International Research Journal of Biochemistry and Bioinformatics Vol. 13(1) pp. 1-3, January, 2023
Available online http://www.interesjournals.org/IRJBB

Mini Review

Tellurium Modified Nucleosides, Nucleotides, and Nucleic Acids

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Received: 01-Feb-2023, Manuscript No. IRJBB-23-88579; **Editor assigned:** 03-Feb-2023, PreQC No. IRJBB-23-88579 (PQ); **Reviewed:** 17-Feb-2023, QC No. IRJBB-23-88579; **Revised:** 21-Feb-2023, Manuscript No. IRJBB-23-88579 (R); **Published:** 28-Feb-2023, DOI: 10.14303/2250-9941.2022.42

Abstract

Here, we present the first synthesis of the Tephosphoramidite and 5-phenyl-telluride-thymidine derivatives. Additionally, we provide here investigations on DNA oligonucleotides that have the nucleobase (thymine) derivatized with 5-phenyl-telluride activity, including their synthesis, structures, and STM current imaging (5-Te). Te-DNA duplex possesses thermo-stability comparable to the corresponding native duplex, while 5-Te-DNA is stable. The 5-Te-DNA duplex structure is nearly equivalent to the native one, according to the crystal structure, and the Te-modified T and native A interact similarly to the native T and A pair. Furthermore, STM imaging of the DNA duplex modified with electron-rich tellurium functionality revealed high topographic and current peaks whereas the equivalent native displayed faint signals, suggesting a viable method for directly imaging DNA without structural disturbance (Hamilton et al., 2002).

Tellurium was successfully integrated into proteins and used in X-ray crystallography to determine the structure of proteins. There have been few researches done on how tellurium modifies DNA and RNA. The current progress in Te-modified nucleosides, nucleotides, and nucleic acids is highlighted in this study, which also outlines the key synthetic methods used to create the 5-PhTe, 2′-MeTe, and 2′-PhTe modifications. These alterations are persistent throughout Te-oligonucleotide purification and consistent with solid-phase synthesis. Te-modified DNA and RNA also have excellent potential uses in 3D crystal structure determination using X-ray diffraction due to the outstanding electrical and atomic characteristics of tellurium for creating clear isomorphous signals. Te-modified DNA exhibits high topographic and current peaks, according to an STM study, which instantly points to possible uses in molecular electronics, diagnostics, nanomaterials, and direct imaging of nucleic acids. Theoretical investigations suggest that Te-modified nucleosides may be used in the treatment of cancer (Craveiro et al., 2018).

Keywords: Crystallography, Nucleic acids, Tellurium

INTRODUCTION

Numerous base-modified nucleosides exhibit important biological characteristics and function, among others, as antiviral or anticancer medications. The conversion of the nucleosides into ethenonucleosides is one of their potential alterations. Thus, some bifunctional reagents (such as -halocarbonyl compounds) can react with nucleosides or their corresponding heterocyclic bases to produce products that include an extra five-membered imidazole ring. These molecules have an exocyclic amino group and nearby endocyclic nitrogen. The lone exception to this rule is Y-nucleosides, which are extremely fluorescent tricyclic derivatives of guanosine that are found in the anticodon loop of certain phenylalanine transfer ribonucleic acids (Connor et al., 2007).

The construction of DNA nanostructures and their self-assembly, the detection of disease-causing agents at the single molecule level, the development of oligonucleotide drugs, and the design of nanoelectronic devices based on DNA conductivity and charge migration have all been stimulated by the well-behaved base pair recognitions and

duplex structures of DNAs and RNAs. Additionally, chemical modifications of nucleobases have been widely used to selectively tailor the chemical and biophysical properties of DNAs and RNAs as well as to probe their chemical and biochemical functions. These modifications include base pairing specificity, polymerase recognition, DNA damaging and repairing, and DNA current/conductivity imaging (Ibba 2002).

Biopolymers and macromolecules called nucleic acids are necessary for all known forms of life. They are constructed of monomers called nucleotides, which are composed of a nitrogenous base, a phosphate group, and a 5-carbon sugar. Deoxyribonucleic acid (DNA) and ribonucleic acid are the two primary types of nucleic acids (RNA). If the sugar is ribose, the polymer will be RNA; if it is deoxyribose, the polymer will be DNA. Natural chemical substances called nucleic acids make up the genetic material and are the main information-carrying molecules in cells. All living organisms include large amounts of nucleic acids, which are used to build, encode, and then store the information that is contained in every living cell of every type of life on Earth. They then serve to convey and express that information to the internal processes of the cell, and ultimately to the offspring of each living thing, both inside and outside the cell nucleus. The nucleic acid sequence, which provides the "ladder-step" ordering of nucleotides within the molecules of RNA and DNA, contains and transmits the encoded information. They are particularly crucial in controlling protein synthesis (Andreini et al., 2012).

Adenine, cytosine, guanine, thymine, and uracil are the five primary, or canonical, nucleobases. Strings of nucleotides are joined to create helical backbones—typically one for RNA, two for DNA—and formed into chains of base-pairs. Only DNA and RNA contain thymine and uracil, respectively. The precise sequencing of these nucleobase pairs in DNA allows for the storage and transmission of coded instructions as genes through the use of amino acids and the procedure known as protein synthesis. Base-pair sequencing in RNA enables the production of new proteins that define the structural components and the majority of the chemical reactions in all living things (Feig et al., 2002).

DISCUSSION

A novel family of chemically altered nucleic acid components called ethenonucleosides was originally synthesised for the first time in the 1970s. Thus, utilising 9-methyladenine and 1-methylcytidine as models for suitable nucleosides, chloroacetaldehyde (CAA) treatment produced hitherto unidentified luminous bases. Adenosine and cytidine then underwent a similar reaction to produce 1, N6-ethenoadenosine and 1,N4-ethenocytidine, which are the corresponding nucleosidic products. For this process, the ideal pH was determined to be 3.5 for cytosine and 4.5 for adenosine. The synthesis's yield typically ranged from acceptable to quantitative. However, it actually did not react with aq. chloroacetaldehyde. They also demonstrated that another naturally occurring nucleoside, guanosine, met the structural conditions to generate an etheno derivative (Vuong et al., 2008).

The macromolecules known as nucleic acids are composed of nucleotide monomers. For the continuation of life, they are the most crucial macromolecules. They include a cell's genetic code and instructions on how the cell should operate. The blueprints for the proteins that cells produce are contained in nucleic acids, which are information molecules. Additionally, because reproducing cells convey the blueprints to their progeny, they serve as the genetic material in cells. Deoxyribonucleic acid (DNA) and ribonucleic acid are the two primary forms of nucleic acids (RNA). All living things have genetic material called DNA. Eukaryotic cells have it in their nuclei, chloroplasts, and mitochondria. DNA is not contained in a nucleus in prokaryotes (Alic et al., 2016).

The ability of forensic scientists to characterise biological evidence has been improved by molecular biology technologies to the point that it is now possible to analyse minuscule samples and obtain high levels of individualization. Despite the forensic DNA field's maturity, there are still a lot of areas that might use improvement. These include developing integrated microfluidic/microfabrication devices to process DNA samples with higher throughput, quicker turnaround times, lower risk of contamination, and reduced labour. Genetic information and novel markers are also being used to provide investigative leads. Automation is also being improved with robotics, various chemistries, and better software tools. There are knowledge gaps and new approaches where molecular biology is likely to influence the discipline of forensics. This review seeks to offer a road map for people who are interested in helping forensic genetics advance (Kelley et al., 2010).

Another strategy that should be taken into consideration is expanding the pool of template molecules that can be obtained from LCN samples. In fact, we have shown that DNA extracted from cotton swatches or swabs that was collected from whole blood or buccal cells does not effectively remove the DNA from the collecting equipment. Often, the sample collection medium still contains more DNA than was extracted (data not shown). The goal should be to extract DNA from current sample collection equipment more effectively. More template molecules may be produced via sample recovery and extraction techniques that are more effective (like voltage-induced release and cutting-edge ion-exchange columns). Alternately, improved collecting tools should be created that are more effective at retrieving samples from crime scenes or that improve extraction by being inert to DNA or dissolving during extraction to totally liberate the DNA held therein. Increasing the amount of template molecules acquired from degraded DNA samples may be possible by repairing lesions in DNA that have developed as a result of exposure to environmental stresses.

The scientific community has started to receive several DNA repair kits, namely PreCR Repair Mix (New England Biolabs, Ipswich, MA, USA). The use of linear multiple strand displacement may then enable WGA (Salmela et al., 2011).

CONCLUSIONS

In summary, we effectively synthesised the Te-nucleobase-modified nucleoside, phosphoramidite, and DNA oligonucleotides after first incorporating the Ph- Te-functionality (5-Te) to the 5-position of a pyrimidine. The native and modified duplexes share a similar stability with the Te-modified DNA. Our biophysical and structural studies show that the native T and A pair and the Te-modified T and A pair interact similarly, and the structures of the native and Te-derivatized duplexes are essentially the same. Additionally, under STM, the Te-DNA duplex is clearly visible, providing a possible method for directly imaging DNA without structural disruption. This Te-modification will open up a fresh line of inquiry into the mechanisms and functions of nucleic acids, as well as into STM imaging and nano-electronic materials.

An approach that shows promise for studying the structure and operation of nucleic acids is the modification of DNA and RNA using Te. Only a few papers on the topic have been published in the past ten years, and investigations in this area are still extremely scarce. The 2'- and 5-position tellurium modified nucleosides have both been made successfully, and both can be made, deprotected, and purified in solid phases. Studying DNA fragmentation and nucleobase damage may benefit from the 2'-Te modified DNA oligo's unique redox characteristics and selective elimination. The melting temperature of the duplex is directly influenced by the placement of the Te functionality alteration and the size of the protective group, which may be a valuable method for identifying DNA and RNA polymerization and catalysis. Additionally, the Te-modified DNA duplex becomes visible under STM due to the tellurium atom's metallic characteristic, suggesting a possible method for the direct imaging of DNA without structural disturbance. This will make it easier for us to perform investigations on mechanisms and functions or possibly create new nano-electronic materials.

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