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Review Article

Green Chemistry Influences in Organic Synthesis : A Review

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Abstract

Environmental pollution and global warming cause serious problems in our life. Since the demand for human daily appliances had been increased by years, the organic chemical-based industries response that demand increment by increasing their production process. Because of that, the environmental pollution becomes worse and worse. Green chemistry thus was introduced to influence the chemical industries to strive for better environmental sustainability. Over 20 years, green chemistry principles have to influence the organic chemistry field especially as many researchers have put their attention on that field of research. So far, synthesis process involving organic compounds has been considered on waste prevention, safer solvents, design for high energy efficiency, and usage of renewable feedstocks. This review comprehensively discusses in brief about the implementation of green chemistry principles and their applications in the synthesis process of organic compounds.

Keywords: environmental sustainability, green chemistry, organic compound, synthesis process

1. INTRODUCTION

The recent environmental quality is depleting to an anxious level and greatly influences the human life [1]. Environmental pollution is defined as a serious environment status where the concentration of pollutant is higher than the normal level due to natural or artificial contamination. Shortly, environmental pollution is a disequilibrium condition in any system of environmental life [2]. Environmental pollution, including soil, water and air pollution, is worsened by days mainly due to industrial activities. Moreover, released greenhouse gasses deteriorate the environmental status by increasing the earth temperature (known as global warming). Those problems require serious attention to keep our sustainable environment. Therefore, industrial processes should not focus only on economic advantage and neglecting environmental protection [3].

In the ancient era, chemical industries mostly considered on the yield of reaction and the purity of the desired product [4] and rarely consider about the environmental issues, energy usage, and the efficiency of the chemical process. Even though the national and international regulations have been decided for chemical industries, environmental pollution looks like a never-ending problem, especially in developing countries [5]. Because of that, since the governmental point of view seems not efficient enough to keep the environmental sustainability, researchers are doing their best to develop the chemical industries in a “green” and environmental-friendly stage [6].

Many efforts have been placed to develop and improve those environmental issues until Anastas and Warner introduced the green chemistry concept in 1998. Green chemistry is defined as the utilization of a set of principles that reduces or eliminates the usage or generation of hazardous substances in the design, manufacture and application of chemical products [7][8]. There are 12 principles of green chemistry as shown in Figure 1.

However, we mainly focused this review on 4 main principles, i.e. waste prevention, safer solvents, design for high energy efficiency, and usage of renewable feedstocks. However, the description of those four principles also briefly dilate the other principles. This review would also discuss on the implementation of green chemistry principle and their application in the synthesis process of organic compounds.

Figure 1. 12 Principles of green chemistry [8].

2. WASTE PREVENTION

"It always better to prevent the generation of waste rather than to manage or treat or eliminate them."

Waste is defined as byproduct material which is generated during a process. Waste from chemical processes always scary the human community because it is toxic, non-biodegradable, and radioactive. Furthermore, those wastes are continuously generated as long as the chemical industries are on operation [9]. In general, waste could be classified into 2 major classes, liquid and solid wastes. Liquid and solid wastes are distinguished by their phase either in liquid or solid form, respectively. Liquid waste usually contains acid, base, metal ions (precious metals, alkali and base metals and heavy metals), organic pollutants (dyes, biomolecules), and so on. Meanwhile, solid waste usually composed of plastics, paper, solid metals, ceramics, and glasses [10].

The chemical process should be designed to incorporate all used materials as far as possible to form the desired product. Because of that, waste prevention should be manifested by rational and effective design of the chemical process using green chemistry quantitative metrics, such as effective mass yield, product efficiency, carbon efficiency, atom economy, reaction mass efficiency, ecoscale, environmental factor, and biologictool plots [11]. Effective mass yield is defined as the ratio between the mass of the desired product relative to the mass of all non-benign materials (water, dilute alcohol, NaCl, etc.) used in its chemical process [12]. However, this parameter is quite subjective to define "non-benign" material and it fails to describe the toxicity level of the chemical process. On the other hand, product efficiency is the ratio between the real mass of the desired product versus the theoretical total atomic mass of the desired product.

Carbon efficiency is a parameter which describes how much the carbon atoms are utilized in the product. Even though it is a good parameter for the pharmaceutical industry, this parameter is useless in inorganic industries such as the production of metal oxide, inorganic paint, inorganic polymer, and advanced materials. Barry Trost in 1995 designed the atom economy formula based on how much of the reactants present in the desired product. Although the atom economy calculation ignores the homogeneous catalyst and used solvents because they are not considered as reactants in the chemical process, atom economy still known as a good parameter for organic and inorganic processes as for today. However, it should be noted that atom economy is just a theoretical parameter since it is considered only from the handwriting reaction equation [13].

In contrast, reaction mass efficiency considers the atom economy, chemical yield and reaction stoichiometry. However, similar to carbon efficiency parameter, reaction mass efficiency is still an ideal calculation showing the "green-ness" of the reaction but not of the real process because it is neglecting any solvent and energy usage. In 2006, the ecoscale metric was proposed by Van Aken et al. [14]. Similar to the effective mass yield parameter, the ecoscale gives a score from 0 to 100 considering account cost, safety, technical set-up, energy and purification aspects. It is obtained by assigning a value of 100 to an ideal reaction defined as "compound A undergoes a reaction with compound B to give the desired compound C in 100% yield at room temperature with a minimal risk for the operator and a minimal impact on the environment", and then subtracting penalty points for non-ideal conditions. However, this ideal condition is rarely established in the real chemical process.

So far, the environmental factor (E-factor) remains as one of the most flexible green chemistry quantitative metrics. Roger A. Sheldon in 2007 [15] proposed the E-factor formula as the ratio between total waste over the desired product. E-factor considers the solvent and catalyst usage making it is comprehensive enough to evaluate the chemical process is environmentally friendly or not. The annual production of oil refining, bulk chemicals, fine chemicals and pharmaceutical processes are 106-108, 104-106, 102-104, and 10-103 tons, respectively. Meanwhile, the waste produced by oil refining, bulk chemicals, fine chemicals and pharmaceutical processes are 105-107, 104 -105, 10-104, and 102-105 tons, respectively. These data show that the E-factor of oil refining, bulk chemicals, fine chemicals and pharmaceutical processes are 0.1, 1-5, 5-50, and 25 -100, respectively. It means that the oil refining industry is the cleanest chemical industry while the pharmaceutical industry is the worst industry in the E-factor point of view as for today.

The latest green chemistry quantitative metrics called biologic tool plot was introduced by Lie et al. [16]. This parameter offers an easy representation of a chemical route from the available data such as starting material, intermediates and product names and chemical formula, and yields of reaction steps. The mass percentage of heteroatoms in the materials is plotted against their molar masses to obtain the biologic tool score. When the biologic tool score is closer to 1, the more rational the chemical route would be. This parameter is pivotal to the design and evaluation of a whole chemical process in the industries. Equations for those green chemistry metrics are shown as below.

In our previous work, the esterification reaction of fatty acid with ethanol was developed to achieve a “greener” synthesis protocol for biodiesel production. The green quantitative metrics of that process are shown in Table 1. It was found that sulfuric acid gave a higher yield percentage and a higher reaction mass efficiency than KSF montmorillonite under reflux method. However, KSF montmorillonite gave 17 times lower E-factor than sulfuric acid process demonstrating that KSF montmorillonite-catalyzed reaction is better to be implemented as an alternative green method [17].

When waste prevention could not be avoided, waste remediation stage is absolutely required to minimize the negative effect on the environment [18]. Several liquid waste remediation techniques have been established, such as coagulation, precipitation, adsorption, bioremediation, and photocatalysis methods [9]. Coagulation and precipitation are carried out by changing the liquid state of the pollutants to solid or semi-solid state either by physical process (centrifugation) or chemical process (precipitated as their insoluble materials). Adsorption is a process by which solid materials are utilized to trap the pollutants on their pore and surface [18]. Bioremediation is a chemical process involving enzyme and/or microorganism for pollutant degradation [19]. While photocatalysis is defined as a chemical degradation process using a catalyst material under light irradiation [20]. On the other hand, solid waste treatment usually performed through an incineration process followed by landfill application [9].

As an example, phenol (C_6H_5OH) is a useful raw material on the production of herbicide, detergents, polycarbonate, bakelite, and nylon polymer materials. Although the demand for phenol is kept in-

$$\text{Effective mass yield (\%)} = \frac{\text{mass of products x 100\%}}{\text{mass of non-benign reagents}} \tag{1}$$

$$\text{Product efficiency} = \frac{\text{real mass of the desired product x 100\%}}{\text{theoretical total atomic mass of the desired product}} \tag{2}$$

$$\text{Carbon efficiency (\%)} = \frac{\text{amount of carbon in product x 100\%}}{\text{total carbon present in reactants}} \tag{3}$$

$$\text{Atom economy} = \frac{\text{m.w. of desired product x 100\%}}{\Sigma\ \text{(m.w. of used reactant)}} \tag{4}$$

$$\text{Reaction mass efficiency} = \frac{\text{molecular weight of the product x yield}}{\text{m.w. reactant A + (m.w. reactant B x molar ratio reactant B/A)}} \tag{5}$$

$$\text{E-factor} = \frac{\text{total waste}}{\text{product}} \tag{6}$$

creasing because of its irreplaceable role, phenol belongs as one of 129 dangerous pollutants according to the Agency for Environmental Protection [19]. Because of that, several phenolic wastewater treatments are developed and optimized. Phenol adsorption had been investigated using various heterogeneous materials to obtain as high as possible maximum adsorption capacity (mg phenol/g adsorbent). However, phenol desorption is sometimes not easy thus leaving a toxic solid material. Bioremediation of phenol becoming an alternative way to degrade phenol through enzymatic metabolism of bacteria, however, the bacteria require specific and stable environmental condition such as pH 7.4 at 310 K [21]. That limitation makes the chemical process is not facile enough to be carried out in a large-scale commercialization stage.

In contrast, phenol degradation to carbon dioxide and water is possible to be performed under light irradiation in the presence of metal oxide catalyst material [22]. This treatment is quite simple and efficient because it only needs light and reusable catalyst materials. In our previous work, we utilized red amaranth natural pigments to sensitize the P25 TiO_2 nanoparticles for phenol degradation under visible light. Bare P25 TiO_2 did not give any photodegradation activity under visible light, however, sensitized-P25 TiO_2 gave 22% photodegradation activity of phenol, which was remarkable [20]. This finding shows that a suitable combination of organic compounds with inorganic materials could serve as an ideal smart material for the phenol photodegradation to water and carbon dioxide.

3. SAFER SOLVENTS

> *"Chemical products should be designed to optimize their function while minimizing their toxic effect."*

Solvent is the major liquid compound which is required to dissolve the chemicals to form a solution. In a simple chemical process, sometimes a large volume of solvent is required for reaction media and/or purification stage [23]. Since the main role of the solvent is only for diluting the chemicals in the chemical reaction, it is quite possible to prevent the usage of flammable, toxic and environmentally damaging solvents such as benzene, carbon tetrachloride, formaldehyde, etc. [24]. Highly volatile solvents such as carbon tetrachloride are easily evaporated thus making hazardous air pollution as well as high risk for human exposure [23]. On the other hand, high polarity solvents such as formaldehyde are unfavorable because they are possible to be accumulated in aquatic environment generating health damages to human population [25]. Because of that, several efforts for solvent substitution are going on to achieve a better environmental sustainability. Of course, solvent-free reactions such as grinding method and sol-gel reaction are the most desirable condition on the chemical processes [26].

Benzene recently had been substituted by toluene due to its carcinogenic effect while carbon tetrachloride had been substituted by either chloroform or dichloromethane due to its effect in depleting the ozone layer of the atmosphere [27]. Byrne, et al. introduced "green solvent" term as an environmen-

Table 1. The green quantitative metrics esterification reaction of fatty acid under reflux using different catalyst [17].

Parameter	**Catalyst**	
	H_2SO_4	**KSF mont**
Yield (%)	90.0	52.0
Atom economy (%)	75.0	75.0
Reaction mass efficiency (mg/g)	11.0	6.3
E-factor	12.0	0.7

Table 2. List of solvent recommendation according to Pfizer and Sanofi [28].

Class	Solvent	Pfizer recommendation	Sanofi recommendation
Alcohols	Methanol	Preferred	Recommended
	Ethanol	Preferred	Recommended
	1-Propanol	Preferred	Recommended
	2-Propanol	Preferred	Recommended
	1-Butanol	Preferred	Recommended
	Ethylene glycol	Usable	Substitution advisable
Hydrocarbons	*n*-Pentane	Undesirable	Banned
	n-Hexane	Undesirable	Substitution advisable
	Cyclohexane	Usable	Substitution advisable
	Benzene	Undesirable	Banned
	Toluene	Usable	Substitution advisable
	Xylene	Usable	Substitution advisable
Dipolar aprotic	Dimethyl sulfoxide	Usable	Substitution advisable
	Acetonitrile	Usable	Recommended
	N,N-dimethyl formamide	Undesirable	Substitution advisable
Esters	Methyl acetate	Preferred	Substitution advisable
	Ethyl acetate	Preferred	Recommended
Ethers	Tetrahydrofurane	Usable	Substitution advisable
	Diethyl ether	Undesirable	Banned
	1,4-Dioxane	Undesirable	Substitution advisable
	2-methyl tetrahydrofurane	Usable	Recommended
Ketones	Acetone	Preferred	Recommended
	Methylethylketone	Preferred	Recommended
Halogenated	Carbon tetrachloride	Undesirable	Banned
	Chloroform	Undesirable	Banned
	Dichloromethane	Undesirable	Substitution advisable
Miscellaneous	Water	Preferred	Recommended
	Acetic acid	Usable	Substitution advisable
	Pyridine	Undesirable	Substitution advisable

Table 3. List of the alternative solvents for a safer chemical process [28].

Solvent	Issues	Alternatives
n-Pentane	Low flashpoint	*n*-Heptane
Diethyl ether	Low flashpoint	2-Methyl tetrahydrofurane
Hexane	Toxic	Heptane
Benzene	Carcinogenic	Toluene
Chloroform	Carcinogenic	Dichloromethane
Pyridine	Carcinogenic	Triethylamine
N,*N*-dimethyl formamide	Reproductive toxicity	Acetonitrile

tally friendly solvent which is derived from the renewable sources with low net cumulative energy demand during its production process. As an example, ethanol is a “greener” solvent than N,N-dimethyl formamide because ethanol could be easily produced by a largescale fermentation process from the biomass waste. Table 2 list the solvent classification according to Pfizer and Sanofi based on their environmental effect and the production energy intake [28].

In general, solvent-replacement is considered from the physicochemical properties of the solvent. As long as the alternative solvents have nearly same physicochemical properties to the used solvent, it is quite possible to do the solvent replacement. Those physicochemical properties are solubility (d), acidity (a), basicity (b) and polarity (p*) called as Kamlet-Taft parameters. Through a careful investigation of those parameters, a rational design on solvent replacement could be achieved [29]. Several alternatives solvents have been reported to minimize the environmental damages from the chemical processes and they are listed in Table 3. Supercritical fluids and ionic liquids are also recently welcomed in several chemical processes.

4. DESIGN FOR HIGH ENERGY EFFICIENCY

“If possible, all chemical processes should be conducted at room temperature and pressure.”

Chemical reactions sometimes need high temperature to pass the activation energy and/or make the reaction possible from the thermodynamic point of view. As examples, some inorganic materials require calcination at >700 K to form the desired crystal structure. On the other hand, organic reactions usually carried out through a reflux method [30]. Nowadays, several “green” reaction conditions have been established well such as sonochemistry, microwave chemistry, photocatalysis reaction and microfluidics reaction. The main keyword on applying the alternative reaction method is to deliver energy rapidly from the heat sources to the chemicals thus the reaction time could be drastically shortened. Another way to decrease the energy usage of the chemical processes is by using catalyst material to shorten the reaction and purification process [31]. Catalyst is a chemical substance that enhances the reaction rate by decreasing the activation energy, however, the catalyst itself does not undergo any permanent chemical change [32]. By

Table 4. The comparison of ethyl 9,10-dihydroxyoctadecanoate synthesis using reflux and sonochemistry methods [17].

Parameter	Method	
	Reflux	Sono-chemical
Yield (%)	52	86
Atom economy (%)	75	75
Reaction mass efficiency (mg/g)	6.3	11
E-factor	0.7	0.4
Energy (kWatt)	15.998	257

changing the catalyst materials, it is possible to control the reaction selectivity as well as its stereochemistry to obtain the desired product in very high yield and purity percentage [33]. It means the selective and high catalytic efficiency of the catalyst material is much better than obtaining racemic a mixture in a time-consuming reaction.

Coming back to the green reaction conditions, sonochemistry method is defined as a process utilizing the ultrasonic radiation (20 kHz – 10 MHz) to undergo the chemical reaction. The main advantage of the sonochemistry method is generation of the hot spots with 5,000-25,000 K temperatures and 1,000 atm pressure at a very short time (heating rate > 1011 K s^{-1}) due to unique cavitation phenomena [34]. In our previous work, esterification of 9,10-dihydroxyoctadecanoic acid with ethanol using KSF montmorillonite as the catalyst with reflux and sonochemical method had been investigated and the results are shown in Table 4. It was found that sonochemical method gave a higher yield and reaction mass efficiency than reflux method. Furthermore, the E-factor and consumed energy were much lower than reflux method demonstrating that sonochemical method is a better and greener way to produce ethyl 9,10-dihydroxyoctadecanoate [17].

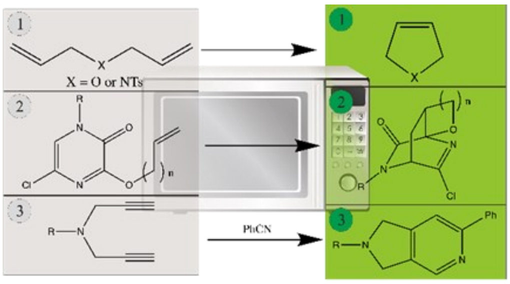

Figure 2. MAOS process for several organic reactions.

Microwave-assisted reaction happens through a suitable interaction between the chemicals and electromagnetic energy through collision and/or conduction process [35]. Recently, organic reaction utilizing microwave heating is known as Microwave-Assisted Organic Synthesis (MAOS) and it had been thoroughly applied for some organic reactions, such as ring-closing metathesis of diallyl derivatives, intramolecular hetero-Diels-Alder cycloaddition of alkenyl-tethered 2(1H)-pyrazolines, cyclotrimerization reaction between the diyne and benzonitrile, and so on [36]. For the cyclotrimerization reaction, the reaction yield was significantly improved from 9% (conventional heating) to 92% using microwave-solid support method (300 Watt, 10 min), which was remarkable. The reaction scheme of these compounds using microwave was shown in Figure 2.

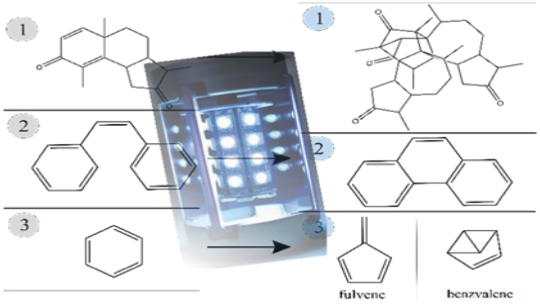

Figure 3. Photochemistry reaction for the production of organic compounds.

On the other hand, catalyzed photochemical reactions such as Claisen rearrangement, Diels Alder reaction, and other pericyclic reactions are greatly focused due to manipulation of the orbital molecules and/or charge transfer of the chemicals under ultraviolet (400-750 nm) or infrared (750-2,500 nm) irradiation [37]. The first photochemical reaction was reported by Trommsdorff in 1834 by reacting a -santonin under visible light. Through visible light irradiation, the a-santonin was rearranged, dimerized and reacted to form a single crystal [38]. Other useful reactions are the transformation of (Z)-1,2-diphenylethene to phenanthrene through a photooxidation reaction, and the transformation of benzene to fulvene and benzvalene. Transformation benzene to fulvene is remarkable because that finding breaks an impossible issue of benzene to be degraded in a very simple way [39]. The reaction scheme of these compounds using photochemistry method is shown in Figure 3.

Last but not least is the microfluidics reaction which is defined as the reaction on the micro-vessel device. Microfluidics offers high mass transfer rate as well as large surface contact area and very short diffusion distance [40][41]. Because of that, microfluidics knowledge has been applied for several applications including chemical synthesis. Yoshida and coworkers have studied the application of the microfluidic device to synthesis organic compounds in submillisecond reaction time [41]. A very short reaction time could be achieved due to extremely fast reaction mixing which is impossible to be achieved in conventional reactors. Additionally, microfluidics offered higher reaction selectivity due to good kinetic control thus suppressing the unnecessary waste generation [42]. Due to rapid mixing velocity, the organic reaction is possible to be performed in mild condition at ambient temperature thus cryogenic condition and usage of protecting groups could be avoided. The miniaturized device making this technology is feasible to be used as a portable system thus reducing the energy for chemicals distribution. It means that microfluidics served as an ideal reaction platform owing to high atom- and step-economical straightforward synthesis [41].

Organolithium compounds are known as highly reactive and pyrophoric compounds owing unstable carbon-lithium bonds. However, thank to merits of the microfluidics, organolithium reagents could be handled for an anionic Fries rearrangement (within a second), a catalyst-free amination of aromatic compounds (within a minute), a functionalization of 2,5-norbornadiene (within 3 minutes), a Suzuki-Miyaura cross-coupling reaction (within 5 minutes) and so on [44]. Furthermore, by using microfluidic technology, large-scale total synthesis of Pristane and Pauciflorol F compounds could be achieved within 5 minutes process, which was quite remarkable [43].

5. USAGE OF RENEWABLE FEEDSTOCKS

> *"Feedstocks are better in renewable stage thus it could be stable either in technically or economically practice."*

As the fossil material sources are depleting by years, renewable sources are more glimpsed and greatly utilized recently [45][46]. Plastics industry from the petroleum feedstocks is facing serious condition because the demand is much higher than the production rate. Because of that, several industries try to shift from petroleum-based polymer to biomass-derived polymer [46]. Preparation of biopolymer using an atom transfer radical (ATRP) polymerization had been known as an environmental-friendly method because it could be conducted in mild condition. Furthermore, by using a suitable catalyst material, the polymerization rate, polymerization degree and polymerization selectivity could be well controlled [47]. The catalyst material usually is built from an impregnation process on the silica materials making the process is cheap and convenient for the large-scale process. So far polylactide (polylactic acid) could be used to replace polystyrene and/or polyethene materials. It was because polylactide could be degraded easily in aerobic condition or under ultraviolet irradiation which was much easier than the degradation of either polystyrene or polyethene materials (> 1,000 years). Other biomass-derived polymers such as polyglyconic acid and bio-polyethene have been commercially produced from sugar beet and biomass fermentation, respectively, delivering good news for our earth [48].

As the fossil-based material stock is diminished, researchers are developing biomaterials from waste oils [17]. Several biolubricants, biogreases, and biosurfactants have been designed and evaluated their possibility to be applied in the commercial process [49]. In our previous work, we utilized used frying oil as the raw material to prepare cyclic ketal of 9,10-dihydroxyoctadecanoates, as well as other heterocyclic compounds [17][50][51][52]. At first, the used frying oil was transesterified, hydrolyzed, and then oxidized to obtain 9,10-dihydroxyoctadecanoic acid. That fatty acid was esterified and further reacted with carbonyl compounds to obtain the desired product. From that process, dioxane-dione (A), dioxepame (B), dioxolane (C, F-I), and dioxaspiro (D and E) compounds have been successfully prepared. Their chemical structures are shown in Figure 4 while their physicochemical properties are shown in Table 5.

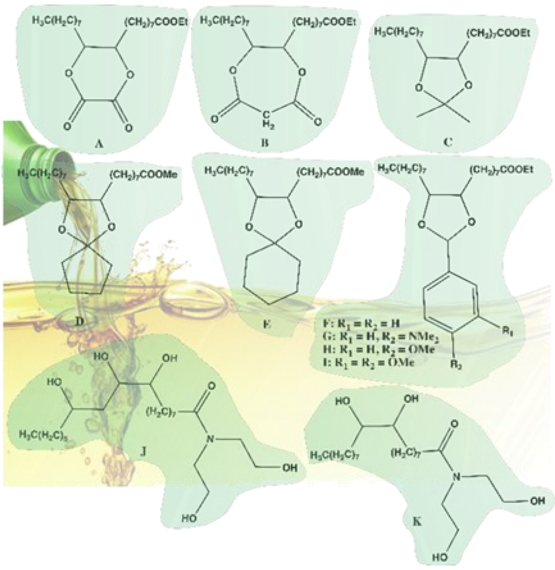

Figure 4. Structure of Biolubricant compound A-K.

From the physicochemical properties evaluation, the biolubricants A-E gave good density value, and much lower total acid number (TAN) and iodine value (IV) than either used frying oil or fossil-based lubricant, which was remarkable. Meanwhile, the total base number (TBN) is varied from low to medium due to the variance of the attached substituents on the heterocyclic moiety. On the other hand, biogreases F-I also give lower TAN and IV but

Table 5. Physicochemical properties of several biolubricants, biogreases, and biosurfactants synthesized from used frying oil waste [52].

No	Compounds	Physicochemical properties			
		Density (g/mL)	TAN (mg KOH/g)	TBN (mg KOH/g)	IV (mg I_2/g)
1	**A**	1.045	1.37	3.53	0.72
2	**B**	0.939	2.89	6.61	0.69
3	**C**	0.824	14.5	48.95	0.76
4	**D**	0.916	11.0	24.24	21.28
5	**E**	0.913	5.46	14.04	17.73
6	**F**	-	1.71	14.12	0.25
7	**G**	-	3.95	5.71	0.78
8	**H**	-	2.53	9.03	0.51
9	**I**	-	2.87	8.92	0.51
10	Used frying oil	0.910	7340	0.41	5380
11	Fossil-based lubricant	0.893	85.37	5.36	31.73

higher TBN demonstrating that they are potential to be applied as biomaterial for machine-based chemical processes [20]. Further utilization of plant oils is the preparation of nonionic biosurfactants J and K. From the investigation of their physicochemical properties, it was found that their surface tensions were 16.1 and 14.2 mN/m, their foam stability values for 100 mins were 3.0 and 42 mL, their critical micelle concentrations were 1.5 and 1.5 g/L, and while their emulsification indexes were 10.0 and 68.0% for 4 days observation, respectively. These physicochemical data show that the prepared nonionic biosurfactants are good candidates for industrial application [53].

6. CONCLUSIONS

As a conclusion, careful attention is very crucial to establish an efficient and effective design of organic synthesis process, as well as to maintain our environmental sustainability. This condition could be achieved by applying the green chemistry principles, i.e. 1) preventing of generated waste by observing the green chemistry quantitative metrics, 2) utilizing the safer and biofriendly solvents, 3) using a suitable synthesis method owing high energy efficiency, and 4) considering the use of renewable feedstocks such from the unused wastes. By that, there is no excuse to neglect the green chemistry perspective on running the chemical industries for better future of our earth.

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