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Synthetic Pathways of *trans*-Substituted Porphyrins Bearing Pentafluorophenyl Groups from Dipyrromethanes †

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Abstract: Different approaches were evaluated to obtain 5,15-bis[4-(*N*,*N*-diphenyl)aminophenyl]-10,20-bis(pentafluorophenyl)porphyrin and 5,15-bis[4-(9-carbazolyl)phenyl]-10,20-bis(pentafluorophenyl)porphyrin. First, the reaction of 5-pentafluorophenyldypyrromethane with the corresponding benzaldehyde catalyzed by boron trifluoride diethyl etherate in dichloromethane led to a high level of scrambling that produces a mixture of porphyrins. These products involve ABAB (3%), A_3B (15%) and A_4 (4%) symmetries, where A represents a pentafluorophenyl group. These porphyrins have similar polarities and they are very difficult to separate by column chromatography. Therefore, the reagents were changed to pentafluorobenzaldehyde and dipyrromethane. When 0.5:1 molar ratio was used, A_4 porphyrin was not obtained and the main products were ABAB (19%) and A_3B (6%). Therefore, condensation of a dipyrromethane with pentafluorobenzaldehyde provides a general method for the rational synthesis of ABAB-porphyrins in good yield with lower scrambling.

Keywords: dipyrromethane; porphyrin; synthesis

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1. Introduction

trans-Substituted porphyrins (ABAB) are commonly synthesized through the reaction of an aldehyde with a dipyrromethane at room temperature and under acid catalysis with trifluoroacetic acid (TFA) or boron trifluoride diethyl etherate ($BF_3.O(C_2H_5)_2$). In a second step, the oxidation of the tetraphenylporphyrinogen cycle (reduced form of porphyrin) is produced with the addition of 2,3-dichloro-5,6-dicyanobenzoquinone (DDQ) [1,2]. In particular, these specific substituent patterns are crucial building blocks in obtaining different materials.

Nevertheless, in this acid-catalyzed condensation process, there is a continuous risk of fragmentation followed by recombination of the reagents (Figure 1). As a result, this method can cause the rearrangement of *meso*-substituents, leading to the production of a mixture of porphyrins [3].

In this work, several synthesis routes were explored to synthesize 5,15-bis[4-(N,N-diphenyl)aminophenyl]-10,20-bis(pentafluorophenyl)porphyrin and 5,15-bis[4-(9-carbazolyl)phenyl]-10,20-bis(pentafluorophenyl)porphyrin. These particular substituent arrangements are essential components in the development of diverse materials [4–7].

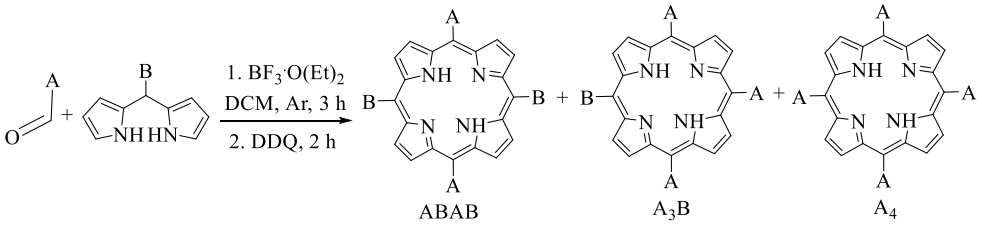

Figure 1. Substitution patterns of porphyrins obtained by condensation of an aldehyde with a dipyrromethane.

2. Materials and Methods

2.1. Equipment and Chemical Reagents

Proton NMR spectra were recorded using a Bruker Avance DPX400 FT-NMR spectrometer (Bruker BioSpin, Rheinstetten, Germany). Mass spectra were obtained with a Bruker micrO-TOF-QII (Bruker Daltonics, Billerica, MA, USA) featuring an ESI source (ESI-MS). Compounds from Sigma-Aldrich (Milwaukee, WI, USA) were utilized as received. Silica gel TLC plates (250 microns) were sourced from Analtech (Newark, DE, USA), and silica gel 60 (0.040–0.063 mm, 230–400 mesh) was supplied by Merck (Darmstadt, Germany).

2.2. Synthesis

5-(Pentafluorophenyl)dipyrromethane and 4-(9-carbazolyl)benzaldehyde were synthesized following the previously described methodology [8,9]. Diphenylaminophenyl)dipyrromethane and di(4-(9-carbazolyl))dipyrromethane were obtained through the typical synthesis of dipyrromethanes [10].

3. Results and Discussion

In this study, various synthetic pathways were investigated to produce 5,15-bis[4-(*N*,*N*-diphenyl)aminophenyl]-10,20-bis(pentafluorophenyl)porphyrin and 5,15-bis[4-(9-carbazolyl)phenyl]-10,20-bis(pentafluorophenyl)porphyrin. In the first instance, both porphyrins were synthesized by acid-catlayzed condensation from the 4-(*N*,*N*-diphenylamino)benzaldehyde or 4-(9-carbazolyl)benzaldehyde and perfluoro-substituted dipyrromethane (5-(pentafluorophenyl)dipyrromethane) in a 1:1 molar ratio (Figure 2). The reaction was carried out in dichloromethane (DCM) and maintained under argon atmosphere during 3 h. Then, DDQ was added to obtained the oxidized porphyrin. The product was purified by flash column chromatography (hexanes/DCM 8:2), to obtain a 3% yield of the ABAB porphyrin.

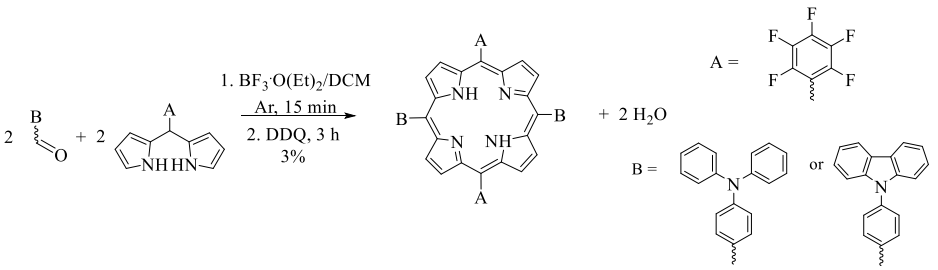

Figure 2. Synthetic pathway of trans-substituted porphyrins through 5-(pentafluorophenyl)dypyrromethane with the corresponding benzaldehyde.

In this case, acid catalysis by $BF_3.O(C_2H_5)_2$ led to a high level of scrambling, which produced a mixture of porphyrins. The desired porphyrin (ABAB) was obtained in a low yield (~3%), while porphyrins A_3B and A_4 had yields of 15% and 4%, respectively. In this structures, A represents the pentafluorophenyl substituent. Due to the similarity in

polarity of these porphyrins, purification of the porphyrin mixture was difficult by flash chromatography.

Therefore, due to these disadvantages, the reagents were exchanged to 5-(diphenylaminophenyl)dipyrromethane or di(4-(9-carbazolyl))dipyrromethane and 5-pentafluorobenzaldehyde, to obtain the desired porphyrins (Figure 3).

Firstly, a 1:1 molar ratio of these reagents were kept under argon atmosphere for 15 min. Then, ($BF_3.O(C_2H_5)_2$) was added and the mixture was stirred for 3 h in the dark. After this time, the addition of DDQ allowed obtaining the oxidized form of the porphyrins. The product were purified by flash column chromatography (hexanes/DCM 80:20). Under these conditions, the obtained products also resulted in a mixture of the above-mentioned porphyrins (ABAB, A_3B and A_4).

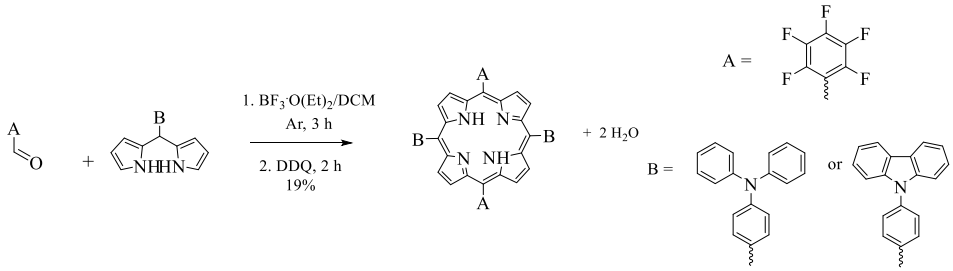

Figure 3. Synthetic pathway of *trans*-substituted porphyrins through pentafluorobenzaldehyde and the corresponding dipyrromethane.

Therefore, it was decided to carry out the reaction under the same experimental conditions, but with a different molar ratio of the reagents. When molar ratios of 1:0.7 and 1:0.5 (dipyrromethane:aldehyde) were used, the yields obtained for the mixture of porphyrins increased to 20% and 25%, respectively. Furthermore, in the latter case (1:0.5 molar ratio), there was no formation of porphyrin A_4. After the purification by *flash* column chromatography, the yields of the products were determined, obtaining 19% for porphyrin ABAB and 6% for porphyrin A_3B. This may be due to the stability offered by the different dipyrromethane to acidolysis and/or scrambling processes. Therefore, the best conditions to obtain an adequate yield of these porphyrins, involve the acid-catalyzed condensation between 5-(diphenylaminophenyl)dipyrromethane and 5-pentafluorobenzaldehyde and in a molar ratio of 1:0.5.

4. Conclusions

Two possible synthetic routes were carried out to obtain *trans*-substituted porphyrins (ABAB). The acid-catalyzed condensation of 5-(pentafluorophenyl)dipyrromethane with triphenylamine or carbazole aldehydes, led to an undesired mixture of porphyrins, due to the scrambling phenomenon produced. When the reagents were exchanged, the yields of the desired products were improved. The best results were obtained with a 1:0.5 molar ratio of dipyrromethane derivative to pentafluorobenzaldehyde. Consequently, the condensation of substituted dipyrromethane with pentafluorobenzaldehyde offers an effective approach for the controlled synthesis of ABAB-porphyrins, achieving good yields with reduced scrambling.

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Data Availability Statement:

Conflicts of Interest:

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