Palm-based Materials: Renewable Resources for Film and Coating Technology

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INTRODUCTION

Palm oil is the world's most actively traded oil and remains a highly demanded vegetable oil for meeting the need to fulfill the market requirements of oils and fats worldwide. This trend can be witnessed by the steadily increasing supply of palm oil over the past years with intriguing developments in the up-, mid- and downstream sectors. According to Rabobank (2016), industry analysts predicted that the global demand for edible oils will quadruple between now and 2050, with 60% of that demand being contributed by palm oil.

Exploring the utilisation of palm-based materials as promising, versatile, renewable and bio-degradable resources has steered research towards the formulation and development of biodegradable palm-based films and coatings as alternatives to the mineral-based materials. This is achieved through multi-disciplinary approaches for research and development in food technology, oleo-chemistry, biotechnology and engineering. Hence, the purpose of this article is to highlight the prospects of palm oil and its derivatives as renewable resources in making films and coatings for both edible and non-edible applications.

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PALM OIL AS A POTENTIAL CONTENDER IN COATING MATERIALS

Classification of Oils

Plant oils can be classified as drying, semi-drying and non-drying oils according to their iodine value, *i.e.* a measurement of their degree of unsaturation (Koleske, 1995). This inherent property of oils is influenced by the amount and characteristics of the carbon-carbon double bond (C=C) functionality present, *i.e.* the conjugation and geometrical arrangement of the substituents about the double bonds. A high iodine value indicates a high level of unsaturation, which makes a molecule more reactive. The classification of oils based on their iodine value has been defined by Rheineck and Austin (1968) as can be seen in *Table 1*.

TABLE 1. CLASSIFICATION OF OILS BY IODINE VALUE

Oil class	Iodine value
Drying oil	> 140
Semi-dry	125 – 140
Non-drying oil	< 125

Source: Rheineck and Austin (1968).

Each vegetable oil has a different chemical composition with a different degree of unsaturation, thus leading to different behavior. The classification of selected plant oils is shown in *Table 2.*

Palm oil, one of the major vegetable oils, falls into the non-drying oil category because of its low iodine value which is contributed by the balanced amounts of saturated (palmitic acid) and unsaturated (oleic acid) fatty acids (*Table 2*). This means the oil will not form a coating film upon exposure to air. Hence, using palm oil in its original form as a coating material is not really promising. Nevertheless, this can be countered by derivatisation of

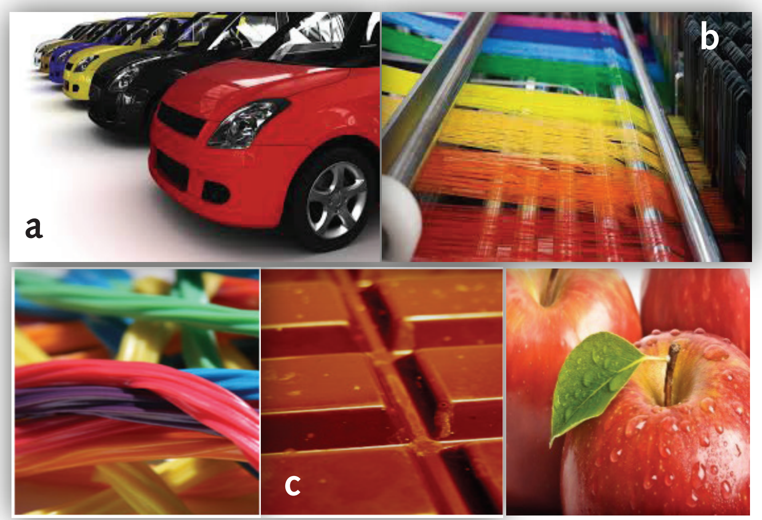

Figure 1. Examples of the film and coating industry: (a) automotive; (b) textile; and (c) food.

TABLE 2. CLASSIFICATION OF SELECTED VEGETABLE OILS

Oil	Major fatty acid	Iodine value	Classification
Linseed	Linolenic, C18:2 (51%-60%)	175 – 195	Drying oil
Wood/Tung	Eleostearic, C18:3 conj. (78%-82%)	158 – 180	Drying oil
Safflower	Linoleic, C18:2 (70%-80%)	135 – 148	Semi-drying oil
Soyabean	Linoleic, C18:2 (50%-56%)	129 – 143	Semi-drying oil
Sunflower	Linoleic, C18:2 (56%-70%)	112 – 138	Semi-drying oil
Rapeseed	Oleic, C18:1 (56%-62%)	100 – 125	Non-drying oil
Rapeseed	Erucic, C22:1 (45%-55%)	100 – 120	Non-drying oil
Arachis	Oleic, C18:1 (35%-45%);	85 – 105	Non-drying oil
(Groundnut)	Linoleic, C18:2 (35%-45%)		
Castor	Ricinoleic, C18:1 OH (83%-90%)	82 – 90	Non-drying oil
Palm[a]	Palmitic, C16:0 (39%-46%);	50 – 54	Non-drying oil
	Oleic, C18:1 (37%-44%)		
Palm kernel[a]	Lauric acid, C12:0 (46%-51%)	16 – 19	Non-drying oil

Source: [a]Obtained from Anon (2016).

the palm oil at the reactive sites, namely, the double bond and carboxylic acid functionalities (Alam *et al.*, 2014), or by incorporation of other additives.

BIODEGRADABLE FILMS AND COATINGS: NON-EDIBLE AND EDIBLE

Biodegradable films and coatings represent an interesting alternative to conventional plastic materials which are derived from petroleum by-products. Coating is a process in which a substance is applied to the surface of other materials to change their surface properties, such as colour, gloss, resistance to wear or chemical attack, or permeability, without changing the bulk properties. Surface coatings involve the formation of a thin film upon application, and the curing (or drying) of any mixture of film-forming materials plus pigments, solvents, and other additives, including such materials as paints, varnishes, enamels, oils, greases, waxes, concrete, lacquers, powder coatings, metal coatings and fire-retardant formulations (Anon., 2002). Edible coatings and films, on the other hand, are defined as primary packaging that directly coats food, or are formed into a film and used as a food-active or biopackaging material, without changing the characteristics of the original ingredients or the processing techniques. The thin layer of material used in edible coatings and films provides a barrier against moisture and gas, improves the mechanical properties, sensory perceptions, convenience and microbial protection, as well as prolongs the shelf life of various food products (Galus and Kadzińska, 2015; Falguera *et al.*, 2011; Krochta, 2002; Debeaufort *et al.*, 1998).

The efficiency of the films and coatings depends on the nature of the lipid used, and particularly its structure and functional properties, chemical arrangement and polarity, length of aliphatic chains, the degree of unsaturation, physical state (solid or liquid) and lipid interactions with incorporated components such as proteins, polysaccharides or combinations of these components (Galus and Kadzińska, 2015; Rhim and Shellhammer, 2005; Morillon *et al.*, 2002). As edible coatings or films will be consumed, the components used should be generally recognised as safe (GRAS), approved by the US Food and Drug Administration (FDA), and must comply to the regulations that apply to the food product concerned (FDA, 2016; Dhall, 2013; Vargas *et al.*, 2008; Krochta and Mulder-Johnston, 1997; Guilbert *et al.*, 1996 and 1995; Park *et al.*, 1994).

APPLICATIONS OF PALM-BASED FILMS AND COATINGS

Here, we highlight the potential applications of palm-based film and coating materials according to previous and current studies.

Non-edible Coating Applications

Some of the previous studies on the use of palm-based materials for non-edible coating applications are summarised below:

i) Anti-corrosion coating (Taharim and Jai, 2012; Taharim *et al.*, 2012)
ii) Wood coating (Ghani *et al.*, 2009)
iii) Polyol coating (Yeong *et al.*, 2012, Hoong *et al.*, 2005)
iv) Polyurethane (PU) coating (Rajput *et al.*, 2014; Yeong *et al.*, 2012)

Edible Coating Applications

These technologies find applications for palm-based edible coatings as follows:

i) Fruits and vegetables (Nurul Hanani *et al.*, 2012; Vargas *et al.*, 2006; Ayranci and Tunc, 2004)
ii) Meat and poultry products (Stuchell and Krochta, 1995)
iii) Confectionery fat products (Goh, 1994)
iv) Frozen products (Rico-Peña and Torres, 1991)
v) Bakery products (Galus and Kadzińska, 2015; Talens *et al.*, 2012)
vi) Pharmaceuticals (Amin *et al.*, 2007)

FUTURE PROSPECTS FOR PALM-BASED FILMS AND COATINGS

In advanced coating technologies, petroleum-based coatings such as coal-tar epoxies are the major key player fulfilling the demand for more durable and hard-wearing products. However, due to impending depletion of this non-renewable resource and growing environmental concern over the use of fossil fuels, current research efforts are being directed towards producing coatings from renewable resources.

Legal requirements have been imposed in favor of environment-compatible coating processes such as the 1999 EU directive which led to the introduction of water-based paints and powder coatings (Goldschmmidt and Streitberger, 2003). Biodegradability, availability and non-toxicity are among the attractive properties of palm-based derivatives for use as 'green' and renewable coating materials. However, the difficulties encountered in processing for industrial-scale exploitation require the development of more efficient and low-cost technologies (Rastogi and Samyn, 2015).

Meanwhile, in an edible coating study, the scope of nanotechnology coatings, such as nanoencapsulation and multi-layered systems, may help in the incorporation and/or controlled release of active compounds (anti-microbials, texture enhancers and nutraceuticals) to improve the quality and functionality of fresh-fruit cuts under specific conditions (Rastogi and Samyn, 2015; Dhall, 2013; Zambrano-Zaragoza *et al.*, 2011). Besides that, there have been coatings developed with improved functional characteristics which are compatible with or will enhance the properties of the fruit or fresh products to be preserved (Dhall, 2013; Marsh and Bugusu, 2007).

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