ACES Asian Chemical Editorial Society

doi.org/10.1002/ajoc.202500513

ASIAN JOURNAL OF ORGANIC CHEMISTRY
Research Article

www.asianjoc.org

Plantacare 2000: A Biosurfactant for an Eco-Friendly Palladium Catalyzed Cyanation of Aromatic Bromides

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We introduce here Plantacare 2000 (PL-2000), a renewable biosurfactant for sustainable palladium-catalysed cyanation reactions in water. PL-2000 is derived from plant-based raw materials, is fully biodegradable, nontoxic to the aquatic environment and commercially available without the need for complex synthesis. It represents a safer alternative for Pd-catalysed cyanation reactions using $K_4[Fe(CN)_6]$, while maintaining acceptable synthetic efficiency and a wide substrate scope. PL-2000 proved to be superior to PEG-based surfactants in terms of environmental compatibility and retention of surfactant properties at high temperatures (cloud point > 100 °C). It is also compatible with microwave heating (MW) for challenging substrates. The approach eliminates the need for deoxygenation processes and the use of organic co-solvents and limits the use of additives. Analysis of green chemistry metrics shows that this method achieves an optimal balance between efficiency and environmental impact compared to existing alternatives. The results show that PL-2000 is a promising alternative for surfactant-assisted, metal-catalysed reactions in aqueous media and paves the way for more environmentally friendly synthetic transformations.

1. Introduction

The elimination (or reduction) of organic solvents used in organic synthesis is one of the main goals of green chemistry.[1,2] Among the many possible alternatives, the use of water eliminates the dangers of toxicity to humans and the environment and the flammability inherent to most solvents, while avoiding the use of substances derived from nonrenewable sources.[3,4] Unfortunately, most organic molecules, catalysts and reagents used in synthesis are not soluble in water, which has long limited the use of this solvent to special cases. One possible approach to overcome these limitations was the use of aqueous solutions containing small amounts of surfactants, which improve the water solubility of the reagents.[5,6] The formation of micelles also allows the creation of a confined environment that can accelerate the reaction through a proximity effect between the reagents.[7] These are so reactive that one can often speak of micellar catalysis.[5,8–11]

Over the years, several neutral or ionic surfactants have been developed to perform organic reactions in water, including the commercially available sodium dodecyl sulphate (SDS),[12] Triton-X,[13,14] Brij-30,[15] ethoxylated castor oil,[16] the vitamin E-based TPGS-750-M,[17] the fatty acid and proline-based PS750-M[18] or the abietyl alcohol-derived APGS-2000-M.[19] Although these surfactants are very efficient in various organic transformations, they contain polyethylene glycol (PEG) functions as the hydrophilic moiety, which can impair the biodegradability of the derived surfactant, preventing easy downstream wastewater treatment.[20,21] Therefore, biodegradable substitutes for PEG and pegylated surfactants would be desirable. The "designed" surfactant SAVIE[22] based on polysarcosine has recently been described as an alternative to TPGS-750-M. Although it is very efficient, it is not yet commercially available and has to be prepared in 4 steps, including the production of polysarcosine. In search of a simpler and more readily available alternative, we turned our attention to a commercial biosurfactant used for cosmetic preparations that belongs to the class of alkyl polyglycosides (APGs), nonionic surfactants formed from sugars and fatty alcohols.[23] Structurally, these compounds are formed from naturally occurring alcohols of various chain lengths and oligoglycosides with up to 10 glycoside units.[24] These compounds, which are commercially available under the generic name Plantacare,[25] are 100% renewable and certified as sustainable according to RSPO-MB. They are also fully biodegradable and nontoxic to the aquatic environment according to CE Directive No. 648/2004.[26]

We report here the first application[27] of this family of neutral biosurfactants for organic transformation in water, as we found that Plantacare 2000 UP (PL-2000, Scheme 1), a commercially

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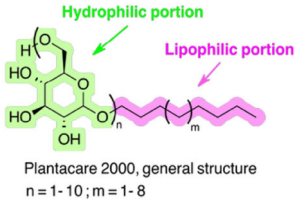
Supporting information for this article is available on the WWW under https://doi.org/10.1002/ajoc.202500513



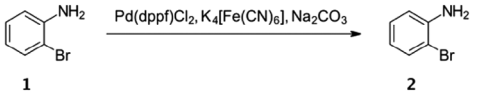
Scheme 1. General formula of plantacare 2000 (PL-2000).

available nonionic surfactant derived from renewable plant raw materials, can be used as an additive for the Pd-catalysed cyanation of aryl halides in water. The Pd -catalysed direct substitution of an aryl halide derivative with a CN group has been intensively investigated over the years.[28,29] The introduction of CN groups often requires the use of cyanide ions or their precursors, leading to objective toxicity concerns.[30] Table S1 summarises the main agents used for the transition metal-catalysed cyanation of aryl halides (taken from ref. 30), ranked according to their toxicity values. Although not directly comparable, the data in Table S1 highlight $K_4[Fe(CN)_6]$ as the safest cyanation reagent. The LD_{50} (6400 mg/kg, oral to rat) is higher than that of some common natural food ingredients that are considered safe, such as citric acid (LD_{50} 3000 mg/kg oral to rat) or caffeine (LD_{50} 200 mg/kg oral to rat). However, most of the cyanation process based on $K_4[Fe(CN)_6]$ occur in organic solvents[30] and only a few examples have been described to occur in water, but these requires co-solvents or additives such as NMP, dioxane, MeCN *i*-PrOH or PEG-4000.[13,31–36] A short list of solvents used in the metal-catalysed cyanation of aryl halides using $K_4(Fe(CN)_6$ as a cyanide source, ordered by Prat classification[37,38] and flammability, is given in Supporting Information (Table S2). When cyanation in water alone under dielectric microwave heating was described, stoichiometric amounts of ecotoxic tetrabutylammonium bromide and aqueous noxious NaF were required to achieve good results.[39] Recently, the Lipshutz group described a very efficient and mild cyanation process but using the PEG-based surfactant Brij-30 and the more toxic $Zn(CN)_2$ (IC_{50} = 8.35 mg/Kg) as the cyanation agent.[15]

2. Results and Discussion

The explorative work of cyanation of aryl halides with a biosurfactant in water was attempted on *o*-bromoaniline (**1**, Table 1) in the presence of various Pd sources. Based on previous experiments, the reaction was carried out at 120 °C for 12 h in the presence of Na_2CO_3 and 1,1′-bis(diphenylphosphino)-ferrocene]palladium(II)dichloride ($Pd(dppf)Cl_2$) as catalyst.[40] The comparison included the reaction in NMP, in water and in water with TPGS-750-M and PL-2000. In this first study, we were pleased to find that: 1) the use of surfactants in water gave a better result with the selected substrate than NMP or water alone (entries 3 and 4). 2) that PL-2000 gave comparable yields to the well-known TPGS-750-M, which is often used in metal-catalyzed conversions under micellar catalysis.

Table 1. Explorative work.[a)]



1 **2**

Entry	Solvent	Surfactant	Solvent	2 (%)[a)]
1	NMP	–	NMP	53
2	H_2O	–	H_2O	48
3	H_2O	TPGS-750-M	H_2O	69
4	H_2O	PL-2000	H_2O	65

[a)] Conditions: Na_2CO_3 (0.41 mmol), K_4 $[Fe(CN)_6]$ (0.125 mmol), $Pd(dppf)Cl_2$ (0.045 mmol), the solvent (1 mL), the surfactant (1.5% wt) and compound **1** (0.41 mmol) were mixed in a pressure tube and heated at 120 °C for 12 h.

To optimize the reaction conditions, we changed all other parameters and chose $Pd(dppf)Cl_2$ (or $Pd(dppf)Cl_2.CH_2Cl_2$) as the common catalyst (see Table 2). First, we investigated the influence of the amount of $K_4[Fe(CN)_6]$ and found that it can be lowered to 1.02 equivalents relative to the starting aryl bromide without affecting the yield. By lowering the temperature to 80 °C, compound **2** was produced in 95% yield (entry 2). Following literature reports,[40] the first reactions were carried out after careful deoxygenation of the starting reaction mixture. However, after obtaining good yields, we repeated the reaction without deoxygenating the reaction mixture and obtained the same yields as with the deoxygenated solution. Consequently, all further reactions (from entry 4 to 17) were carried out without a modified atmosphere. Lowering the reaction to 60 °C or prolonged heating did not increase the reaction yield. The use of dielectric microwave heating (MW) did not lead to an increase in the reaction yield, which remained at 83% even after 1.5 h of heating at 80 °C (entry 9). The influence of the base was further investigated, and we found that it was possible to reduce the amount of base by up to 12% with respect to the moles of **1**, even increasing the product yield (entry 5). Since we were working in water, the initial and final pH was recorded, and we observed a decrease in the value at the end of the reaction. The pH of reactions with high conversion rates was around 5.0, while reactions that did not exceed 85% yield had a final pH of around 7–8. The type of base also influenced the reaction, as when the reaction was carried out in the presence of Cs_2CO_3, NaOH or Et_3N, the yield of product **2** decreased (entries 10–12). Without any base, only a very small amount of product was observed. Lowering the amount of Pd gave a decrease in the yield of **2** (entry 13). Finally, we investigated the use of different Pd sources for catalysis (entries 14–18 in Table 2). The most satisfactory results, although not comparable to the reaction carried out with $Pd(dppf)Cl_2$, are obtained with $Pd(OAc)_2$ as catalyst and dppf as ligand, giving 50% yield of **2**. Other Pd sources give unsatisfactory results (entries 14–18).

After finding the optimal reaction conditions (K_4 $[Fe(CN)_6]$ 17mol%, $Pd(dppf)Cl_2$ 9.8% mol, 2 mL PL-2000 1.5 wt% in water, Na_2CO_3 12% mol, 80 °C for 12 h), we compared different

Table 2. Optimisation of reaction conditions.

1 2

Entry	Pd Catalyst/Ligand	Base	Conditions[a)]	Initial – Final pH	2 (%)[b)]
1	$Pd(dppf)_2Cl_2$·	Na_2CO_3 (100%)	120 °C, 16 h	–	75
2	$Pd(dppf)_2Cl_2$·	Na_2CO_3 (100%)	80 °C, 16 h	–	94
3	$Pd(dppf)_2Cl_2.CH_2Cl_2$	Na_2CO_3 (100%)	80 °C, 16 h	–	93
4	$Pd(dppf)_2Cl_2.CH_2Cl_2$	Na_2CO_3 (50 mol%)	80 °C, 16 h	–	92
5	$Pd(dppf)_2Cl_2.CH_2Cl_2$	Na_2CO_3 (12 mol%)	80 °C, 16 h	10 – 5	96
6	$Pd(dppf)_2Cl_2.CH_2Cl_2$	Na_2CO_3 (12 mol%)	80 °C, 20 h	10 – 5	94
7	$Pd(dppf)_2Cl_2.CH_2Cl_2$·	Na_2CO_3 (12 mol%)	80 °C, 8 h	10 – 8	75
8	$Pd(dppf)_2Cl_2.CH_2Cl_2$	Na_2CO_3 (4 mol%)	80 °C, 16 h	8 – 4	84
9	$Pd(dppf)_2Cl_2.CH_2Cl_2$	Na_2CO_3 (12 mol%)	80 °C, 1.5 h[c)]	10 – 7	83
10	$Pd(dppf)_2Cl_2.CH_2Cl_2$·	Cs_2CO_3 (12 mol%)	80 °C, 16 h	9 – 5	81
11	$Pd(dppf)_2Cl_2.CH_2Cl_2$	NaOH (12 mol%)	80 °C, 16 h	12 – 6	80
12	$Pd(dppf)_2Cl_2.CH_2Cl_2$·	Et_3N (12 mol%)	80 °C, 16 h	10 – 9	55
13	$Pd(dppf)_2Cl_2.CH_2Cl_2$[d)]	Na_2CO_3 (12 mol%)	80 °C, 20 h	10 – 5	65%
14	$Pd(OAc)_2$	Na_2CO_3 (12 mol%)	80 °C, 16 h	10 – 9	5
15	$Pd(OAc)_2$ and dppf	Na_2CO_3 (12 mol%)	80 °C, 20 h	10 – 6	50
16	$Pd(CH_3CN)Cl_2$	Na_2CO_3 (12 mol%)	80 °C, 16 h	10 – 7	10
17	$Pd(PPh_3)Cl_2$	Na_2CO_3 (12 mol%)	80 °C, 16 h	10 – 5	53
18	$PdCl_2$	Na_2CO_3 (12 mol%)	80 °C, 16 h	10 – 9	–

[a)] Conditions: base, Na_2CO_3 (see table), K_4 [$Fe(CN)_6$] (0.170 mmol), Pd catalyst (0.098 mmol) and compound **1** (1.0 mmol) were mixed in a pressure tube containing 2 mL of a solution of PL-2000 1.5% wt in water and heated at various temperature for different times. [b)] Isolated yields after chromatography. [c)] Reaction done under MW dielectric heating. [d)] Reaction done using 0.048 mmol of Pd catalyst.

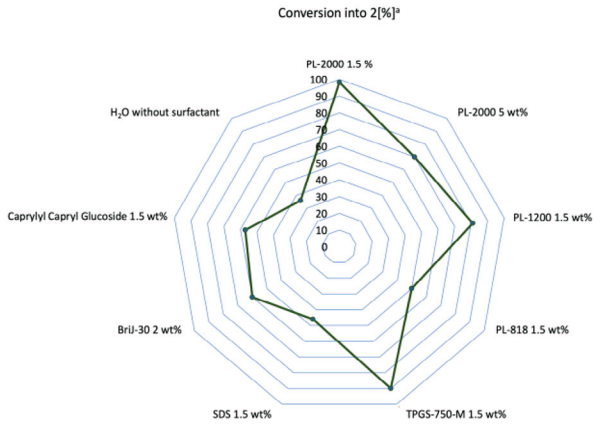


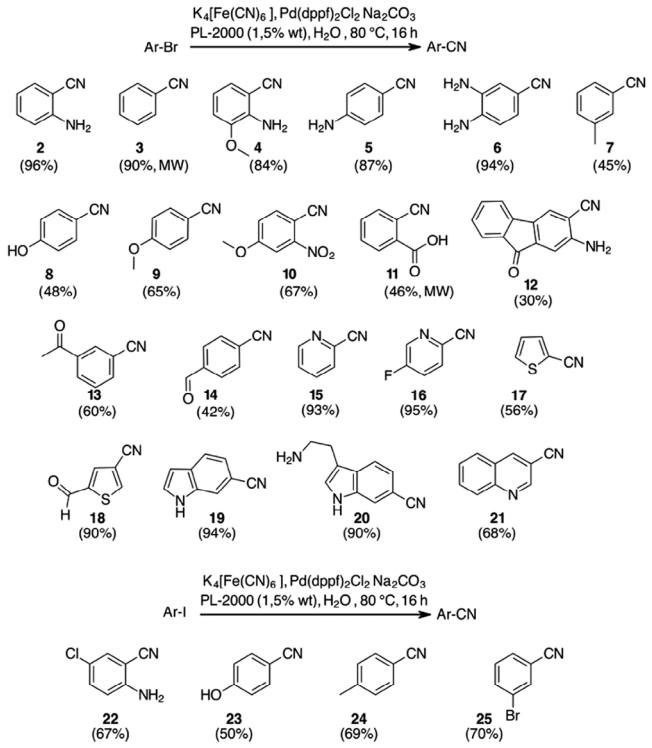
Figure 1. Comparison of different types of surfactants in transformation of compound **1** into **2**. Conditions: Na_2CO_3 (0.122 mmol), K_4 [$Fe(CN)_6$] (0.170 mmol), $Pd(dppf)_2Cl_2$ (0.098 mmol) and compound **1** (1.0 mmol) were mixed in a pressure tube containing 2 mL of a solution of the surfactant in water and heated at 80 °C for 16 h.

types of surfactants, including another experiment without any surfactant.

The results shown in Figure 1 demonstrate the superiority of PL-2000 over all other surfactants used, including other components of the Plantacare family of different sizes (PL-818 and PL-1200 on the right). A low product yield was also obtained by increasing to 5% the amount of PL-2000 in the reaction mixture. Unsatisfactory results were also obtained when other surfactants were used. A satisfactory yield was only obtained with the structurally more complex TPGS-750-M. When the reaction was carried out in water without a surfactant, product **2** was obtained in only 36% yield.

This protocol has been applied to other aryl halides. In general, PL-2000 gave good to acceptable yields of the desired benzonitriles in water when aryl bromides were used as starting materials. Scheme 2 lists the products obtained with a representative series of aryl bromides.

The reaction worked very well with electron-donating (slightly alkaline) substituents as in the case of products **2–6** and **9**, while the presence of an acid group on the aromatic ring partially deactivated the reaction (product **11**). Similarly, we observed a decrease in product yield in the presence of electron-withdrawing groups (product **10**). This behaviour could be related to the type of ligand on the catalyst, as the literature reports the use of "Buckwald type" ligands for cyanation reactions on electron-deficient substrates.[41] Given the potential difficulties in preparing these types of complexes in an aqueous environment, this aspect has not yet been investigated. Heterocyclic bromides worked well regardless of the type of ring and gave the corresponding cyanides **15–21** in good yields. In general, the lower yields were associated with



Scheme 2. Reaction scope. Conditions: Na_2CO_3 (0.122 mmol), K_4 [$Fe(CN)_6$] (0.170 mmol), $Pd(dppf)_2Cl_2$ (0.098 mmol) and aryl bromide (1.0 mmol) were mixed in a pressure tube containing 2 mL of a PL-2000 solution in water (1.5% wt) and heated at 80 °C for 16 h. Isolated yields after chromatography.

the simple substitution of the bromine by a hydrogen on the aromatic ring, probably due to the presence of the protic solvent. Products **3** and **11** were obtained by MW-assisted cyanation, as conventional heating synthesis produced a by-product or was unreactive (for MW-assisted cyanation conditions see Supporting Information). To try to overcome the limitations observed with some substrates (for example, *p*-bromophenol did not react at all under our conditions), we used the corresponding iodides and observed an improvement in the yields of the reactions leading to products **22–25** starting from the corresponding iodides. In the case of compounds **25**, we observed a complete selectivity in favour of the iodide for the introduction of the cyanide. The compatibility of the reaction conditions with the main functional groups appears to be high, including phenols, carboxylic acids, aldehydes, ketones and aliphatic or aromatic amines.

When the reaction was carried out at 5 mole scale (approx. 1.0 g), product purification was possible without the use of chromatographic techniques. Indeed, at the end of the reaction, after cooling, the separation of a solid phase, an aqueous liquid phase and an oily organic phase was observed on the surface. The addition of EtOAc (50 mL) allowed the selective extraction of the oily phase which, after evaporation of the solvent, led to the isolation of the reaction product in practically pure form (see Supporting Information, Figure S1). In cases where the conversion to the final product was lower, chromatographic purification was required. The remaining two phases were separated by filtration and the metal contents were determined by MP-AES analysis. Most of the Pd (90% of the total amount determined in the three phases) was contained in the solid, while only a very low concentration was found in the water. The organic phase contained 9% of the total Pd, which is consistent with the solubility of the catalyst in organic solvents. Fe was almost completely concentrated in the insoluble residue, probably in the form of poly-coordinated oxides or hydroxides, which could induce co-flocculation of Pd species (see Supporting Information, Table S4). Considering the stoichiometry of $K_4[Fe(CN)_6]$, we used 1.02 equivalents with respect to the amount of aryl bromide, and since the corresponding cyanide was isolated in 96% yield, the iron-containing residue should not contain more than 4–5% of a complexed cyanide.

Table 3. DLS analysis. Row data and images are reported in Supporting Information.

Entry	Sample	Size Distribution	Zeta Potential
1	H_2O, PL-2000 (1.5%), rt	2147 ± 535 (98%)	−29,1 ± 5
2	Reaction mixture before heating	807 ± 84 (100%)	−28 ± 4
3	H_2O, PL-2000 (1.5%), heated at 80 °C for 16 h	253 ± 27 (81%),11 ± 1 (18%)	−1.9 ± 4
4	Crude reaction mixture after heating	23 ± 8 (80%), 155 ± 42 (19%)	−12 ± 8
5	Aqueous solution after separation	227 ± 14 (100%)	0.2 ± 7

Based on these findings, a second cyanation cycle was attempted by adding new $K_4[Fe(CN)_6]$, Na_2CO_3 and aryl bromide to the solid residue and aqueous solution. After heating at 80 °C for 12 h, the aryl cyanide was isolated with a yield of 82%. The metal content in the three phases of the crude product was again determined by MP-AES analysis. In this case, too, most of the Pd and Fe were in the solid residue, although the amount of Pd appeared to have decreased in absolute terms (Table S4). A third attempt to recycle the metal-containing phases for a further cyanation reaction failed and resulted in the formation of the aryl cyanide with a yield of about 20%. It is worth noting that in the third recycling attempt, the addition of new $K_4[Fe(CN)_6]$ resulted in an intense blue colouration of the solution, indicating the formation of Prussian blue (Figure S2), the oxidised form of iron(II) ferrocyanide, which is known to interact with, bind and remove heavy metals by various mechanisms and may have deactivated the catalyst.[42,43] It is likely that the acidic environment created by the reaction carried out in air could promote the oxidation of Fe(II) to Fe(III). However, when we tried to perform the recycling experiments under N_2 atmosphere, we still observed the formation of a blue colour and obtained a comparably low yield of aryl cyanide. When more Na_2CO_3 was added to buffer the acidity, the yield of **2** was still low.

To further investigate the phenomena occurring during this transformation and to characterize the contribution of the surfactant, we performed a DLS analysis of solutions taken at different stages of the reaction (see Table 4). The presence of PL-2000 (1.5% wt) in water leads to the formation of large aggregates at room temperature. The addition of the organic

Table 4. Procedure compared for green metric calculations.

Methods	Reagents	Reaction Conditions
Method A – our method	Substrate (1 mmol) Na_2CO_3 (0.12 mmol) $K_4[Fe(CN)_6]$ (0.170 mmol) $Pd(dppf)_2Cl_2$ (0.098 mmol) PL-2000 in H_2O 1.5 wt% (5 mL)	80 °C, 16 h
MethodB[15]	Substrate (1.0 mmol), Pd catalyst (0.005 mmol), $Zn(CN)_2$ (0.56 mmol), PMHS (1 mmol), 2 wt % Brij-30 10% in H_2O/THF10% (2 mL)	65 °C, 20 h
MethodC[36]	Substrate (1.0 mmol), $K_4[Fe(CN)_6]$ $3H_2O$ (0.4 mmol), $Pd(PPh_3)_4$ (0.02 mmol), DBU (0.25 mmol), *t*-BuOH/H_2O (1:1, 3.0 mL)	85 °C, 6 h
MethodD[39]	Substrate (1.0 mmol), $K_4[Fe(CN)_6]$ $3H_2O$ (0.22 mmol), $Pd(OAc)_2$ (0.05 mmol), TBAB (1 mmol), NaF (1 mmol) H_2O (2 mL)	150 °C, 20 min

substrates and the salts leads to a reduction in the size of the particles (800 nm) and an analogous behavior was observed when the solution containing PL-2000 alone was heated to 80 °C (entry 3 in Table 3). The crude reaction mixture was characterized by a significant decrease in the average particle size, which remained unchanged when reactants and sodium carbonate were added. Heating during the reaction leads to a further decrease in the average micelle size. After treatment with EtOAc, which extracts the organic components from the solution, the particle size tends to increase and reaches values comparable to those of the initial PL-2000 solution heated in water, justifying the possibility of recycling the aqueous solution containing the surfactant. The zeta potential values are consistent with the alkaline nature of the surfactant and the fluctuations in pH observed during the reaction.

Visual analysis of the heated solution shows that, unlike PEG-ylated surfactants (such as TPGS-750-M), PL-2000 does not exhibit a cloud point effect. At 100 °C, the solution is still clear and retains its surfactant properties, foaming when shaken (see Supporting Information, Figure S3). This means that PL-2000 retains its surfactant functionality even at higher temperatures, suggesting possible further applications in reactions involving heat.

Observing the pH variations during the reaction helps us to hypothesise about the fate of $K_4[Fe(CN)_6]$ during the reaction. After the expected insertion of palladium at the Ar-Br bond, the reaction proceeds with consumption of $K_4[Fe(CN)_6]$ and aryl bromide, leading to the formation of KBr and $FeBr_2$ in solution (Figure S5). Since we are using a substoichiometric amount of Na_2CO_3, both iron hydroxide and a small amount of HBr (from the aqueous hydrolysis of $FeBr_2$) should be formed, which determines the observed pH drop.

To determine the actual environmental impact of the cyanation reaction in water containing PL-2000, classical green chemistry metrics such as yield, atom economy (AE), generalised and nuclear reaction mass efficiency (gRME and MRP respectively), stoichiometric factor (1/SF) and E-factor [44] were selected as the best metrics for the sustainability assessment of the production of *o*-aminobenzonitrile (**2**) in comparison with other methods listed in Table 4.

The analysis of the green metrics for the four methods examined shows clear differences in terms of efficiency and environmental compatibility. Among the alternatives considered, the proposed method (A) stands out as a particularly convincing solution as it effectively balances sustainability parameters and chemical performance. The radar charts provide a visual representation of the key green metrics and give a deeper insight into the strengths and weaknesses of each method (Figure 2). Our method has a more balanced distribution of the assessed parameters. It achieves high yield (Y) and atom economy (AE) and shows better performance on RME core and 1/SF compared to method B, which shows either a compact radar profile with strong performance on yield or AE. Compared to method B, the E-factor (165.3) of our method (A) is higher because we used more catalyst and a larger amount of solvent in the work-up. However, our method offers remarkable advantages due to the complete biodegradability of the surfactant used and the lower toxicity of the —CN source. This factor, which is not directly reflected in the green metrics, remains an important concern when selecting a safer and more sustainable method. Methods C and D, on the other hand, prove to be the least sustainable choice, with significantly higher values compared to the other two methods. These data clearly show that the proposed method achieves an optimal trade-off between efficiency and environmental impact, making it a good candidate for further improvements and large-scale applications.

3. Conclusion

Plantacare-2000 (PL-2000) has proven to be a suitable surfactant for carrying out Pd-catalysed reactions in an aqueous micellar environment. Its application in the cyanation of aryl bromide using $K_4[Fe(CN)_6]$ as a cyanide source represents a significant improvement for the sustainable production of aromatic nitriles for the following reasons

- PL-2000 is a commercially available, nonionic biosurfactant that belongs to the alkyl polyglycoside class, is 100% renewable, 100% biodegradable, nontoxic to the aquatic environment and, as a non-novel chemical entity,[45] non harmful to the biosphere
- The cyanation reaction takes place in water containing a small amount of the biosurfactant and requires only a minimal amount of the cyanation agent and a limited amount of the additive (Na_2CO_3). In contrast to previously described methods, no deoxygenation of the water is required
- The reactivity with bromides and iodides is comparable to previously described methods, including aryl compound containing different functional groups and heterocycles,
- The green metric values are better compared to other methods in water with $K_4[Fe(CN)_6]$ precisely because the amount of additives is minimised.

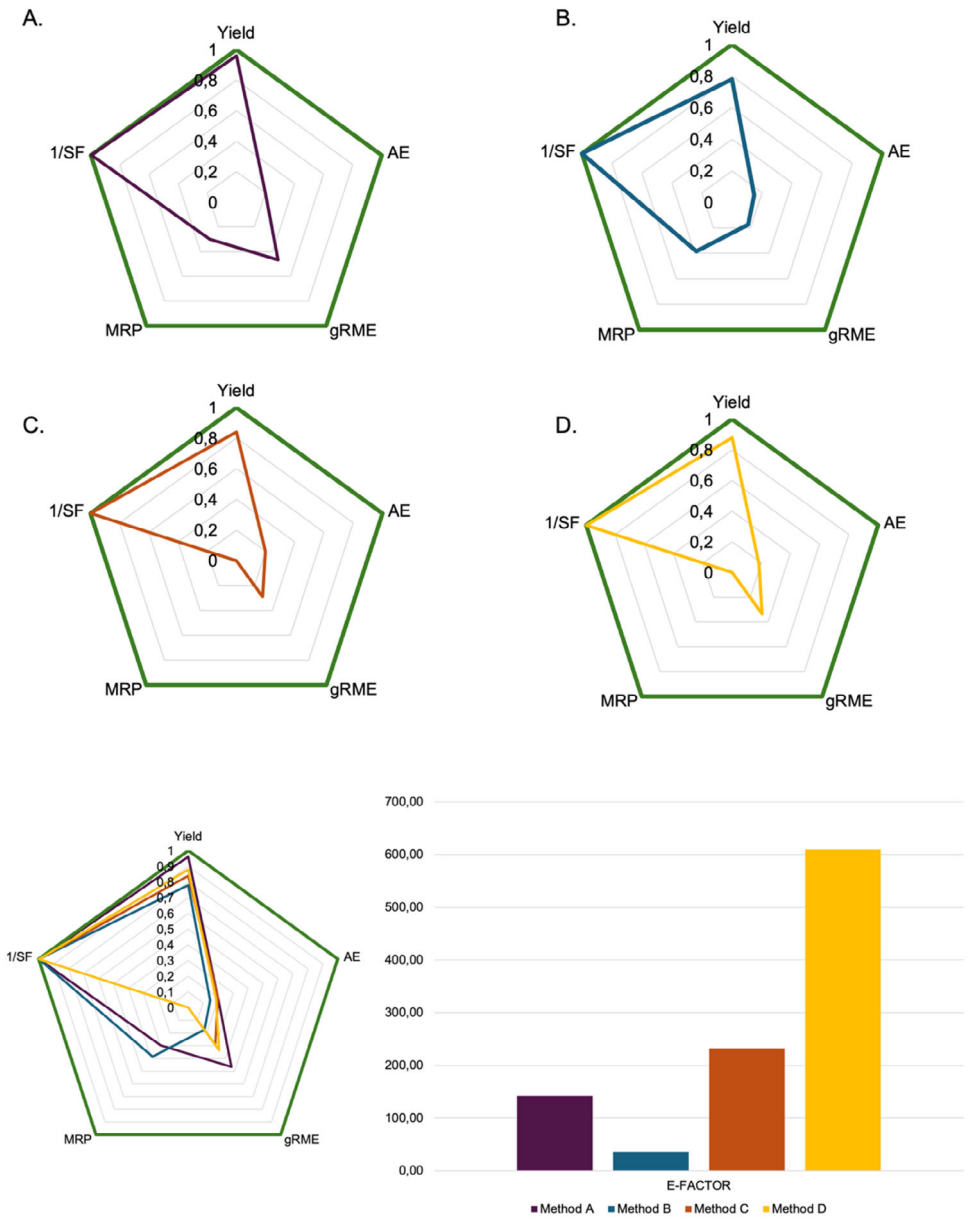


Figure 2. Green metrics calculations and comparison of different types of cyanation on *o*-bromoaniline.

The main limitations at present are the amount of Pd required to carry out the reaction (just under 10% in moles) and the poor recyclability of the catalyst, which is probably due to the large amount of iron salts in the phases containing the catalyst. In our opinion, the optimisation of these parameters goes beyond the objectives of this work, which aims to introduce for the first time a 100% biosurfactant into the landscape of surfactants used for a more sustainable organic synthesis (Figure 2).

Supporting Information

General synthetic methods, characterization of reaction process and products, green metrics and spectra. The authors have cited additional references relative to the characterization of nitriles **2**–**25** within the Supporting Information.[46–60]

Acknowledgments

The work was financially supported within the MUR-2022 PRIN project n 20223ARWAY — REWIND. The authors thanks also Chiesi Farmaceutici (Italy) for partial financial support.

Open access publishing facilitated by Universita degli Studi di Siena, as part of the Wiley - CRUI-CARE agreement.

Conflict of Interests

The authors declare no conflict of interest.

Data Availability Statement

The data that support the findings of this study are available in the supplementary material of this article.

Keywords: Biosurfactant · Micellar catalysis · Nitriles · Pd catalysis · Water

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Manuscript received: June 4, 2025
Version of record online: ■■, ■■