amounts of antimicrobial proteins and peptides (e.g., uromodulin, RNase 7, and antimicrobial peptides), particularly as a consequence of urinary tract inflammation (e.g., [11]). Including such factors into a biofilm model, however, is difficult because of high costs and challenges in the purification of such peptides and proteins. In addition, factors such as temperature, shear stress (i.e., flow vs static conditions), and osmolarity can influence the outcome of an *in vitro* biofilm study. In some settings, continuous medium flow is closer to reality compared to static growth conditions because, in many cases, antimicrobials can elute in a single burst of release, with a subsequent loss of functionality of the bioactive coating.

In a biological environment, (antimicrobial) devices are in contact with biotic interphases, such as epithelial cells and/or biological fluids. Extracellular polymeric substances (EPS), whether host- or bacteria-derived, as well as cellular debris, can compromise the performance of antimicrobials by acting as scavengers [12]. These EPS and cell debris can also cover the antimicrobial surfaces, increasing bacterial attachment and shielding the bacteria. In some studies, small percentages of serum are added to the medium, which is a step in the right direction [13].

Even higher complexity can be added to a biofilm model once the interactions with the host cells are taken into account. For example, an *in vitro* model including bacteria, osteoblast-like cells, and macrophages for bone-implant testing has been reported to possess the features concurring with clinical observations [14]. Damage of the host cells by the presence of biomaterials may play a key role in susceptibility to bacterial infections. In the urinary tract, cell surfaces are covered by a mucoid layer of glycoproteins (i.e., the uroplakins) that reduce friction forces and serve as an antimicrobial barrier. The presence of medical devices such as ureteral stents or catheters may compromise the cells, particularly when an abrasive crystalline biofilm has formed on the medical device. As a consequence, bacteria may attach to and invade the epithelial cells, thereby forming intracellular bacterial communities that are not recognized by the immune system and are difficult to treat with antibiotics [15]. Hence, prokaryotic/eukaryotic coculture biofilm models would provide deep insights into the antimicrobial performance of materials, but such models are inherently associated with major challenges. The above presented challenges encountered in *in vitro* biofilm models for studying urinary catheter/stent materials demonstrate the difficulty of including all relevant factors and the need for an appropriate selection of parameters that are relevant to the biological setting of interest.

Concluding Remarks

Even though many of the commonly employed *in vitro* biofilm models provide valuable insights into biofilm behavior on a given surface, it must be recognized that each model is limited owing to the use of specific bacteria under specific environmental conditions. Thus, when evaluating data generated by such models, it is crucial to consider the clinical relevance of the model. Consideration of cellular interactions, for example with commensal bacteria and/or human cells, would potentiate the relevance of novel and advanced *in vitro* models.

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Science & Society

Can We Get Rid of Palm Oil?

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Concerns over the sustainability of palm oil have triggered debates about its role in a bio-based economy, but can we get rid of it? Although the quick answer is no, we should eliminate unsustainable land-use practices. However, currently, technical and financial support for land-users to adopt sustainable land-use practices in the cultivation of palm oil is largely missing.

Why No Palm Oil?

Concerns over the sustainability of palm oil have triggered debates about its role in a bio-based economy that aims to substitute fossil-based materials with renewable organic materials. Oil palm is often labeled not only as an efficient crop with high yield and attractive economic returns, but also as the culprit of intensive land-use change that involves massive carbon stock loss. Many organizations or movements, especially in Europe, have advocated excluding palm oil from the market, translating into policies or actions such as the 'No Palm Oil' label in France and Belgium. Here, I briefly scan some facts and findings relating to the production and use of palm oil and discuss the possibility of not having palm oil in a bio-based economy.

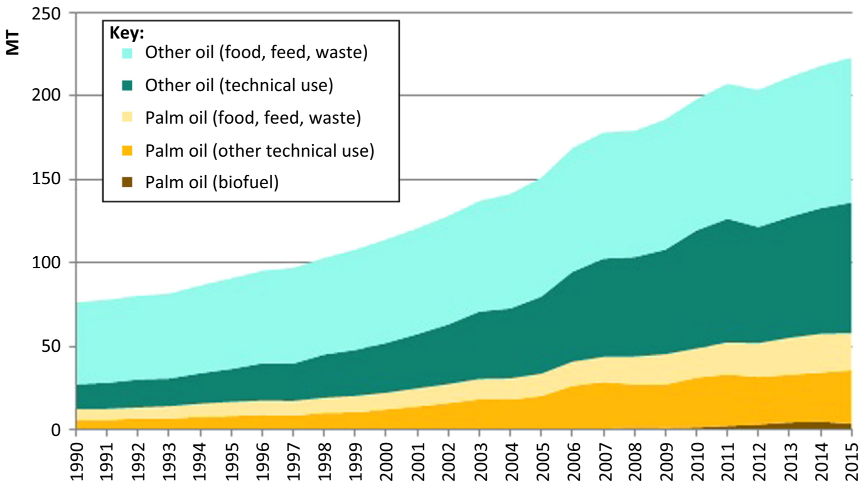

Figure 1. Amount of Vegetable Oils Consumed Globally for Food, Feed, Waste, and Technical Purposes. Calculated based on information from FAOSTAT[v] and the USDA[vi].

The Role of Palm Oil in the Global Bio-Based Market

Figure 1 shows the trend in the global consumption of vegetable oil for technical purposes (i.e., not food or feed) in comparison to its other uses. In 2011, about a quarter of the global vegetable oil demand was fulfilled by palm oil, and about two-thirds of the total palm oil was used for technical purposes. Most of this palm oil was consumed in the chemical industry, with a relatively small amount devoted to biofuel production. Figure 2 illustrates the use of palm oil for biofuel and other technical purposes. Palm oil has been used for biofuel production since 2007, especially in Europe. Indonesia and, to a lesser extent, Malaysia have historically produced palm-based biofuel for export purposes until they started to create domestic markets in 2011. In 2014, domestic consumption in these two countries had reached about half of what is consumed in Europe, while there was a sharp fall in Indonesian exports due to antidumping duties imposed by the EU[i]. In addition to its well-publicized use as biofuel, palm oil is also widely used in personal care and cosmetics products, as well as in pharmaceutical ingredients. In fact, the volume of palm oil used for these purposes is more than six times that used for biofuel. Based on these figures, at first glance, it is questionable whether more sustainable alternatives can be found to replace such a large amount of palm oil in the global bio-based market.

Sustainability of Palm Oil

Although a palm oil crop has very high yields and only requires a very small amount of land area compared with other oil crops (e.g., soybean and rapeseed), its cultivation has been associated with massive deforestation and peatland loss in the tropics. This change in land use has become a main concern of consumers particularly in Europe and the USA. To recover the environmental reputation of palm oil, a certification system called 'Roundtable Sustainable Palm Oil' (RSPO) has been created to distinguish palm oil that is sustainably produced. In 2015, the amount of RSPO-certified palm oil sales had increased to 6.2 MT from the first 0.3 MT batch in 2009[ii]. However, the introduction of RSPO has met with difficulties in dealing with a range of stakeholders, especially smallholders who lack financial capacity and organization[iii]. Accounting for nearly 40% of the total palm oil production globally[iv], smallholders in Southeast Asia are a group of stakeholders with

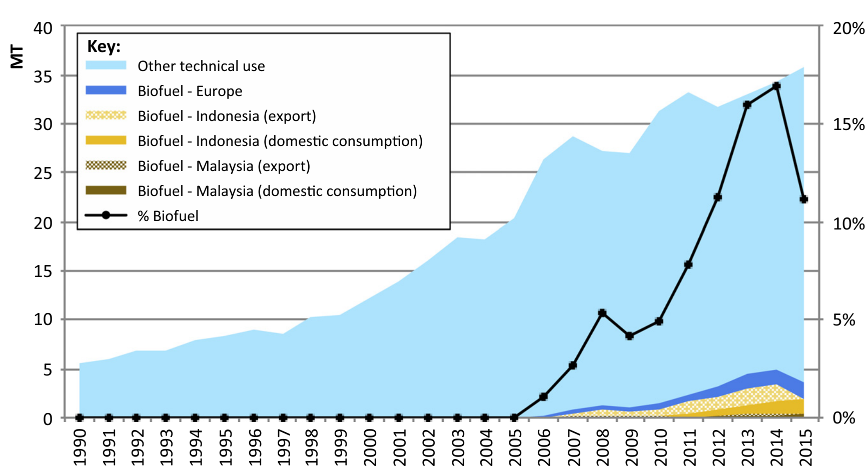

Figure 2. Amount of Palm Oil Consumed Globally for Technical Purposes. Calculated based on information from FAOSTAT[v] and the USDA[vi].

diverse land-use practices, business models, and socioeconomic backgrounds (e.g., [1]). Rigid crop-oriented requirements for sustainability appear to encourage more large-scale monoculture cultivations, which are easier to monitor and control. However, such cultivations are not necessarily more environmentally friendly compared with the other land-use options.

Furthermore, studies have also shown that it is difficult to explicitly quantify the role of oil palm in land-use change, because such change often involves a web of stakeholders and multiple drivers (e.g., timber harvesting, mining, and improper land-use practices using fire) across a significant time frame (from several years to more than a decade) [2,3]. While certain companies have been found to directly trigger carbon stock loss from land-use change (i.e., by converting forest or peatland into plantations), the links of oil palm to land-use change could be more complex in many cases. For example, deforestation sometimes occurs as a result of an individual obtaining a land-use permit under the name of oil palm development, but no oil palm is cultivated once the timber has been extracted (e.g., [4]).

In addition, various biofuel certifications have also been implemented to assure that none of the palm oil used for biofuel production has adverse environmental effects. While the biofuel market is comparatively small compared to the food and chemical sector, it is nevertheless the starting point for debates on carbon leakage, especially ‘indirect land-use change’. This concept holds that, regardless of which vegetable oil is consumed or its end use, the additional demand will trigger the production of some other vegetable oil to fill the gap in the global market. For example, if rapeseed oil is diverted towards biofuel production, palm oil production will increase to meet the gap in demand in the food market left by rapeseed oil. Thus, oil-based biofuel, regardless of the feedstock, will bear the burden of indirect land-use change caused by the cultivation of all oil crops in a global context. While this concept is still debatable due to uncertainties in measuring it, it nevertheless shows that is almost impossible to evaluate the sustainability of a crop for use in a bio-based economy because the market effects of global trade are inevitable (e.g., [5–7]).

Can We Get Rid of Palm Oil from A Bio-Based Economy?

The quick answer is no: ruling out palm oil in a global context is not possible. By contrast, palm oil will continue to have a major role in the global market for non-food-related purposes. In fact, motivation for economic incentives will drive further palm oil production in developing countries, because this is a key opportunity for those who have no or few other economic options that can provide the same return as palm oil. The interconnected socioeconomic interests among the various land-use stakeholders make things even more complicated (e.g., [8]).

A Way Forward: Can We Get Rid of Unsustainable Land-Use Practices Related to Oil Palm?

Instead of asking whether it is possible to remove palm oil from a bio-based economy, we should perhaps be asking whether it is possible to remove unsustainable land-use practices associated with the cultivation of this oil; such a question creates a more meaningful paradigm for future research. Importantly, land-use dynamics in the producing region and the local underlying motivations of oil palm expansions have to be recognized instead of generalizing situations by the type of crop. To influence land-use stakeholders, mediation by governments from both consuming and producing regions would be necessary. In addition to the strong enforcement of environmental law to prevent large-scale destruction of forest and peatland, it is crucial to provide alternative options, such as creative business models to support the emergence of sustainable smallholders who should have a role in the global bio-based market. Currently, local technical and financial support for stakeholders to maintain sustainable land-use practices are largely missing and it is clear that there are few attractive alternative economically viable options. If we cannot get rid of palm oil from a bio-based economy, whether we can eliminate unsustainable land-use practices would be the immediate question to address.

Resources

[i] http://europa.eu/rapid/press-release_IP-13-1140_en.htm

[ii] www.rspo.org/about/impacts

[iii] www.crem.nl/files/upload/documents/downloads/file/ 1310_Report_lessons_learned_FINAL.pdf

[iv] www.rspo.org/certification/smallholders

[v] http://faostat3.fao.org/download/FB/*/E

[vi] http://gain.fas.usda.gov/Lists/Advanced%20Search/AllItems.aspx

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