its application. *Lwt*, *141*(November 2020), 110934. https://doi.org/10.1016/j.lwt.2021.110934

Raeisi, M., Tajik, H., Yarahmadi, A., & Sanginabadi, S. (2015). Antimicrobial Effect of Cinnamon Essential Oil Against Escherichia Coli and Staphylococcus aureus. *Health Scope*, *4*(4), 0–4. https://doi.org/10.17795/jhealthscope-21808

Razavi, S. M. A., Mohammad Amini, A., & Zahedi, Y. (2015). Characterisation of a new biodegradable edible film based on sage seed gum: Influence of plasticiser type and concentration. *Food Hydrocolloids*, *43*, 290–298. https://doi.org/10.1016/j.foodhyd.2014.05.028

Sahari, J., Sapuan, S. M., Zainudin, E. S., & Maleque, M. A. (2012). A New Approach to Use Arenga Pinnata as Sustainable Biopolymer: Effects of Plasticizers on Physical Properties. *Procedia Chemistry*, *4*, 254–259. https://doi.org/10.1016/j.proche.2012.06.035

Sahari, J., Sapuan, S. M., Zainudin, E. S., & Maleque, M. A. (2013). Thermo-mechanical behaviors of thermoplastic starch derived from sugar palm tree (*Arenga pinnata*). *Carbohydrate Polymers*, *92*(2), 1711–1716. https://doi.org/10.1016/j.carbpol.2012.11.031

Sánchez Aldana, D., Andrade-Ochoa, S., Aguilar, C. N., Contreras-Esquivel, J. C., & Nevárez-Moorillón, G. V. (2015). Antibacterial activity of pectic-based edible films incorporated with Mexican lime essential oil. *Food Control*, *50*, 907–912. https://doi.org/10.1016/j.foodcont.2014.10.044

Sanyang, M L, Sapuan, S. M., Jawaid, M., Ishak, M. R., & Sahari, J. (2016). Effect of plasticizer type and concentration on physical properties of biodegradable films based on sugar palm (*arenga pinnata*) starch for food packaging, *53*(January), 326–336. https://doi.org/10.1007/s13197-015-2009-7

Sanyang, Muhammed L., Sapuan, S. M., Jawaid, M., Ishak, M. R., & Sahari, J. (2015). Effect of plasticizer type and concentration on tensile, thermal and barrier properties of biodegradable films based on sugar palm (*Arenga pinnata*) starch. *Polymers*, *7*(6), 1106–1124. https://doi.org/10.3390/polym7061106

Sari, N. H., Pruncu, C. I., Sapuan, S. M., Ilyas, R. A., Catur, A. D., Suteja, S., Pullen, G. (2020). The effect of water immersion and fibre content on properties of corn husk fibres reinforced thermoset polyester composite. *Polymer Testing*, *91*, 106751. https://doi.org/10.1016/j.polymertesting.2020.106751

Suppakul, P., Chalernsook, B., Ratisuthawat, B., Prapasitthi, S., & Munchukangwan, N. (2013). Empirical modeling of moisture sorption characteristics and mechanical and barrier properties of cassava flour film and their relation to plasticizing-antiplasticizing effects. *LWT - Food Science and Technology*, *50*(1), 290–297. https://doi.org/10.1016/j.lwt.2012.05.013

Syafiq, R., Sapuan, S. M., & Zuhri, M. R. M. (2021). Antimicrobial activity, physical, mechanical and barrier properties of sugar palm based nanocellulose/starch biocomposite films incorporated with cinnamon essential oil. *Journal of Materials Research and Technology*, *11*, 144–157. https://doi.org/10.1016/j.jmrt.2020.12.091

Syafiq, R., Sapuan, S. M., Zuhri, M. Y. M., Ilyas, R. A., Nazrin, A., Sherwani, S. F. K., & Khalina, A. (2020). Antimicrobial activities of starch-based biopolymers and biocomposites incorporated with plant essential oils: A review. *Polymers*, *12*(10), 1–26. https://doi.org/10.3390/polym12102403

Tapia-Blácido, D. R., Sobral, P. J. d. A., & Menegalli, F. C. (2013). Effect of drying conditions and plasticizer type on some physical and mechanical properties of amaranth flour films. *LWT - Food Science and Technology*, *50*(2), 392–400. https://doi.org/10.1016/j.lwt.2012.09.008

Tarique, J., Sapuan, S. M., & Khalina, A. (2021). Effect of glycerol plasticizer loading on the physical, mechanical, thermal, and barrier properties of arrowroot (Maranta arundinacea) starch biopolymers. *Scientific Reports*, *11*(1), 1–17. https://doi.org/10.1038/s41598-021-93094-y

Thakur, R., Pristijono, P., Scarlett, C. J., Bowyer, M., Singh, S. P., & Vuong, Q. V. (2019). Starch-based films: Major factors affecting their properties. *International Journal of Biological Macromolecules*, *132*, 1079–1089. https://doi.org/10.1016/j.ijbiomac.2019.03.190

Tunç, S., & Duman, O. (2010). Preparation and characterization of biodegradable methyl cellulose/montmorillonite nanocomposite films. *Applied Clay Science*, *48*(3), 414–424. https://doi.org/10.1016/j.clay.2010.01.016

Tunç, S., & Duman, O. (2011). Preparation of active antimicrobial methyl cellulose/carvacrol/montmorillonite nanocomposite films and investigation of carvacrol release. *LWT - Food Science and Technology*, *44*(2), 465–472. https://doi.org/10.1016/j.lwt.2010.08.018

Tunç, S., Duman, O., & Polat, T. G. (2016). Effects of montmorillonite on properties of methyl cellulose/carvacrol based active antimicrobial nanocomposites. *Carbohydrate Polymers*, *150*, 259–268. https://doi.org/10.1016/j.carbpol.2016.05.019

Wińska, K., Mączka, W., Łyczko, J., Grabarczyk, M., Czubaszek, A., & Szumny, A. (2019). Essential oils as antimicrobial agents—myth or real alternative? *Molecules*, *24*(11), 1–21. https://doi.org/10.3390/molecules24112130

Zhang, Yachuan, Rempel, C., & Liu, Q. (2014). Thermoplastic Starch Processing and Characteristics-A Review. *Critical Reviews in Food Science and Nutrition*, *54*(10), 1353–1370. https://doi.org/10.1080/10408398.2011.636156

Zhang, Yunbin, Liu, X., Wang, Y., Jiang, P., & Quek, S. Y. (2016). Antibacterial activity and mechanism of cinnamon essential oil against Escherichia coli and Staphylococcus aureus. *Food Control*, *59*, 282–289. https://doi.org/10.1016/j.foodcont.2015.05.032

References

Aitboulahsen, M., El Galiou, O., Laglaoui, A., Bakkali, M., & Hassani Zerrouk, M. (2020). Effect of plasticizer type and essential oils on mechanical, physicochemical, and antimicrobial characteristics of gelatin, starch, and pectin-based films. *Journal of Food Processing and Preservation*, *44*(6), 1–10. https://doi.org/10.1111/jfpp.14480

ASTM D1938 - 14. (2014). Standard Test Method for Tear-Propagation Resistance (Trouser Tear) of Plastic Film and Thin Sheeting by a Single-Tear Method. In *ASTM International*. West Conshohocken, PA.

ASTM E96-95. (1995). Standard Test Method for Water Vapor Transmission of Materials. In *ASTM International*. West Conshohocken, PA.

ASTM F88. (2000). Standard Test Method for Seal Strength of Flexible Barrier Materials. In *ASTM International*. West Conshohocken, PA. https://doi.org/10.1520/F0088-00

Bakry, N. F., Isa, M. I. N., & Sarbon, N. M. (2017). Effect of sorbitol at different concentrations on the functional properties of gelatin/carboxymethyl cellulose (CMC)/chitosan composite films. *International Food Research Journal*, *24*(4), 1753–1762.

Dai, L., Qiu, C., Xiong, L., & Sun, Q. (2015). Characterisation of corn starch-based films reinforced with taro starch nanoparticles. *FOOD CHEMISTRY*, *174*, 82–88. https://doi.org/10.1016/j.foodchem.2014.11.005

Edhirej, A., Sapuan, S. M., Jawaid, M., & Zahari, N. I. (2017). Preparation and Characterization of Cassava Bagasse Reinforced Thermoplastic Cassava Starch, *18*(1), 162–171. https://doi.org/10.1007/s12221-017-6251-7

Fakhouri, F. M., Martelli, S. M., Caon, T., Velasco, J. I., Buontempo, R. C., Bilck, A. P., Mei, I. (2017). The effect of fatty acids on the physicochemical properties of edible films composed of gelatin and gluten proteins. *LWT - Food Science and Technology*, *87*, 293–300. https://doi.org/10.1016/j.lwt.2017.08.056

Ghasemlou, M., Khodaiyan, F., & Oromiehie, A. (2011). Physical, mechanical, barrier, and thermal properties of polyol-plasticized biodegradable edible film made from kefiran. *Carbohydrate Polymers*, *84*(1), 477–483. https://doi.org/10.1016/j.carbpol.2010.12.010

Han, Y., Yu, M., & Wang, L. (2018). Physical and antimicrobial properties of sodium alginate / carboxymethyl cellulose fi lms incorporated with cinnamon essential oil. *Food Packaging and Shelf Life*, *15*, 35–42. https://doi.org/10.1016/j.fpsl.2017.11.001

Hanani, Z. A. N., Mahony, J. A. O., Roos, Y. H., Oliveira, P. M., & Kerry, J. P. (2014). ScienceDirect Extrusion of gelatin-based composite films : Effects of processing temperature and pH of film forming solution on mechanical and

barrier properties of manufactured films. *Food Packaging and Shelf Life*, *2*(2), 91–101. https://doi.org/10.1016/j.fpsl.2014.09.001

Hazrati, K. Z., Sapuan, S. M., Zuhri, M. Y. M., & Jumaidin, R. (2021). Effect of plasticizers on physical, thermal, and tensile properties of thermoplastic films based on Dioscorea hispida starch. *International Journal of Biological Macromolecules*, *185*(January), 219–228. https://doi.org/10.1016/j.ijbiomac.2021.06.099

Hazrol, M. D., Sapuan, S. M., Zainudin, E. S., Zuhri, M. Y. M., & Wahab, N. I. A. (2021). Corn starch (Zea mays) biopolymer plastic reaction in combination with sorbitol and glycerol. *Polymers*, *13*(2), 1–22. https://doi.org/10.3390/polym13020242

Ilyas, R. A., Sapuan, S. M., Ishak, M. R., & Zainudin, E. S. (2018a). Development and characterization of sugar palm nanocrystalline cellulose reinforced sugar palm starch bionanocomposites. *Carbohydrate Polymers*, *202*(September), 186–202. https://doi.org/10.1016/j.carbpol.2018.09.002

Ilyas, R. A., Sapuan, S. M., Ishak, M. R., & Zainudin, E. S. (2018b). Sugar palm nanocrystalline cellulose reinforced sugar palm starch composite: Degradation and water-barrier properties. *IOP Conference Series: Materials Science and Engineering*, *368*(1), 012006. https://doi.org/10.1088/1757-899X/368/1/012006

Ilyas, R. A., Sapuan, S. M., Ishak, M. R., & Zainudin, E. S. (2018c). Water transport properties of bio-nanocomposites reinforced by sugar palm (Arenga Pinnata) nanofibrillated cellulose. *Journal of Advanced Research in Fluid Mechanics and Thermal Sciences Journal*, *51*(2), 234–246.

Kaya, M., Ravikumar, P., Ilk, S., & Mujtaba, M. (2018). Production and characterization of chitosan based edible films from Berberis crataegina's fruit extract and seed oil. *Innovative Food Science and Emerging Technologies*, *45*, 287–297. https://doi.org/10.1016/j.ifset.2017.11.013

Laohakunjit, N., & Noomhorm, A. (2004). Effect of plasticizers on mechanical and barrier properties of rice starch film. *Starch/Staerke*, *56*(8), 348–356. https://doi.org/10.1002/star.200300249

Li, J., Ye, F., Lei, L., & Zhao, G. (2018). Combined effects of octenylsuccination and oregano essential oil on sweet potato starch films with an emphasis on water resistance. *International Journal of Biological Macromolecules*, *115*, 547–553. https://doi.org/10.1016/j.ijbiomac.2018.04.093

Li, X., Sun, H., Li, S., Chen, S., & Liu, D. (2020). Antibacterial and antioxidant activities of sodium starch octenylsuccinate-based Pickering emulsion films incorporated with cinnamon essential oil. *International Journal of Biological Macromolecules*, *159*, 696–703. https://doi.org/10.1016/j.ijbiomac.2020.05.118

López, O. V., Castillo, L. A., García, M. A., Villar, M. A., & Barbosa, S. E. (2015). Food packaging bags based on thermoplastic corn starch reinforced with talc nanoparticles. *Food Hydrocolloids*, *43*, 18–24. https://doi.org/10.1016/j.foodhyd.2014.04.021

López, O. V., Lecot, C. J., Zaritzky, N. E., & García, M. A. (2011). Biodegradable packages development from starch based heat sealable films. *Journal of Food Engineering*, *105*(2), 254–263. https://doi.org/10.1016/j.jfoodeng.2011.02.029

M. O. Syafiq, R., Sapuan, S. M., & Zuhri, M. R. M. (2020). Effect of cinnamon essential oil on morphological, flammability and thermal properties of nanocellulose fibre–reinforced starch biopolymer composites. *Nanotechnology Reviews*, *9*(1), 1147–1159. https://doi.org/10.1515/ntrev-2020-0087

Menzel, C. (2020). Improvement of starch films for food packaging through a three-principle approach: Antioxidants, cross-linking and reinforcement. *Carbohydrate Polymers*, *250*, 116828. https://doi.org/10.1016/j.carbpol.2020.116828

Nazrin, A., Sapuan, S. M., & Zuhri, M. Y. M. (2020). Mechanical, physical and thermal properties of sugar palm nanocellulose reinforced thermoplastic starch (Tps)/poly (lactic acid) (pla) blend bionanocomposites. *Polymers*, *12*(10), 1–18. https://doi.org/10.3390/polym12102216

Nazrin, Asmawi, Sapuan, S. M., Zuhri, M. Y. M., Tawakkal, I. S. M. A., & Ilyas, R. A. (2021). Water barrier and mechanical properties of sugar palm crystalline nanocellulose reinforced thermoplastic sugar palm starch (TPS)/poly(lactic acid) (PLA) blend bionanocomposites. *Nanotechnology Reviews*, *10*(1), 431–442. https://doi.org/10.1515/ntrev-2021-0033

Nobile, M. A. Del. (2008). Influence of glycerol and chitosan on tapioca starch-based edible film properties. *Journal of Food Engineering*, *88*, 159–168. https://doi.org/10.1016/j.jfoodeng.2008.02.002

Nordin, N., Othman, S. H., Rashid, S. A., & Basha, R. K. (2020). Effects of glycerol and thymol on physical, mechanical, and thermal properties of corn starch films. *Food Hydrocolloids*, *106*(December 2019), 105884. https://doi.org/10.1016/j.foodhyd.2020.105884

Othman, S. H., Amirah, S., Edwal, M., Risyon, N. P., Basha, R. K., & Talib, R. A. (2017). Water sorption and water permeability properties of edible film made from potato peel waste. *Food Science and Technology*, *37*(1), 63–70.

Othman, S. H., Majid, N. A., Syafinaz, I., Amin, M., Basha, K., Nordin, N., & I, R. A. S. (2019). Tapioca starch films reinforced with microcrystalline cellulose for potential food packaging application. *Food Science and Technology*, *39*(3), 1–8.

Razavi, S. M. A., Mohammad Amini, A., & Zahedi, Y. (2015). Characterisation of a new biodegradable edible film based on sage seed gum: Influence of plasticiser type

and concentration. *Food Hydrocolloids*, *43*, 290–298. https://doi.org/10.1016/j.foodhyd.2014.05.028

Ribeiro, R., Andrade, M., Melo, N. R. De, & Sanches-, A. (2017). Use of essential oils in active food packaging: recent advances and future trends. *Trends in Food Science & Technology*, *61*, 132–140. https://doi.org/10.1016/j.tifs.2016.11.021

Sahari, J., Sapuan, S. M., Zainudin, E. S., & Maleque, M. A. (2013). Thermo-mechanical behaviors of thermoplastic starch derived from sugar palm tree (Arenga pinnata). *Carbohydrate Polymers*, *92*(2), 1711–1716. https://doi.org/10.1016/j.carbpol.2012.11.031

Sanyang, M. L., Sapuan, S. M., Jawaid, M., Ishak, M. R., & Sahari, J. (2016). Effect of sugar palm-derived cellulose reinforcement on the mechanical and water barrier properties of sugar palm starch biocomposite films. *BioResources*, *11*(2), 4134–4145. https://doi.org/10.15376/biores.11.2.4134-4145

Sanyang, M L, Sapuan, S. M., Jawaid, M., Ishak, M. R., & Sahari, J. (2016). Effect of plasticizer type and concentration on physical properties of biodegradable films based on sugar palm (arenga pinnata) starch for food packaging, *53*(January), 326–336. https://doi.org/10.1007/s13197-015-2009-7

Sanyang, Muhammed L., Sapuan, S. M., Jawaid, M., Ishak, M. R., & Sahari, J. (2015). Effect of plasticizer type and concentration on tensile, thermal and barrier properties of biodegradable films based on sugar palm (Arenga pinnata) starch. *Polymers*, *7*(6), 1106–1124. https://doi.org/10.3390/polym7061106

Suderman, N., Isa, M. I. N., & Sarbon, N. M. (2018). The effect of plasticizers on the functional properties of biodegradable gelatin-based film: A review. *Food Bioscience*, *24*(June), 111–119. https://doi.org/10.1016/j.fbio.2018.06.006

Šuput, D., Lazić, V., Pezo, L., Markov, S., Vaštag, Ž., Popović, L., Popović, S. (2016). Characterization of starch edible films with different essential oils addition. *Polish Journal of Food and Nutrition Sciences*, *66*(4), 277–285. https://doi.org/10.1515/pjfns-2016-0008

Syafiq, R., Sapuan, S. M., & Zuhri, M. R. M. (2021). Antimicrobial activity, physical, mechanical and barrier properties of sugar palm based nanocellulose/starch biocomposite films incorporated with cinnamon essential oil. *Journal of Materials Research and Technology*, *11*, 144–157. https://doi.org/10.1016/j.jmrt.2020.12.091

Syafiq, R., Sapuan, S. M., Zuhri, M. Y. M., Ilyas, R. A., Nazrin, A., Sherwani, S. F. K., & Khalina, A. (2020). Antimicrobial activities of starch-based biopolymers and biocomposites incorporated with plant essential oils: A review. *Polymers*, *12*(10), 1–26. https://doi.org/10.3390/polym12102403

Tarique, J., Sapuan, S. M., & Khalina, A. (2021). Effect of glycerol plasticizer loading on the physical, mechanical, thermal, and barrier properties of arrowroot (Maranta arundinacea) starch biopolymers. *Scientific Reports*, *11*(1), 1–17. https://doi.org/10.1038/s41598-021-93094-y

Wongphan, P., & Harnkarnsujarit, N. (2020). Characterization of starch, agar and maltodextrin blends for controlled dissolution of edible films. *International Journal of Biological Macromolecules*, *156*, 80–93. https://doi.org/10.1016/j.ijbiomac.2020.04.056

Zhou, Y., Wu, X., Chen, J., & He, J. (2021). Effects of cinnamon essential oil on the physical, mechanical, structural and thermal properties of cassava starch-based edible films. *International Journal of Biological Macromolecules*, *184*(June), 574–583. https://doi.org/10.1016/j.ijbiomac.2021.06.067

REFERENCES

A. Nazrin, S.M. Sapuan, M.Y.M. Zuhri, R.A. Ilyas, R. Syafiq, S. F. K. S. (2020). Nanocellulose Reinforced Thermoplastic Starch (TPS), Polylactic Acid (PLA), and Polybutylene Succinate (PBS) for Food Packaging Applications. *Frontier in Chemistry*, 8, 213.

Abitbol, T., Rivkin, A., Cao, Y., Nevo, Y., Abraham, E., Ben-shalom, T., Lapidot, S., & Shoseyov, O. (2016). Nanocellulose , a tiny fiber with huge applications. *Current Opinion in Biotechnology*, *39*(1), 76–88.

Abral, H., Ariksa, J., Mahardika, M., Handayani, D., Aminah, I., Sandrawati, N., Pratama, A. B., Fajri, N., Sapuan, S. M., & Ilyas, R. A. (2020). Transparent and antimicrobial cellulose film from ginger nanofiber. *Food Hydrocolloids*, *98*, 105266.

Abral, H., Ariksa, J., Mahardika, M., Handayani, D., Aminah, I., Sandrawati, N., Sapuan, S. M., & Ilyas, R. A. (2019). Highly transparent and antimicrobial PVA based bionanocomposites reinforced by ginger nanofiber. *Polymer Testing*, *81*, 106186.

Abral, H., Atmajaya, A., Mahardika, M., Hafizulhaq, F., Kadriadi, Handayani, D., Sapuan, S. M., & Ilyas, R. A. (2020). Effect of ultrasonication duration of polyvinyl alcohol (PVA) gel on characterizations of PVA film. *Journal of Materials Research and Technology*, *9*(2), 2477–2486.

Acosta, S., Jiménez, A., Cháfer, M., González-Martínez, C., & Chiralt, A. (2015). Physical properties and stability of starch-gelatin based films as affected by the addition of esters of fatty acids. *Food Hydrocolloids*, *49*, 135–143.

Adawiyah, D. R., Sasaki, T., & Kohyama, K. (2013). Characterization of *arenga* starch in comparison with sago starch. *Carbohydrate Polymers*, *92*(2), 2306–2313.

Adhikari, B., Chaudhary, D. S., & Clerfeuille, E. (2010). Effect of plasticizers on the moisture migration behavior of low-amylose starch films during drying. *Drying Technology*, *28*(4), 468–480.

Aguirre, A., Borneo, R., & León, A. E. (2013). Properties of triticale protein films and their relation to plasticizing-antiplasticizing effects of glycerol and sorbitol. *Industrial Crops and Products*, *50*, 297–303.

Ahmad, M., Benjakul, S., Prodpran, T., & Agustini, T. W. (2012). Physico-mechanical and antimicrobial properties of gelatin film from the skin of unicorn leatherjacket incorporated with essential oils. *Food Hydrocolloids*, *28*(1), 189–199.

Ahmad, M., Hani, N. M., Nirmal, N. P., Fazial, F. F., Mohtar, N. F., & Romli, S. R. (2015). Optical and thermo-mechanical properties of composite films based on fish gelatin/rice flour fabricated by casting technique. *Progress in Organic Coatings*, *84*, 115–127.

Aisyah, H. A., Paridah, M. T., Sapuan, S. M., Ilyas, R. A., Khalina, A., Nurazzi, N. M., Lee, S. H., & Lee, C. H. (2021). A Comprehensive Review on Advanced Sustainable Woven Natural Fibre Polymer Composites. *Polymers*, *13*(3), 471.

Aisyah, H. A., Paridah, M. T., Sapuan, S. M., Khalina, A., Berkalp, O. B., Lee, S. H., Lee, C. H., Nurazzi, N. M., Ramli, N., Wahab, M. S., & Ilyas, R. A. (2019). Thermal Properties of Woven Kenaf/Carbon Fibre-Reinforced Epoxy Hybrid Composite Panels. *International Journal of Polymer Science*, 1–8.

Aitboulahsen, M., El Galiou, O., Laglaoui, A., Bakkali, M., & Hassani Zerrouk, M. (2020). Effect of plasticizer type and essential oils on mechanical, physicochemical, and antimicrobial characteristics of gelatin, starch, and pectin-based films. *Journal of Food Processing and Preservation*, *44*(6), 1–10.

Akhter, R., Masoodi, F. A., Wani, T. A., & Rather, S. A. (2019). Functional characterization of biopolymer based composite film: Incorporation of natural essential oils and antimicrobial agents. *International Journal of Biological Macromolecules*, *137*, 1245–1255.

Almasi, H., Azizi, S., & Amjadi, S. (2020). Development and characterization of pectin films activated by nanoemulsion and Pickering emulsion stabilized marjoram (Origanum majorana L.) essential oil. *Food Hydrocolloids*, 99, 105338.

Alsubari, S., Zuhri, M. Y. M., Sapuan, S. M., Ishak, M. R., Ilyas, R. A., & Asyraf, M. R. M. (2021). Potential of natural fiber reinforced polymer composites in sandwich structures: A review on its mechanical properties. *Polymers*, *13*(3), 423.

Altiok, D., Altiok, E., & Tihminlioglu, F. (2010). Physical, antibacterial and antioxidant properties of chitosan films incorporated with thyme oil for potential wound healing applications. *Journal of Materials Science: Materials in Medicine*, *21*(7), 2227–2236.

Appendini, P., & Hotchkiss, J. H. (2002). Review of antimicrobial food packaging. *Innovative Food Science & Emerging Technologies*, *3*(2), 113–126.

ASTM 570. (1998). Standard Test Method for Water Absorption of Plastics. In *ASTM International*.

ASTM D 664. (2002). Standard test method for moisture content of paper and paperboard by oven drying. In *ASTM International*.

ASTM D1103. (1977). Method of Test for Alpha-Cellulose in Wood. In *ASTM International*.

ASTM D1104. (1978). Method of Test for Holocellulose in Wood. In *ASTM International*.

ASTM D1938 - 14. (2014). Standard Test Method for Tear-Propagation Resistance (Trouser Tear) of Plastic Film and Thin Sheeting by a Single-Tear Method. In *ASTM International*.

ASTM D882-02. (2002). Standard Test Method for Tensile Properties of Thin Plastic Sheeting. In *ASTM International*.

ASTM E96-95. (1995). Standard Test Method for Water Vapor Transmission of Materials. In *ASTM International*.

ASTM F88. (2000). Standard Test Method for Seal Strength of Flexible Barrier Materials. In *ASTM International*. https://doi.org/10.1520/F0088-00

Ataei, S., Azari, P., Hassan, A., Pingguan-Murphy, B., Yahya, R., & Muhamad, F. (2020). Essential Oils-Loaded Electrospun Biopolymers: A Future Perspective for Active Food Packaging. *Advances in Polymer Technology*, *2020*, 1–21.

Atarés, L., & Chiralt, A. (2016). Essential oils as additives in biodegradable films and coatings for active food packaging. *Trends in Food Science and Technology*, *48*, 51–62.

Atikah, M. S. N., Ilyas, R. A., Sapuan, S. M., Ishak, M. R., Zainudin, E. S., Ibrahim, R., Atiqah, A., Ansari, M. N. M., & Jumaidin, R. (2019). Degradation and physical properties of sugar palm starch / sugar palm nanofibrillated cellulose bionanocomposite. *Polimery*, *64*(10), 27–36.

Atiqah, A., Jawaid, M., Sapuan, S. M., Ishak, M. R., Ansari, M. N. M., & Ilyas, R. A. (2019). Physical and thermal properties of treated sugar palm/glass fibre reinforced thermoplastic polyurethane hybrid composites. *Journal of Materials Research and Technology*, *8(5)*, 3726-3732..

Avila-Sosa, R., Hernández-Zamoran, E., López-Mendoza, I., Palou, E., Munguía, M. T. J., Nevárez-Moorillón, G. V., & López-Malo, A. (2010). Fungal inactivation by mexican oregano (lippia berlandieri schauer) essential oil added to amaranth, chitosan, or starch edible films. *Journal of Food Science*, *75*(3), M127–M133.

Ayu, R. S., Khalina, A., Harmaen, A. S., Zaman, K., Isma, T., Liu, Q., Ilyas, R. A., & Lee, C. H. (2020). Characterization Study of Empty Fruit Bunch (EFB) Fibers Reinforcement in Poly(Butylene) Succinate (PBS)/Starch/Glycerol Composite Sheet. *Polymers*, *12*(7), 1571.

Bakry, N. F., Isa, M. I. N., & Sarbon, N. M. (2017). Effect of sorbitol at different concentrations on the functional properties of gelatin/carboxymethyl cellulose (CMC)/chitosan composite films. *International Food Research Journal*, *24*(4), 1753–1762.

Bhavaniramya, S., Vishnupriya, S., Al-Aboody, M. S., Vijayakumar, R., & Baskaran, D. (2019). Role of essential oils in food safety: Antimicrobial and antioxidant applications. *Grain & Oil Science and Technology*, *2(2)*, 49–55.

Botre, D. A., Soares, N. de F. F., Espitia, P. J. P., Sousa, S. de, & Renhe, I. R. T. (2010). Avaliação de filme incorporado com óleo essencial de orégano para conservação de pizza pronta. *Revista Ceres*, *57*(3), 283–291.

Calo, J. R., Crandall, P. G., O'Bryan, C. A., & Ricke, S. C. (2015). Essential oils as antimicrobials in food systems - A review. *Food Control*, *54*, 111–119.

Campos-Requena, V. H., Rivas, B. L., Pérez, M. A., Figueroa, C. R., Figueroa, N. E., & Sanfuentes, E. A. (2017). Thermoplastic starch/clay nanocomposites loaded with essential oil constituents as packaging for strawberries − In vivo antimicrobial synergy over Botrytis cinerea. *Postharvest Biology and Technology*, *129*, 29–36.

Cano, A., Cháfer, M., Chiralt, A., & González-Martínez, C. (2015). Physical and Antimicrobial Properties of Starch-PVA Blend Films as Affected by the Incorporation of Natural Antimicrobial Agents. *Foods*, *5*(1), 3.

Cao, L., Liu, W., & Wang, L. (2018). Developing a green and edible film from Cassia gum: The effects of glycerol and sorbitol. *Journal of Cleaner Production*, *175*, 276–282.

Cardoso-Ugarte, G. A., López-Malo, A., & Sosa-Morales, M. E. (2016). Cinnamon (Cinnamomum zeylanicum) essential oils. *Essential Oils in Food Preservation, Flavor and Safety*, 339–347.

Cerqueira, M. A., Souza, B. W. S., Teixeira, J. A., & Vicente, A. A. (2012). Effect of glycerol and corn oil on physicochemical properties of polysaccharide films - A comparative study. *Food Hydrocolloids*, *27*(1), 175–184.

Choi, W. S., Singh, S., & Lee, Y. S. (2016). Characterization of edible film containing essential oils in hydroxypropyl methylcellulose and its effect on quality attributes of 'Formosa' plum (Prunus salicina L.). *LWT*, *70*, 213–222.

Chouhan, S., Sharma, K., & Guleria, S. (2017). Antimicrobial Activity of Some Essential Oils—Present Status and Future Perspectives. *Medicines*, *4*(3), 58.

Costa, S. S., Druzian, J. I., Aparecida, B., Machado, S., De, C. O., & Guimara, G. (2014). Bi-Functional Biobased Packing of the Cassava Starch , Glycerol , Licuri Nanocellulose and Red Propolis. *PloS one*, *9*(11), e112554.

Cox, S. D., Mann, C. M., Markham, J. L., Bell, H. C., Gustafson, J. E., Warmington, J. R., & Wyllie, S. G. (2000). The mode of antimicrobial action of the essential oil of Melaleuca alternifolia (Tea tree oil). *Journal of Applied Microbiology*, *88*(1), 170–175.

Cruz-Tirado, J. P., Barros Ferreira, R. S., Lizárraga, E., Tapia-Blácido, D. R., Silva, N. C. C., Angelats-Silva, L., & Siche, R. (2020). Bioactive Andean sweet potato starch-based foam incorporated with oregano or thyme essential oil. *Food Packaging and Shelf Life*, *23*(September 2019), 100457.

Dai, L., Qiu, C., Xiong, L., & Sun, Q. (2015). Characterisation of corn starch-based films reinforced with taro starch nanoparticles. *Food Chemistry*, *174*, 82–88.

Dashipour, A., Razavilar, V., Hosseini, H., Shojaee-Aliabadi, S., German, J. B., Ghanati, K., Khakpour, M., & Khaksar, R. (2015). Antioxidant and antimicrobial carboxymethyl cellulose films containing Zataria multiflora essential oil. *International Journal of Biological Macromolecules*, *72*, 606–613.

Dassanayake, R. S., Wansapura, P. T., Tran, P., Hamood, A., & Abidi, N. (2019). Cotton cellulose-CdTe quantum dots composite films with inhibition of biofilm-forming S. aureus. *Fibers*, *7*(6), 57.

Diyana, Z. N., Jumaidin, R., Selamat, M. Z., Ghazali, I., Julmohammad, N., Huda, N., & Ilyas, R. A. (2021). Physical Properties of Thermoplastic Starch Derived from Natural Resources and Its Blends: A Review. *Polymers*, *13*(9), 1–20.

Djunaedy, A. (2008). Systemic fungicide applications and utilization of mycorrhizae in the framework of the soil control of plant pathogens tular soybean (Glycine max L.). *Embryo*, *5*(2), 1–9.

Donsì, F., & Ferrari, G. (2016). Essential oil nanoemulsions as antimicrobial agents in food. *Journal of Biotechnology*, *233*, 106–120.

Dos Santos Caetano, K., Almeida Lopes, N., Haas Costa, T. M., Brandelli, A., Rodrigues, E., Hickmann Flôres, S., & Cladera-Olivera, F. (2018). Characterization of active biodegradable films based on cassava starch and natural compounds. *Food Packaging and Shelf Life*, *16*, 138–147.

Edhirej, A., Sapuan, S. M., Jawaid, M., & Zahari, N. I. (2017a). Effect of various plasticizers and concentration on the physical, thermal, mechanical, and structural properties of cassava-starch-based films. *Starch/Staerke*, *69*(1–2), 1–11.

Edhirej, A., Sapuan, S. M., Jawaid, M., & Zahari, N. I. (2017b). *Preparation and Characterization of Cassava Bagasse Reinforced Thermoplastic Cassava Starch*. *18*(1), 162–171.

El Atki, Y., Aouam, I., El Kamari, F., Taroq, A., Nayme, K., Timinouni, M., Lyoussi, B., & Abdellaoui, A. (2019). Antibacterial activity of cinnamon essential oils and their synergistic potential with antibiotics. *Journal of Advanced Pharmaceutical Technology and Research*, *10*(2), 63–67.

El Fawal, G. F., Omer, A. M., & Tamer, T. M. (2019). Evaluation of antimicrobial and antioxidant activities for cellulose acetate films incorporated with Rosemary and Aloe Vera essential oils. *Journal of Food Science and Technology*, *56*(3), 1510–1518.

Emiroğlu, Z. K., Yemiş, G. P., Coşkun, B. K., & Candoğan, K. (2010). Antimicrobial activity of soy edible films incorporated with thyme and oregano essential oils on fresh ground beef patties. *Meat Science*, *86*(2), 283–288.

Esmael, A., Hassan, M. G., Amer, M. M., Abdelrahman, S., Hamed, A. M., Abd-raboh, H. A., & Foda, M. F. (2020). Antimicrobial activity of certain natural-based plant oils against the antibiotic-resistant acne bacteria. *Saudi Journal of Biological Sciences*, *27*(1), 448–455.

Fakhouri, F. M., Martelli, S. M., Caon, T., Velasco, J. I., Buontempo, R. C., Bilck, A. P., Helena, L., & Mei, I. (2017). The effect of fatty acids on the physicochemical properties of edible films composed of gelatin and gluten proteins. *LWT - Food Science and Technology*, *87*, 293–300.

Felix de Andrade, M., Diego de Lima Silva, I., Alves da Silva, G., David Cavalcante, P. V., Thayse da Silva, F., Bastos de Almeida, Y. M., Vinhas, G. M., & Hecker de Carvalho, L. (2020). A study of poly (butylene adipate-co-terephthalate)/orange essential oil films for application in active antimicrobial packaging. *LWT*, *125*, 109148.

Ferreira, L. R., Rosário, D. K. A., Silva, P. I., Carneiro, J. C. S., Pimentel Filho, N. J., & Bernardes, P. C. (2019). Cinnamon essential oil reduces adhesion of food pathogens to polystyrene. *International Food Research Journal*, *26*(3), 1103–1110.

Feyaerts, A. F., Luyten, W., & Van Dijck, P. (2020). Striking essential oil: tapping into a largely unexplored source for drug discovery. *Scientific Reports*, *10*(1), 2867.

Gao, W., Wu, W., Liu, P., Hou, H., Li, X., & Cui, B. (2020). Preparation and evaluation of hydrophobic biodegradable films made from corn/octenylsuccinated starch incorporated with different concentrations of soybean oil. *International Journal of Biological Macromolecules*, *142*, 376–383.

Ghasemlou, M., Khodaiyan, F., & Oromiehie, A. (2011). Physical, mechanical, barrier, and thermal properties of polyol-plasticized biodegradable edible film made from kefiran. *Carbohydrate Polymers*, *84*(1), 477–483.

Ghoshal, G., & Singh, D. (2020). Synthesis and characterization of starch nanocellulosic films incorporated with Eucalyptus globulus leaf extract. *International Journal of Food Microbiology*, *332*, 108765.

Gómez-Estaca, J., López de Lacey, A., López-Caballero, M. E., Gómez-Guillén, M. C., & Montero, P. (2010). Biodegradable gelatin-chitosan films incorporated with essential oils as antimicrobial agents for fish preservation. *Food Microbiology*, *27*(7), 889–896.

Günkaya, Z., & Banar, M. (2016). An environmental comparison of biocomposite film based on orange peel-derived pectin jelly-corn starch and LDPE film: LCA and biodegradability. *International Journal of Life Cycle Assessment*, *21*(4), 465–475.

Hafsa, J., Smach, M. ali, Ben Khedher, M. R., Charfeddine, B., Limem, K., Majdoub, H., & Rouatbi, S. (2016). Physical, antioxidant and antimicrobial properties of chitosan films containing Eucalyptus globulus essential oil. *LWT - Food Science and Technology*, *68*, 356–364.

Han, J. H., & Krochta, J. M. (1999). (1999). Water vapor permeability and wetting properties of whey protein coating on paper. In *Am Soc Agricul Eng*, *42*, 1375–1382.

Han, Y., Yu, M., & Wang, L. (2018). Physical and antimicrobial properties of sodium alginate / carboxymethyl cellulose fi lms incorporated with cinnamon essential oil. *Food Packaging and Shelf Life*, *15*, 35–42.

Hanani, Z. A. N., Mahony, J. A. O., Roos, Y. H., Oliveira, P. M., & Kerry, J. P. (2014). ScienceDirect Extrusion of gelatin-based composite films : Effects of processing temperature and pH of film forming solution on mechanical and barrier properties of manufactured films. *Food Packaging and Shelf Life*, *2*(2), 91–101.

Hassan, B., Chatha, S. A. S., Hussain, A. I., Zia, K. M., & Akhtar, N. (2018). Recent advances on polysaccharides, lipids and protein based edible films and coatings: A review. *International Journal of Biological Macromolecules*, *109*, 1095–1107.

Hazrati, K. Z., Sapuan, S. M., Zuhri, M. Y. M., & Jumaidin, R. (2021). Effect of plasticizers on physical, thermal, and tensile properties of thermoplastic films based on Dioscorea hispida starch. *International Journal of Biological Macromolecules*, *185*, 219–228.

Hazrol, M. D., Sapuan, S. M., Ilyas, R. A., Othman, M. L., & Sherwani, S. F. K. (2020). Electrical properties of sugar palm nanocrystalline cellulose reinforced sugar palm starch nanocomposites. *Polimery*, *65*(05), 363–370.

Hazrol, M. D., Sapuan, S. M., Zainudin, E. S., Zuhri, M. Y. M., & Wahab, N. I. A. (2021). Corn starch (Zea mays) biopolymer plastic reaction in combination with sorbitol and glycerol. *Polymers*, *13*(2), 1–22.

Helal, I. M., El-Bessoumy, A., Al-Bataineh, E., Joseph, M. R. P., Rajagopalan, P., Chandramoorthy, H. C., & Ben Hadj Ahmed, S. (2019). Antimicrobial Efficiency of Essential Oils from Traditional Medicinal Plants of Asir Region, Saudi Arabia, over Drug Resistant Isolates. *BioMed Research International*, 1–9.

Hoque, M. S., Benjakul, S., & Prodpran, T. (2011). Properties of film from cuttlefish (Sepia pharaonis) skin gelatin incorporated with cinnamon, clove and star anise extracts. *Food Hydrocolloids*, *25*(5), 1085–1097.

Hosseini, S. F., Rezaei, M., Zandi, M., & Farahmandghavi, F. (2015). Bio-based composite edible films containing Origanum vulgare L. essential oil. *Industrial Crops and Products*, *67*, 403–413.

Hosseini, S. F., Rezaei, M., Zandi, M., & Farahmandghavi, F. (2016). Development of bioactive fish gelatin/chitosan nanoparticles composite films with antimicrobial properties. *Food Chemistry*, *194*, 1266–1274.

Iamareerat, B., Singh, M., Sadiq, M. B., & Anal, A. K. (2018). Reinforced cassava starch based edible film incorporated with essential oil and sodium bentonite nanoclay as food packaging material. *Journal of Food Science and Technology*, *55*(5), 1953–1959.

Ilyas, R. A., & Sapuan, S. M. (2020a). The Preparation Methods and Processing of Natural Fibre Bio-polymer Composites. *Current Organic Synthesis*, *16*(8), 1068–1070.

Ilyas, R. A., & Sapuan, S. M. (2020b). Biopolymers and Biocomposites: Chemistry and Technology. *Current Analytical Chemistry*, *16*(5), 500–503.

Ilyas, R. A., Sapuan, S. M., Atiqah, A., Ibrahim, R., Abral, H., Ishak, M. R., Zainudin, E. S., Nurazzi, N. M., Atikah, M. S. N., Ansari, M. N. M., Asyraf, M. R. M., Supian, A. B. M., & Ya, H. (2020). Sugar palm (*Arenga pinnata [Wurmb .] Merr*) starch films containing sugar palm nanofibrillated cellulose as reinforcement: Water barrier properties. *Polymer Composites*, *41*(2), 459–467.

Ilyas, R. A., Sapuan, S. M., Harussani, M. M., Hakimi, M. Y. A. Y., Haziq, M. Z. M., Atikah, M. S. N., Asyraf, M. R. M., Ishak, M. R., Razman, M. R., Nurazzi, N. M., Norrrahim, M. N. F., Abral, H., & Asrofi, M. (2021). Polylactic Acid (PLA) Biocomposite: Processing, Additive Manufacturing and Advanced Applications. *Polymers*, *13*(8), 1326.

Ilyas, R. A., Sapuan, S. M., Ibrahim, R., Abral, H., Ishak, M. R., Zainudin, E. S., Asrofi, M., Atikah, M. S. N., Huzaifah, M. R. M., Radzi, A. M., Azammi, A. M. N., Shaharuzaman, M. A., Nurazzi, N. M., Syafri, E., Sari, N. H., Norrrahim, M. N. F., & Jumaidin, R. (2019). Sugar palm (*Arenga pinnata (Wurmb.*) Merr) cellulosic fibre hierarchy: a comprehensive approach from macro to nano scale. *Journal of Materials Research and Technology*, *8*(3), 2753–2766.

Ilyas, R. A., Sapuan, S. M., Ibrahim, R., Abral, H., Ishak, M. R., Zainudin, E. S., Atikah, M. S. N., Mohd Nurazzi, N., Atiqah, A., Ansari, M. N. M., Syafri, E., Asrofi, M., Sari, N. H., & Jumaidin, R. (2019a). Effect of sugar palm nanofibrillated celluloseconcentrations on morphological, mechanical andphysical properties of biodegradable films basedon agro-waste sugar palm (*Arenga pinnata(Wurmb.) Merr*) starch. *Journal of Materials Research and Technology*, *8*(5), 4819–4830.

Ilyas, R. A., Sapuan, S. M., Ibrahim, R., Abral, H., Ishak, M. R., Zainudin, E. S., Atiqah, A., Atikah, N., Syafri, E., Asrofi, M., & Jumaidin, R. (2020). Thermal, Biodegradability and Water Barrier Properties of Bio-Nanocomposites Based on Plasticised Sugar Palm Starch and Nanofibrillated Celluloses from Sugar Palm Fibres. *Journal of Biobased Materials and Bioenergy*, *14*, 1–13.

Ilyas, R. A., Sapuan, S. M., & Ishak, M. R. (2018). Isolation and characterization of nanocrystalline cellulose from sugar palm fibres (*Arenga Pinnata*). *Carbohydrate Polymers*, *181*, 1038–1051.

Ilyas, R. A., Sapuan, S. M., Ishak, M. R., & Zainudin, E. S. (2018a). Development and characterization of sugar palm nanocrystalline cellulose reinforced sugar palm starch bionanocomposites. *Carbohydrate Polymers*, *202*, 186–202.

Ilyas, R. A., Sapuan, S. M., Ishak, M. R., & Zainudin, E. S. (2018b). Sugar palm nanofibrillated cellulose (*Arenga pinnata (Wurmb.) Merr)*: Effect of cycles on their yield, physic-chemical, morphological and thermal behavior. *International Journal of Biological Macromolecules*, *123*, 379–388.

Ilyas, R. A., Sapuan, S. M., Ishak, M. R., & Zainudin, E. S. (2018c). Water transport properties of bio-nanocomposites reinforced by sugar palm (*Arenga Pinnata*) nanofibrillated cellulose. *Journal of Advanced Research in Fluid Mechanics and Thermal Sciences Journal*, *51*(2), 234–246.

Ilyas, R. A., Sapuan, S. M., Ishak, M. R., & Zainudin, E. S. (2018d). Sugar palm nanocrystalline cellulose reinforced sugar palm starch composite: Degradation and water-barrier properties. *IOP Conference Series: Materials Science and Engineering*, *368*(1), 012006.

Ilyas, R. A., Sapuan, S. M., Ishak, M. R., Zainudin, E. S., & Atikah, M. S. N. (2018a). Characterization of Sugar Palm Nanocellulose and Its Potential for Reinforcement with a Starch-Based Composite. In *Sugar Palm Biofibers, Biopolymers, and Biocomposites* (1st ed.), 189-220, CRC Press/Taylor & Francis Group.

Ilyas, R. A., Sapuan, S. M., Kadier, A., Kalil, M. S., Ibrahim, R., Atikah, M. S. N., Nurazzi, N. M., Nazrin, A., Lee, C. H., Faiz Norrrahim, M. N., Sari, N. H., Syafri, E., Abral, H., Jasmani, L., & Ibrahim, M. I. J. (2020). Properties and Characterization of PLA, PHA, and Other Types of Biopolymer Composites. In F. Al-Oqla & S. M. Sapuan (Eds.), *Advanced Processing, Properties, and Applications of Starch and Other Bio-Based Polymers*, 1st ed., 111–138. Elsevier.

Ilyas, R. A., Sapuan, S. M., Kadier, A., Krishnan, S., Atikah, M. S. N., Ibrahim, R., Nazrin, A., Syafiq, R., Misri, S., Huzaifah, M. R. M., & Hazrol, M. D. (2020). Mechanical Testing of Sugar Palm Fiber Reinforced Sugar Palm Biopolymer Composites. In F. Al-Oqla & S. M. Sapuan (Eds.), *Advanced Processing, Properties, and Applications of Starch and Other Bio-Based Polymers*, 1st ed., 89–110.

Ilyas, R. A., Sapuan, S. M., Norrrahim, M. N. F., Yasim-Anuar, T. A. T., Kadier, A., Kalil, M. S., Atikah, M. S. N., Ibrahim, R., Asrofi, M., Abral, H., Nazrin, A., Syafiq, R., Aisyah, H. A., & Asyraf, M. R. M. (2020). Nanocellulose/Starch Biopolymer Nanocomposites: Processing, Manufacturing, and Applications. In F. Al-Oqla & S. M. Sapuan (Eds.), *Advanced Processing, Properties, and Applications of Starch and Other Bio-Based Polymers*, 1st ed., 65–88, Elsevier.

Ilyas, R. A., Sapuan, S. M., Sanyang, M. L., & Ishak, M. R. (2016). Nanocrystalline cellulose reinforced starch-based nanocomposite: A review. *5th Postgraduate Seminar on Natural Fiber Composites*, 82–87.

Ilyas, R. A., Sapuan, S. M., Sanyang, M. L., Ishak, M. R., & Zainudin, E. S. (2018). Nanocrystalline Cellulose as Reinforcement for Polymeric Matrix Nanocomposites and its Potential Applications: A Review. *Current Analytical Chemistry*, *14*(3), 203–225.

Ilyas, R., Sapuan, S., Atikah, M., Asyraf, M., Rafiqah, S. A., Aisyah, H., Nurazzi, N. M., & Norrrahim, M. (2020). Effect of hydrolysis time on the morphological, physical, chemical, and thermal behavior of sugar palm nanocrystalline cellulose (*Arenga pinnata (Wurmb.) Merr*). *Textile Research Journal*, *91*(1-2), 152-167.

Ishak, M. R., Leman, Z., Sapuan, S. M., Rahman, M. Z. A., & Anwar, U. M. K. (2011). Effects of Impregnation Time on Physical and Tensile Properties of Impregnated Sugar Palm (*Arenga pinnata*) Fibres. *Key Engineering Materials*, *471–472*, 1147–1152.

Ivanič, F., Jochec-Mošková, D., Janigová, I., & Chodák, I. (2017). Physical properties of starch plasticized by a mixture of plasticizers. *European Polymer Journal*, *93*, 843–849.

Jamróz, E., Juszczak, L., & Kucharek, M. (2018). Investigation of the physical properties, antioxidant and antimicrobial activity of ternary potato starch-furcellaran-gelatin films incorporated with lavender essential oil. *International Journal of Biological Macromolecules*, *114*, 1094–1101.

Jouki, M., Khazaei, N., Ghasemlou, M., & Hadinezhad, M. (2013). Effect of glycerol concentration on edible film production from cress seed carbohydrate gum. *Carbohydrate Polymers*, *96*(1), 39–46.

Jouki, M., Yazdi, F. T., Mortazavi, S. A., & Koocheki, A. (2014). Quince seed mucilage films incorporated with oregano essential oil: Physical, thermal, barrier, antioxidant and antibacterial properties. *Food Hydrocolloids*, *36*, 9–19.

Ju, J., Chen, X., Xie, Y., Yu, H., Guo, Y., Cheng, Y., Qian, H., & Yao, W. (2019). Application of essential oil as a sustained release preparation in food packaging. *Trends in Food Science & Technology*, *92*, 22–32.

Jumaidin, R., Adam, N. W., Ilyas, R. A., Hussin, M. S. F., Taha, M. M., Mansor, M. R., Azlan, U. A. A., & Yob, M. S. (2019). Water transport and physical properties of sugarcane bagasse fibre reinforced thermoplastic potato starch biocomposite. *Journal of Advanced Research in Fluid Mechanics and Thermal Sciences*, *61*(2), 273–281, Akademia Baru.

Jumaidin, R., Khiruddin, M. A. A., Asyul Sutan Saidi, Z., Salit, M. S., & Ilyas, R. A. (2019). Effect of cogon grass fibre on the thermal, mechanical and biodegradation properties of thermoplastic cassava starch biocomposite. *International Journal of Biological Macromolecules*, *146*, 746-755.

Kamaliroosta L. (2012). Extraction of cinnamon essential oil and identification of its chemical compounds. *Journal of Medicinal Plants Research*, *6*(4), 609–614.

Kaya, M., Ravikumar, P., Ilk, S., & Mujtaba, M. (2018). Production and characterization of chitosan based edible films from Berberis crataegina's fruit extract and seed oil. *Innovative Food Science and Emerging Technologies*, *45*, 287–297.

Kechichian, V., Ditchfield, C., Veiga-Santos, P., & Tadini, C. C. (2010). Natural antimicrobial ingredients incorporated in biodegradable films based on cassava starch. *LWT - Food Science and Technology*, *43*(7), 1088–1094.

Khalid Haddi, Lêda R.A. Faroni, and E. E. O. (2017). Cinnamon Oil. *Green Pesticides Handbook Essential Oils for Pest Control*, 117–150, CRC Press.

Klimek-Szczykutowicz, Szopa, & Ekiert. (2020). Citrus limon (Lemon) Phenomenon—A Review of the Chemistry, Pharmacological Properties, Applications in the Modern Pharmaceutical, Food, and Cosmetics Industries, and Biotechnological Studies. *Plants*, *9*(1), 119.

Kurt, A., & Kahyaoglu, T. (2014). Characterization of a new biodegradable edible film made from salep glucomannan. *Carbohydrate Polymers*, *104*(1), 50–58.

Laohakunjit, N., & Noomhorm, A. (2004). Effect of plasticizers on mechanical and barrier properties of rice starch film. *Starch/Staerke*, *56*(8), 348–356.

Lee, C. H., Sapuan, S. M., Ilyas, R. A., Lee, S. H., & Khalina, A. (2020). Development and Processing of PLA, PHA, and Other Biopolymers. In F. Al-Oqla & S. M. Sapuan (Eds.), *Advanced Processing, Properties, and Applications of Starch and Other Bio-Based Polymers*, 1st ed., 47–63. Elsevier.

Lee, J. Y., Garcia, C. V., Shin, G. H., & Kim, J. T. (2019). Antibacterial and antioxidant properties of hydroxypropyl methylcellulose-based active composite films incorporating oregano essential oil nanoemulsions. *Lwt*, *106*, 164–171.

Li, J., Ye, F., Lei, L., & Zhao, G. (2018). Combined effects of octenylsuccination and oregano essential oil on sweet potato starch films with an emphasis on water resistance. *International Journal of Biological Macromolecules*, *115*, 547–553.

Li, S., Yi, J., Yu, X., Wang, Z., & Wang, L. (2020). Preparation and characterization of pullulan derivative/chitosan composite film for potential antimicrobial applications. *International Journal of Biological Macromolecules*, *148*, 258–264.

Li, X., Sun, H., Li, S., Chen, S., & Liu, D. (2020). Antibacterial and antioxidant activities of sodium starch octenylsuccinate-based Pickering emulsion films incorporated with cinnamon essential oil. *International Journal of Biological Macromolecules*, *159*, 696–703.

Li, Z.-H., Cai, M., Liu, Y.-S., Sun, P.-L., & Luo, S.-L. (2019). Antibacterial Activity and Mechanisms of Essential Oil from Citrus medica L. var. sarcodactylis. *Molecules*, *24*(8), 1577.

Liakos, I., Rizzello, L., Scurr, D. J., Pompa, P. P., Bayer, I. S., & Athanassiou, A. (2014). All-natural composite wound dressing films of essential oils encapsulated in sodium alginate with antimicrobial properties. *International Journal of Pharmaceutics*, *463*(2), 137–145.

Liang, R., Xu, S., Shoemaker, C. F., Li, Y., Zhong, F., & Huang, Q. (2012). Physical and antimicrobial properties of peppermint oil nanoemulsions. *Journal of Agricultural and Food Chemistry*, *60*(30), 7548–7555.

Liu, X., Xu, Y., Zhan, X., Xie, W., Yang, X., Cui, S. W., & Xia, W. (2020). Development and properties of new kojic acid and chitosan composite biodegradable films for active packaging materials. *International Journal of Biological Macromolecules*, *144*, 483–490.

López, O. V., Castillo, L. A., García, M. A., Villar, M. A., & Barbosa, S. E. (2015). Food packaging bags based on thermoplastic corn starch reinforced with talc nanoparticles. *Food Hydrocolloids*, *43*, 18–24.

López, O. V., Lecot, C. J., Zaritzky, N. E., & García, M. A. (2011). Biodegradable packages development from starch based heat sealable films. *Journal of Food Engineering*, *105*(2), 254–263.

Lu, F., Ding, Y. C., Ye, X. Q., & Ding, Y. T. (2011). Antibacterial effect of cinnamon oil combined with thyme or clove oil. *Agricultural Sciences in China*, *10*(9), 1482–1487.

Lu, Y., Weng, L., & Cao, X. (2005). Biocomposites of plasticized starch reinforced with cellulose crystallites from cottonseed linter. *Macromolecular Bioscience*, *5*(11), 1101–1107.

Luque-Alcaraz, A. G., Cortez-Rocha, M. O., Velázquez-Contreras, C. A., Acosta-Silva, A. L., Santacruz-Ortega, H. D. C., Burgos-Hernández, A., Argüelles-Monal, W. M., & Plascencia-Jatomea, M. (2016). Enhanced Antifungal Effect of Chitosan/Pepper Tree (Schinus molle) Essential Oil Bionanocomposites on the Viability of Aspergillus parasiticus Spores. *Journal of Nanomaterials*, *38*, 38.

M. O. Syafiq, R., Sapuan, S. M., & Zuhri, M. R. M. (2020). Effect of cinnamon essential oil on morphological, flammability and thermal properties of nanocellulose fibre–reinforced starch biopolymer composites. *Nanotechnology Reviews*, *9*(1), 1147–1159.

Ma, W., Tang, C.-H., Yin, S.-W., Yang, X.-Q., Wang, Q., Liu, F., & Wei, Z.-H. (2012). Characterization of gelatin-based edible films incorporated with olive oil. *Food Research International*, *49*(1), 572–579.

Maniglia, B. C., Tessaro, L., Ramos, A. P., & Tapia-Blácido, D. R. (2019). Which plasticizer is suitable for films based on babassu starch isolated by different methods? *Food Hydrocolloids*, *89*, 143–152.

Mathlouthi, M. (2001). Water content, water activity, water structure and the stability of foodstuffs. *Food Control*, *12*(7), 409–417.

Mazani, N., Sapuan, S. M., Sanyang, M. L., Atiqah, A., & Ilyas, R. A. (2019). Design and Fabrication of a Shoe Shelf From Kenaf Fiber Reinforced Unsaturated Polyester Composites. In *Lignocellulose for Future Bioeconomy*, 315–332. Elsevier.

Melo, A. A. M. de, Geraldine, R. M., Silveira, M. F. A., Torres, M. C. L., Rezende, C. S. M. e, Fernandes, T. H., & Oliveira, A. N. de. (2012). Microbiological quality and other characteristics of refrigerated chicken meat in contact with cellulose acetate-based film incorporated with rosemary essential oil. *Brazilian Journal of Microbiology*, *43*(4), 1419–1427.

Menzel, C. (2020). Improvement of starch films for food packaging through a three-principle approach: Antioxidants, cross-linking and reinforcement. *Carbohydrate Polymers*, *250*, 116828.

Mith, H., Duré, R., Delcenserie, V., Zhiri, A., Daube, G., & Clinquart, A. (2014). Antimicrobial activities of commercial essential oils and their components against food-borne pathogens and food spoilage bacteria. *Food Science & Nutrition*, *2*(4), 403–416.

Mohd Nurazzi, N., Asyraf, M. R. M., Khalina, A., Abdullah, N., Sabaruddin, F. A., Kamarudin, S. H., Ahmad, S., Mahat, A. M., Lee, C. L., Aisyah, H. A., Norrrahim, M. N. F., Ilyas, R. A., Harussani, M. M., Ishak, M. R., & Sapuan, S. M. (2021). Fabrication, Functionalization, and Application of Carbon Nanotube-Reinforced Polymer Composite: An Overview. *Polymers*, *13*(7), 1047.

Mohsenabadi, N., Rajaei, A., Tabatabaei, M., & Mohsenifar, A. (2018). Physical and antimicrobial properties of starch-carboxy methyl cellulose film containing rosemary essential oils encapsulated in chitosan nanogel. *International Journal of Biological Macromolecules*, *112*, 148–155.

Mousavi Khaneghah, A., Hashemi, S. M. B., & Limbo, S. (2018). Antimicrobial agents and packaging systems in antimicrobial active food packaging: An overview of approaches and interactions. *Food and Bioproducts Processing*, *111*, 1–19.

Murbach Teles Andrade, B. F., Nunes Barbosa, L., da Silva Probst, I., & Fernandes Júnior, A. (2014). Antimicrobial activity of essential oils. *Journal of Essential Oil Research*, *26*(1), 34–40.

Muscat, D., Adhikari, B., Adhikari, R., & Chaudhary, D. S. (2012). Comparative study of film forming behaviour of low and high amylose starches using glycerol and xylitol as plasticizers. *Journal of Food Engineering*, *109*(2), 189–201.

Mustapha, F. A., Jai, J., Nik Raikhan, N. H., Sharif, Z. I. M., & Yusof, N. M. (2019). Response surface methodology analysis towards biodegradability and antimicrobial activity of biopolymer film containing turmeric oil against Aspergillus niger. *Food Control*, *99*, 106–113.

N. Jain, K. S. Somvanshi, P. C. G. and V. K. S. (2019). Mechanical characterization and machining performance evaluation of rice husk/epoxy an agricultural waste based composite material. *Journal of the Mechanical Behavior of Materials*, *28*(1), 29–38.

Nazari, M., Majdi, H., Milani, M., Abbaspour-Ravasjani, S., Hamishehkar, H., & Lim, L. T. (2019). Cinnamon nanophytosomes embedded electrospun nanofiber: Its effects on microbial quality and shelf-life of shrimp as a novel packaging. *Food Packaging and Shelf Life*, *21*, 100349.

Nazrin, A., Sapuan, S. M., & Zuhri, M. Y. M. (2020). Mechanical, physical and thermal properties of sugar palm nanocellulose reinforced thermoplastic starch (Tps)/poly (lactic acid) (pla) blend bionanocomposites. *Polymers*, *12*(10), 1–18.

Nazrin, A., Sapuan, S. M., Zuhri, M. Y. M., Ilyas, R. A., Syafiq, R., & Sherwani, S. F. K. (2020). Nanocellulose Reinforced Thermoplastic Starch (TPS), Polylactic Acid (PLA), and Polybutylene Succinate (PBS) for Food Packaging Applications. *Frontiers in Chemistry*, *8*(213), 1–12.

Nazrin, A., Sapuan, S. M., Zuhri, M. Y. M., Tawakkal, I. S. M. A., & Ilyas, R. A. (2021). Water barrier and mechanical properties of sugar palm crystalline nanocellulose reinforced thermoplastic sugar palm starch (TPS)/poly(lactic acid) (PLA) blend bionanocomposites. *Nanotechnology Reviews*, *10*(1), 431–442.

Nazzaro, F., Fratianni, F., De Martino, L., Coppola, R., & De Feo, V. (2013). Effect of essential oils on pathogenic bacteria. *Pharmaceuticals*, *6*(12), 1451–1474.

Nielsen, P. V., & Rios, R. (2000). Inhibition of fungal growth on bread by volatile components from spices and herbs, and the possible application in active packaging, with special emphasis on mustard essential oil. *International Journal of Food Microbiology*, *60*(2–3), 219–229.

Nobile, M. A. Del. (2008). Influence of glycerol and chitosan on tapioca starch-based edible film properties. *Journal of Food Engineering*, *88*, 159–168.

Nordin, N., Othman, S. H., Rashid, S. A., & Basha, R. K. (2020). Effects of glycerol and thymol on physical, mechanical, and thermal properties of corn starch films. *Food Hydrocolloids*, *106*, 105884.

Noshirvani, N., Ghanbarzadeh, B., Gardrat, C., Rezaei, M. R., Hashemi, M., Le Coz, C., & Coma, V. (2017). Cinnamon and ginger essential oils to improve antifungal, physical and mechanical properties of chitosan-carboxymethyl cellulose films. *Food Hydrocolloids*, *70*, 36–45.

Nurazzi, N. M., Asyraf, M. R. M., Khalina, A., Abdullah, N., Aisyah, H. A., Rafiqah, S. A., Sabaruddin, F. A., Kamarudin, S. H., Norrrahim, M. N. F., Ilyas, R. A., & Sapuan, S. M. (2021). A Review on Natural Fiber Reinforced Polymer Composite for Bullet Proof and Ballistic Applications. *Polymers*, *13*(4), 646.

Ochs, D. (2000). Antimicrobials. In *Plastic Additives Handbook*, Hanser: Munich, Germany, 647–680.

Ojagh, S. M., Rezaei, M., Razavi, S. H., & Hosseini, S. M. H. (2010). Development and evaluation of a novel biodegradable film made from chitosan and cinnamon essential oil with low affinity toward water. *Food Chemistry*, *122*(1), 161–166.

Oliveira da Silva, A., Cortez-Vega, W. R., Prentice, C., & Fonseca, G. G. (2020). Development and characterization of biopolymer films based on bocaiuva (Acromonia aculeata) flour. *International Journal of Biological Macromolecules*, *155*, 1157–1168.

Omran, A. A. B., Mohammed, A. A. B. A., Sapuan, S. M., Ilyas, R. A., Asyraf, M. R. M., Koloor, S. S. R., & Petrů, M. (2021). Micro- and Nanocellulose in Polymer Composite Materials: A Review. *Polymers*, *13*(2), 231.

Otero, V., Becerril, R., Santos, J. A., Rodríguez-Calleja, J. M., Nerín, C., & García-López, M.-L. (2014). Evaluation of two antimicrobial packaging films against Escherichia coli O157:H7 strains in vitro and during storage of a Spanish ripened sheep cheese (Zamorano). *Food Control*, *42*, 296–302.

Othman, S. H., Edwal, S. A. M., Risyon, N. P., Basha, R. K., & A. Talib, R. (2017). Water sorption and water permeability properties of edible film made from potato peel waste. *Food Science and Technology*, *37*, 63–70.

Othman, S. H., Majid, N. A., Tawakkal, I. S. M. A., Basha, R. K., Nordin, N., & Shapi'i, R. A. (2019). Tapioca starch films reinforced with microcrystalline cellulose for potential food packaging application. *Food Science and Technology*, *39*(3), 605–612.

Oussalah, M., Caillet, S., Salmieri, S., Saucier, L., & Lacroix, M. (2007). Antimicrobial Effects of Alginate-Based Films Containing Essential Oils on Listeria monocytogenes and Salmonella Typhimurium Present in Bologna and Ham. *Journal of Food Protection*, *70*(4), 901–908.

Oussalah, M., Caillet, S., Salmiéri, S., Saucier, L., & Lacroix, M. (2004). Antimicrobial and Antioxidant Effects of Milk Protein-Based Film Containing Essential Oils for the Preservation of Whole Beef Muscle. *Journal of Agricultural and Food Chemistry*, *52*(18), 5598–5605.

Oussalah, M., Caillet, S., Saucier, L., & Lacroix, M. (2006). Antimicrobial effects of selected plant essential oils on the growth of a Pseudomonas putida strain isolated from meat. *Meat Science*, *73*(2), 236–244.

Oussalah, M., Caillet, S., Saucier, L., & Lacroix, M. (2007). Inhibitory effects of selected plant essential oils on the growth of four pathogenic bacteria: E. coli O157:H7, Salmonella Typhimurium, Staphylococcus aureus and Listeria monocytogenes. *Food Control*, *18*(5), 414–420.

Peng, Y., & Li, Y. (2014). Combined effects of two kinds of essential oils on physical, mechanical and structural properties of chitosan films. *Food Hydrocolloids*, *36*, 287–293.

Perdana, M. I., Ruamcharoen, J., Panphon, S., & Leelakriangsak, M. (2021). Antimicrobial activity and physical properties of starch/chitosan film incorporated with lemongrass essential oil and its application. *Lwt*, *141*, 110934.

Perdones, Á., Escriche, I., Chiralt, A., & Vargas, M. (2016). Effect of chitosan–lemon essential oil coatings on volatile profile of strawberries during storage. *Food Chemistry*, *197*, 979–986.

Pirouzifard, M., Yorghanlu, R. A., & Pirsa, S. (2020). Production of active film based on potato starch containing Zedo gum and essential oil of Salvia officinalis and study of physical, mechanical, and antioxidant properties. *Journal of Thermoplastic Composite Materials*, *33*(7), 915–937.

Raeisi, M., Tajik, H., Yarahmadi, A., & Sanginabadi, S. (2015). Antimicrobial Effect of Cinnamon Essential Oil Against Escherichia Coli and Staphylococcus aureus. *Health Scope*, *4*(4), 0–4.

Rattaya, S., Benjakul, S., & Prodpran, T. (2009). Properties of fish skin gelatin film incorporated with seaweed extract. *Journal of Food Engineering*, *95*(1), 151–157.

Raucci, G. L., Lanna, R., Silveira, F. da, & Capitani, H. D. (2019). Developtment of wheater derivatives: evidence from the Brazilian soybean market. *Italian Review of Agricultural Economics*, *74*, 17–28.

Razavi, S. M. A., Mohammad Amini, A., & Zahedi, Y. (2015). Characterisation of a new biodegradable edible film based on sage seed gum: Influence of plasticiser type and concentration. *Food Hydrocolloids*, *43*, 290–298.

Resianingrum R, Atmaka W, Khasanah LU, Kawiji, Utami R, P. D. (2016). Characterization of cassava starch-based edible film enriched with lemongrass oil (Cymbopogon citratus). *Nusantara Bioscience*, *8*(2), 278–282.

Restrepo, A. E., Rojas, J. D., García, O. R., Sánchez, L. T., Pinzón, M. I., & Villa, C. C. (2018). Mechanical, barrier, and color properties of banana starch edible films incorporated with nanoemulsions of lemongrass (Cymbopogon citratus) and rosemary (Rosmarinus officinalis) essential oils. *Food Science and Technology International*, *24*(8), 705–712.

Ribeiro, R., Andrade, M., Melo, N. R. De, & Sanches-, A. (2017). Use of essential oils in active food packaging: recent advances and future trends. *Trends in Food Science & Technology*, *61*, 132–140.

Rojas-Graü, M. A., Avena-Bustillos, R. J., Olsen, C., Friedman, M., Henika, P. R., Martín-Belloso, O., Pan, Z., & McHugh, T. H. (2007). Effects of plant essential oils and oil compounds on mechanical, barrier and antimicrobial properties of alginate-apple puree edible films. *Journal of Food Engineering*, *81*(3), 634–641.

Rosa, M. F., Medeiros, E. S., Malmonge, J. A., Gregorski, K. S., Wood, D. F., Mattoso, L. H. C., Glenn, G., Orts, W. J., & Imam, S. H. (2010). Cellulose nanowhiskers from coconut husk fibers: Effect of preparation conditions on their thermal and morphological behavior. *Carbohydrate Polymers*, *81*(1), 83–92.

Saad, N. Y., Muller, C. D., & Lobstein, A. (2013). Major bioactivities and mechanism of action of essential oils and their components. *Flavour and Fragrance Journal*, *28*(5), 269–279.

Sahari, J., Sapuan, S. M., Zainudin, E. S., & Maleque, M. A. (2012a). A New Approach to Use *Arenga Pinnata* as Sustainable Biopolymer: Effects of Plasticizers on Physical Properties. *Procedia Chemistry*, *4*, 254–259.

Sahari, J., Sapuan, S. M., Zainudin, E. S., & Maleque, M. A. (2012b). Sugar palm tree: A versatile plant and novel source for biofibres, biomatrices, and biocomposites. *Polymers from Renewable Resources*, *3*(2), 61–78.

Sahari, J., Sapuan, S. M., Zainudin, E. S., & Maleque, M. A. (2013a). Effect of water absorption on mechanical properties of sugar palm fibre reinforced sugar palm starch (SPF/SPS) biocomposites. *Journal of Biobased Materials and Bioenergy*, *7*(1), 90-94.

Sahari, J., Sapuan, S. M., Zainudin, E. S., & Maleque, M. A. (2013b). Thermo-mechanical behaviors of thermoplastic starch derived from sugar palm tree (*Arenga pinnata*). *Carbohydrate Polymers*, *92*(2), 1711–1716.

Salarbashi, D., Tajik, S., Ghasemlou, M., Shojaee-Aliabadi, S., Noghabi, M. S., & Khaksar, R. (2013). Characterization of soluble soybean polysaccharide film incorporated essential oil intended for food packaging. *Carbohydrate Polymers*, *98*(1), 1127–1136.

Salgado, P. R., López-Caballero, M. E., Gómez-Guillén, M. C., Mauri, A. N., & Montero, M. P. (2013). Sunflower protein films incorporated with clove essential oil have potential application for the preservation of fish patties. *Food Hydrocolloids*, *33*(1), 74–84.

Salzer, U. J., & Furia, T. E. (1977). The Analysis of Essential Oils and Extracts (Oleoresins) from Seasonings - A Critical Review. *C R C Critical Reviews in Food Science and Nutrition*, *9*(4), 345–373.

Sánchez-González, L., González-Martínez, C., Chiralt, A., & Cháfer, M. (2010). Physical and antimicrobial properties of chitosan-tea tree essential oil composite films. *Journal of Food Engineering*, *98*(4), 443–452.

Sánchez-González, L., Pastor, C., Vargas, M., Chiralt, A., González-Martínez, C., & Cháfer, M. (2011). Effect of hydroxypropylmethylcellulose and chitosan coatings with and without bergamot essential oil on quality and safety of cold-stored grapes. *Postharvest Biology and Technology*, *60*(1), 57–63.

Sánchez Aldana, D., Andrade-Ochoa, S., Aguilar, C. N., Contreras-Esquivel, J. C., & Nevárez-Moorillón, G. V. (2015). Antibacterial activity of pectic-based edible films incorporated with Mexican lime essential oil. *Food Control*, *50*, 907–912.

Sanyang, M. L., Ilyas, R. A., Sapuan, S. M., & Jumaidin, R. (2018). Sugar Palm Starch-Based Composites for Packaging Applications. In *Bionanocomposites for Packaging Applications*, 125–147. Springer International Publishing.

Sanyang, M. L., Sapuan, S. M., Jawaid, M., Ishak, M. R., & Sahari, J. (2015). Effect of plasticizer type and concentration on tensile, thermal and barrier properties of biodegradable films based on sugar palm (*Arenga pinnata*) starch. *Polymers*, *7*(6), 1106–1124.

Sanyang, M. L., Sapuan, S. M., Jawaid, M., Ishak, M. R., & Sahari, J. (2016a). *Effect of plasticizer type and concentration on physical properties of biodegradable films based on sugar palm (arenga pinnata) starch for food packaging*. *53*, 326–336.

Sanyang, M. L., Sapuan, S. M., Jawaid, M., Ishak, M. R., & Sahari, J. (2016b). Effect of sugar palm-derived cellulose reinforcement on the mechanical and water barrier properties of sugar palm starch biocomposite films. *BioResources*, *11*(2), 4134–4145.

Sanyang, M. L., Sapuan, S. M., Jawaid, M., Ishak, M. R., & Sahari, J. (2016c). Development and characterization of sugar palm starch and poly(lactic acid) bilayer films. *Carbohydrate Polymers*, *146*(4), 36–45.

Sapper, M., Wilcaso, P., Santamarina, M. P., Roselló, J., & Chiralt, A. (2018). Antifungal and functional properties of starch-gellan films containing thyme (Thymus zygis) essential oil. *Food Control*, *92*, 505–515.

Sari, N. H., Pruncu, C. I., Sapuan, S. M., Ilyas, R. A., Catur, A. D., Suteja, S., Sutaryono, Y. A., & Pullen, G. (2020). The effect of water immersion and fibre content on properties of corn husk fibres reinforced thermoset polyester composite. *Polymer Testing*, *91*, 106751.

Sarifuddin, N., Shahrim, N. A. A., & Azman, K. S. (2018). Effect of Oregano Essential on the Properties of Mango Kernel Starch Films. *IOP Conference Series: Materials Science and Engineering*, *429*(1), 012062.

SCOPUS. (2020). *Keyword search: starch AND essential oil*. Elsevier. https://www.scopus.com/term/analyzer.uri?sid=6acfe22b5dad630071cfc2cd7a7cc905&origin=resultslist&src=s&s=KEY%28starch%2C+essential+oil%29&sort=plf-f&sdt=b&sot=b&sl=26&count=377&analyzeResults=Analyze+results&txGid=7e906aacd3d4cfd70dc34ee3dd63f01af

Sedaghat Doost, A., Nikbakht Nasrabadi, M., Kassozi, V., Nakisozi, H., & Van der Meeren, P. (2020). Recent advances in food colloidal delivery systems for essential oils and their main components. *Trends in Food Science & Technology*, *99*, 474–486.

Shahbazi, Y. (2017). The properties of chitosan and gelatin films incorporated with ethanolic red grape seed extract and Ziziphora clinopodioides essential oil as biodegradable materials for active food packaging. *International Journal of Biological Macromolecules*, *99*, 746–753.

Shankaranarayana, M. L., Raghavan, B., Abraham, K. O., & Natarajan, C. P. (1981). Titrimetric Determination of Total Aldehydes in Cinnamon Bark and Leaf Oils Using Chloramine-T Reagent. *Journal of Food Quality*, *4*(1), 35–41.

Shojaee-Aliabadi, S., Hosseini, H., Mohammadifar, M. A., Mohammadi, A., Ghasemlou, M., Ojagh, S. M., Hosseini, S. M., & Khaksar, R. (2013). Characterization of antioxidant-antimicrobial κ-carrageenan films containing Satureja hortensis essential oil. *International Journal of Biological Macromolecules*, *52*, 116–124.

Silva, J. B. A., Pereira, F. V, & Druzian, J. I. (2012). *Cassava Starch-Based Films Plasticized with Sucrose and Inverted Sugar and Reinforced with Cellulose Nanocrystals*. *77*(6), 14–19.

Silveira, M. P., Silva, H. C., Pimentel, I. C., Poitevin, C. G., da Costa Stuart, A. K., Carpiné, D., de Matos Jorge, L. M., & Jorge, R. M. M. (2019). Development of active cassava starch cellulose nanofiber-based films incorporated with natural antimicrobial tea tree essential oil. *Journal of Applied Polymer Science*, *48726*(21), 1–11.

Song, X., Zuo, G., & Chen, F. (2018). Effect of essential oil and surfactant on the physical and antimicrobial properties of corn and wheat starch films. *International Journal of Biological Macromolecules*, *107*, 1302–1309.

Souza, A. C., Goto, G. E. O., Mainardi, J. A., Coelho, A. C. V., & Tadini, C. C. (2013). Cassava starch composite films incorporated with cinnamon essential oil: Antimicrobial activity, microstructure, mechanical and barrier properties. *LWT - Food Science and Technology*, *54*(2), 346–352.

Suderman, N., Isa, M. I. N., & Sarbon, N. M. (2018). The effect of plasticizers on the functional properties of biodegradable gelatin-based film: A review. *Food Bioscience*, *24*, 111–119.

Sun, L., Sun, J., Chen, L., Niu, P., Yang, X., & Guo, Y. (2017). Preparation and characterization of chitosan film incorporated with thinned young apple polyphenols as an active packaging material. *Carbohydrate Polymers*, *163*, 81–91.

Suppakul, P., Chalernsook, B., Ratisuthawat, B., Prapasitthi, S., & Munchukangwan, N. (2013). Empirical modeling of moisture sorption characteristics and mechanical and barrier properties of cassava flour film and their relation to plasticizing-antiplasticizing effects. *LWT - Food Science and Technology*, *50*(1), 290–297.

Suppakul, P., Miltz, J., Sonneveld, K., & Bigger, S. W. (2003). Antimicrobial properties of basil and its possible application in food packaging. *Journal of Agricultural and Food Chemistry*, *51*(11), 3197–3207.

Šuput, D., Lazić, V., Pezo, L., Markov, S., Vaštag, Ž., Popović, L., Radulović, A., Ostojić, S., Zlatanović, S., & Popović, S. (2016). Characterization of starch edible films with different essential oils addition. *Polish Journal of Food and Nutrition Sciences*, *66*(4), 277–285.

Syafiq, R., Sapuan, S. M., & Zuhri, M. R. M. (2021). Antimicrobial activity, physical, mechanical and barrier properties of sugar palm based nanocellulose/starch biocomposite films incorporated with cinnamon essential oil. *Journal of Materials Research and Technology*, *11*, 144–157.

Syafiq, R., Sapuan, S. M., Zuhri, M. Y. M., Ilyas, R. A., Nazrin, A., Sherwani, S. F. K., & Khalina, A. (2020). Antimicrobial activities of starch-based biopolymers and biocomposites incorporated with plant essential oils: A review. *Polymers*, *12*(10), 1–26.

Syafri, E., Sudirman, Mashadi, Yulianti, E., Deswita, Asrofi, M., Abral, H., Sapuan, S. M., Ilyas, R. A., & Fudholi, A. (2019). Effect of sonication time on the thermal stability, moisture absorption, and biodegradation of water hyacinth (Eichhornia crassipes) nanocellulose-filled bengkuang (Pachyrhizus erosus) starch biocomposites. *Journal of Materials Research and Technology*, *8*(6), 6223–6231.

Taban, A., Saharkhiz, M. J., & Khorram, M. (2020). Formulation and assessment of nano-encapsulated bioherbicides based on biopolymers and essential oil. *Industrial Crops and Products*, *149*, 112348.

Taghizadeh, M., Sabouri, N., & Ghanbarzadeh, B. (2013). Polyvinyl alcohol:starch:carboxymethyl cellulose containing sodium montmorillonite clay blends; mechanical properties and biodegradation behavior. *SpringerPlus*, *2*(1), 376.

Takala, P. N., Vu, K. D., Salmieri, S., Khan, R. A., & Lacroix, M. (2013). Antibacterial effect of biodegradable active packaging on the growth of Escherichia coli, Salmonella typhimurium and Listeria monocytogenes in fresh broccoli stored at 4 °C. *LWT - Food Science and Technology*, *53*(2), 499–506.

Tao, C., Wang, Y., Zhang, X., Li, L., Wu, Y., & … X. H.-. (2019). Mechanism of Action of Essential Oils Extracted from Bamboo (Phyllostachys heterocycla cv. pubescens) Leaves: Chemical Composition and Antimicrobial Activity. *BioResources*, *14*(1), 1419–1434.

Tapia-Blácido, D. R., Sobral, P. J. d. A., & Menegalli, F. C. (2013). Effect of drying conditions and plasticizer type on some physical and mechanical properties of amaranth flour films. *LWT - Food Science and Technology*, *50*(2), 392–400.

Tarique, J., Sapuan, S. M., & Khalina, A. (2021). Effect of glycerol plasticizer loading on the physical, mechanical, thermal, and barrier properties of arrowroot (Maranta arundinacea) starch biopolymers. *Scientific Reports*, *11*(1), 1–17.

Teymourpour, S., Abdorreza, M. N., & Nahidi, F. (2015). Functional, thermal, and antimicrobial properties of soluble soybean polysaccharide biocomposites reinforced by nano TiO2. *Carbohydrate Polymers*, *134*, 726–731.

Thakur, R., Pristijono, P., Scarlett, C. J., Bowyer, M., Singh, S. P., & Vuong, Q. V. (2019). Starch-based films: Major factors affecting their properties. *International Journal of Biological Macromolecules*, *132*, 1079–1089.

Tongnuanchan, P., & Benjakul, S. (2014). Essential Oils: Extraction, Bioactivities, and Their Uses for Food Preservation. *Journal of Food Science*, *79*(7), 1231–1249.

Tongnuanchan, P., Benjakul, S., & Prodpran, T. (2013). Physico-chemical properties, morphology and antioxidant activity of film from fish skin gelatin incorporated with root essential oils. *Journal of Food Engineering*, *117*(3), 350–360.

Tongnuanchan, P., Benjakul, S., Prodpran, T., Pisuchpen, S., & Osako, K. (2016). Mechanical, thermal and heat sealing properties of fish skin gelatin film containing palm oil and basil essential oil with different surfactants. *Food Hydrocolloids*, *56*, 93–107.

Tunç, S., & Duman, O. (2010). Preparation and characterization of biodegradable methyl cellulose/montmorillonite nanocomposite films. *Applied Clay Science*, *48*(3), 414–424.

Tunç, S., & Duman, O. (2011). Preparation of active antimicrobial methyl cellulose/carvacrol/montmorillonite nanocomposite films and investigation of carvacrol release. *LWT - Food Science and Technology*, *44*(2), 465–472.

Tunç, S., Duman, O., & Polat, T. G. (2016). Effects of montmorillonite on properties of methyl cellulose/carvacrol based active antimicrobial nanocomposites. *Carbohydrate Polymers*, *150*, 259–268.

Turek, C., & Stintzing, F. C. (2013). Stability of essential oils: A review. *Comprehensive Reviews in Food Science and Food Safety*, *12*(1), 40–53.

Utami, R., Khasanah, L. U., Manuhara, G. J., & Ayuningrum, Z. K. (2019). Effects of cinnamon bark essential oil (cinnamomum burmannii) on characteristics of edible film and quality of fresh beef. *Pertanika Journal of Tropical Agricultural Science*, *42*(4), 1173–1184.

Vilay, V., Mariatti, M., Mat Taib, R., & Todo, M. (2008). Effect of fiber surface treatment and fiber loading on the properties of bagasse fiber-reinforced unsaturated polyester composites. *Composites Science and Technology*, *68*(3–4), 631–638.

Vu, K. D., Hollingsworth, R. G., Leroux, E., Salmieri, S., & Lacroix, M. (2011). Development of edible bioactive coating based on modified chitosan for increasing the shelf life of strawberries. *Food Research International*, *44*(1), 198–203.

Wińska, K., Mączka, W., Łyczko, J., Grabarczyk, M., Czubaszek, A., & Szumny, A. (2019). Essential oils as antimicrobial agents—myth or real alternative. *Molecules*, *24*(11), 1–21.

Wong, Y., Ahmad-Mudzaqqir, M., & Wan-Nurdiyana, W. (2014). Extraction of Essential Oil from Cinnamon (Cinnamomum zeylanicum). *Oriental Journal of Chemistry*, *30*(1), 37–47.

Wongphan, P., & Harnkarnsujarit, N. (2020). Characterization of starch, agar and maltodextrin blends for controlled dissolution of edible films. *International Journal of Biological Macromolecules*, *156*, 80–93.

Xu, Y. X., Kim, K. M., Hanna, M. A., & Nag, D. (2005). Chitosan-starch composite film: Preparation and characterization. *Industrial Crops and Products*, *21*(2), 185–192.

Yun, J., Fan, X., Li, X., Jin, T. Z., Jia, X., & Mattheis, J. P. (2015). Natural surface coating to inactivate Salmonella enterica serovar Typhimurium and maintain quality of cherry tomatoes. *International Journal of Food Microbiology*, *193*, 59–67.

Zerrifi, S. E. A., Kasrati, A., Redouane, E. M., Tazart, Z., Khalloufi, F. El, Abbad, A., Oudra, B., Campos, A., & Vasconcelos, V. (2020). Essential oils from Moroccan plants as promising ecofriendly tools to control toxic cyanobacteria blooms. *Industrial Crops and Products*, *143*, 111922.

Zeuthen Peter, and L. B.-S. (Eds) (2003). *Food preservation techniques*. Elsevier.

Zhang, Y., Liu, X., Wang, Y., Jiang, P., & Quek, S. Y. (2016). Antibacterial activity and mechanism of cinnamon essential oil against Escherichia coli and Staphylococcus aureus. *Food Control*, *59*, 282–289.

Zhang, Y., Rempel, C., & Liu, Q. (2014). Thermoplastic Starch Processing and Characteristics-A Review. *Critical Reviews in Food Science and Nutrition*, *54*(10), 1353–1370.

Zhou, Y., Wu, X., Chen, J., & He, J. (2021). Effects of cinnamon essential oil on the physical, mechanical, structural and thermal properties of cassava starch-based edible films. *International Journal of Biological Macromolecules*, *184*, 574–583.

Zinoviadou, K. G., Koutsoumanis, K. P., & Biliaderis, C. G. (2009). Physico-chemical properties of whey protein isolate films containing oregano oil and their antimicrobial action against spoilage flora of fresh beef. *Meat Science*, *82*(3), 338–345.

LIST OF PUBLICATIONS

Journal articles

R. Syafiq, S.M. Sapuan, M.Y.M. Zuhri, Antimicrobial activity, physical, mechanical and barrier properties of sugar palm based nanocellulose/starch biocomposite films incorporated with cinnamon essential oil, Journal of Materials Research and Technology (JMRT), vol. 11, 144-157, 2021, (IF= 5.039) Q1 in JCR. (Chapter 4 of the thesis)

R.M.O Syafiq, S.M. Sapuan, M.Y.M. Zuhri, Effect of cinnamon essential oil on morphological, flammability and thermal properties of nanocellulose fibre reinforced starch biopolymer composites, Nanotechnology reviews , vol.9, 1147-1159,2020,(IF= 3.639) Q1 in JCR. (Chapter 5 of the thesis)

Razali M. O. Syafiq, Salit Mohd Sapuan*, Mohamed Yusoff Mohd Zuhri, Siti H. Othman, and Rushdan Ahmad Ilyas, Effect of plasticizers on the properties of sugar palm nanocellulose/cinnamon essential oil reinforced starch bionanocomposite films, Nanotechnology reviews ,(IF= 7.848) Q1 in JCR, Accepted. (Chapter 6 of the thesis)

R.M.O. Syafiq, S.M. Sapuan, M.Y.M. Zuhri, S.H. Othman, R.A. Ilyas, Water barrier and biodegradable properties of cinnamon essential oil/sugar palm nanocellulose/starch biopolymer composites, Physical Sciences Reviews (Scopus index), Accepted. (Chapter 7 of the thesis)

Review papers

R. Syafiq, S.M. Sapuan, M.Y.M. Zuhri, R.A. Ilyas, A. Nazrin, S.F.K. Sherwani, A. Khalina, Antimicrobial activities of starch-based biopolymers and biocomposites incorporated with plant essential oils: A review, Polymers 2020, 12(10), 2403, (IF = 3.426) Q1 in JCR

A. Nazrin, S.M. Sapuan, M.Y.M. Zuhri, R.A. Ilyas, R. Syafiq, S.F.K. Sherwani, Nanocellulose Reinforced Thermoplastic Starch (TPS), Polylactic Acid (PLA), and Polybutylene Succinate (PBS) for Food Packaging Applications, Frontier in Chemistry 2020, 8:213, (IF=3.782) (Q2)

Chapter in Book

RA Ilyas, SM Sapuan, W Kirubaanand, ZM Zahfiq, MSN Atikah, R Ibrahim, AM Radzi, R Nadlene, MRM Asyraf, MD Hazrol, SFK Sherwani, MM Harussani, J Tarique, A Nazrin, R Syafiq, Chapter 1-Roselle: Production, Product Development, and Composites, Roselle, 2021, Pages 1-23.

Norrrahim MN, Sapuan SM, Yasim-Anuar TA, Padzil FN, Sharip NS, Ng LY, Megashah LN, Shazleen SS, Rahim NF, Syafiq R, Ilyas RA., Antimicrobial Studies on Food Packaging Materials., Food Packaging. 2020 Oct 21:141-70

Ilyas RA, Sapuan SM, Atikah MS, Ibrahim R, Syafiq R, Hazrol MD, Nazrin A, Ibrahim MI., Tensile Properties of Sugar Palm Fiber-Reinforced Polymer Composites: A Comprehensive Review, Biofiller-Reinforced Biodegradable Polymer Composites. 2020 Oct 28:243-66

R.A. Ilyas, S.M. Sapuan, Mohd Nor Faiz Norrahim, Tengku Aisyah Tengku Yasim-Anuar, Abudukeremu Kadier, Mohd Sahaid Kalil, M.S.N Atikah, R. Ibrahim, Mochamad Asrofi, Hairul Abral, A. Nazrin, R. Syafiq, H.A. Aisyah, and M.R.M. Asyraf, Chapter 6: Nano-cellulose/starch biopolymer nanocomposites: Processing, manufacturing and application, Advanced Processing, Properties, and Application of Starch and Other Bio-based Polymers (Editor: Faris. M. Al-Oqla and S.M. Sapuan), Elsevier Inc., Amsterdam, Netherlands, 2020, pp. 65-88, ISBN 978-012-819661-8.

R.A. Ilyas, S.M. Sapuan, Abudukeremu Kadier, Santhana Krishnan, M.S.N Atikah, R. Ibrahim, A. Nazrin, R. Syafiq, S. Misri, M.R.M. Huzaifah, and M.D. Hazrol., Chapter 7, Mechanical testing of sugar palm fibre reinforced sugar palm biopolymer composites, in Advanced Processing, Properties, and Application of Starch and Other Bio-based Polymers, (Editor: Faris. M. Al-Oqla and S.M. Sapuan), Elsevier Inc., Amsterdam, Netherlands, 2020, pp. 65-88, ISBN 978-012-819661-8.

R.A. Ilyas, S.M. Sapuan, M.S.N Atikah, R. Ibrahim, R. Syafiq, M.D. Hazrol, A. Nazrin, S. Misri, and M.I.J. Ibrahim, Chapter 14: Tensile Properties, of sugar palm fibre-reinforced polymer composites: A Comprehensive review, Biofiller-Reinforced Biodegradable Polymer Composites (Editor: R. Jumaidin, S.M. Sapuan and I. Hanafi), CRC Press, Boca Raton, USA, pp. 227-242, 2021 ISBN 978-0-367-27264-7.

Conferences/ Seminar

R. Syafiq, S.M. Sapuan, M.Y.M. Zuhri, R.A. Ilyas, A. Nazrin, Antimicrobial properties of starch biopolymer composites incorporated with lemon, peppermint and cinnamon essential, Proceedings of the 7th Postgraduate Seminar on Natural Fibre Reinforced Polymer Composites 2020, 17 Nov 2020, INTROP, UPM Serdang, Selangor, Malaysia, pp. 2-9 ISSN 2735-1246.

R. Syafiq, S.M. Sapuan, M.Y.M. Zuhri, R.A. Ilyas, A. Nazrin, Formulation of anti-microbacterial agent reinforced starch nanocomposites: a review, Prosiding Seminar Enau Kebangsaan 1-2 April 2019, pp. 2-11, ISBN 978-983-44426-8-2

R. Syafiq, S.M. Sapuan, M.Y.M. Zuhri, R.A. Ilyas, A. Nazrin, Mechanical properties of anti-microbacterial agent reinforced starch nanocomposites: a review, 2nd Wood & Biofibre International Conference (WOBIC2019)

R. Syafiq, S.M. Sapuan, M.Y.M. Zuhri, R.A. Ilyas, A. Nazrin, Water Barrier Properties of Anti-Microbacterial Agent Reinforced Starch Nanocomposites: A Review, 2nd

International Conference on Advances in Mechanical and Manufacturing Engineering (ICAM2E) 2019

R.A. Ilyas, S.M. Sapuan, Mohd Nurrazi Norizan, M.S.N Atikah, M.R.M. Huzaifah, A.M. Radzi, M.R. Ishak, E.S. Zainudin, S. Izwan, A.M. Noor Azammi, R. Jumaidin, Ainun Zuriyati Mohamed, R. Syafiq, A. Nazrin, A. Atiqah, Potential of natural fibre composites for transport industry: a review, Prosiding Seminar Enau Kebangsaan, 1-2 April 2019, pp. 2-11, ISBN 978-983-44426-8-2

R.A. Ilyas, S.M. Sapuan, M.S.N Atikah, R. Ibrahim, M.D. Hazrol, S.F.K. Sherwani, M.M. Harussani, T. Jamal, A. Nazrin and R. Syafiq, Natural Fibre: A promising source for the production of nanocellulose, Proceedings of the 7th Postgraduate Seminar on Natural Fibre Reinforced Polymer Composites 2020, 17 Nov 2020, INTROP, UPM Serdang, Selangor, Malaysia, pp. 2-9 ISSN 2735-1246

S.F.K. Sherwani, S.M. Sapuan, Z. Leman, E.S. Zainudin, A. Khalina, R.A. Ilyas, R. Syafiq, Water absorption behaviour and diffusion coefficient of sugar palm fibre reinforced polylactic acid composites, Proceedings of the 7th Postgraduate Seminar on Natural Fibre Reinforced Polymer Composites 2020, 17 Nov 2020, INTROP, UPM Serdang, Selangor, Malaysia, pp. 2-9 ISSN 2735-1246

R.A. Ilyas, S.M. Sapuan, A. Nazrin, R. Syafiq, M.S.N Atikah, R. Ibrahim, Tensile properties of sugar palm fibre reinforced polymer composites: review, Second Wood and Biofibre International Conference (WOBIC 2019), 3-5 December 2019, The Premonade Hotel, Kota Kinabalu, Sabah, Malaysia, abstract published in Book of Abstract, p.87

A. Nazrin, R.A. Ilyas, S.M. Sapuan, R. Syafiq, Tensile properties of sugar palm fibre reinforced polymer composites: review, Second Wood and Biofibre International Conference (WOBIC 2019), 3-5 December 2019, The Premonade Hotel, Kota Kinabalu, Sabah, Malaysia, abstract published in Book of Abstract, p. 106

R.A. Ilyas, S.M. Sapuan, A. Nazrin, R. Syafiq, M.S.N Atikah, R. Ibrahim, Nanocellulose based functional materials for packaging application, Second International Conference on Advances Mechanical and Manufacturing Engineering (ICAM2E), 21-23 October 2019, Langkawi, Malaysia.

A. Nazrin, R.A. Ilyas, S.M. Sapuan, R. Syafiq, Water barrier properties of nanocellulose/starch reinforced poly (butylene succinate) (PBS) bionanocomposites: A review, Second International Conference on Advances Mechanical and Manufacturing Engineering (ICAM2E), 21-23 October 2019, Langkawi, Malaysia

Book

S.M. Sapuan, R. Syafiq, Book: Fibre Plants of Malaysia, (To be published)