Methods Using O^6-Alkylguanine-DNA Alkyltransferases

Field of the Invention

The present invention relates to methods of transferring a label from a substrate to a fusion protein comprising a protein of interest and an O^6-alkylguanine-DNA alkyltransferase (AGT), and in particular to methods which further comprise detecting and/or manipulating the labelled fusion protein.

Background of the Invention

Progress in understanding complex biological systems depends on characterizing the underlying interactions of biomolecules, in particular proteins. While the DNA sequencing of an increasing number of organisms has identified their open reading frames (ORF), the possibilities to study the behaviour of the corresponding proteins in the living cell and to characterize multi-protein interactions *in vivo* and *in vitro* are limited. Most strategies that aim at realizing this objective are based on the construction of a fusion protein that, upon changes in the environment of the coupled protein, elicits a physical, physiological or chemical response. Examples include the yeast-two hybrid system, split-ubiquitin and green fluorescent protein (GFP) fusion proteins. However, all these techniques have various limitations or disadvantages.

German Patent Application No: 199 03 895 A (Kai Johnsson) describes an ELISA assay for the detection of O^6-alkylguanine-DNA alkyltransferase (AGT). The mutagenic and carcinogenic effects of electrophiles such as N-methyl-N-nitrosourea are mainly due to the O^6-alkylation of guanine in DNA. To protect themselves against DNA-

alkylation, mammals and bacteria possess a protein, O^6-alkylguanine-DNA alkyltransferases (AGT) which repairs these lesions [Pegg et al., 1995]. AGT transfers the alkyl group in a S_N2 reaction to one of its own cysteines, resulting in an irreversibly alkylated enzyme. As overexpression of AGT in tumour cells enables them to acquire drug resistance, particularly to alkylating drugs such as procarbazine, dacarbazine, temozolomide and bis-2-chloroethyl-N-nitrosourea, inhibitors of AGT have been proposed for use as sensitisers in chemotherapy [Pegg et al., 1995]. DE 199 03 895 A discloses an assay for measuring levels of AGT which relies on the reaction between biotinylated O^6-alkylguanine-derivatives and AGT which leads to biotinylation of the AGT. This in turn allows the separation of the AGT on a streptavidin coated plate and its detection, e.g. in an ELISA assay. The assay is suggested for monitoring the level of AGT in tumour tissue, adjusting treatment using AGT inhibitors as sensitisers in chemotherapy and for use in screening for AGT inhibitors.

Damoiseaux, Keppler and Johnsson (ChemBiochem., 4: 285-287, 2001) discloses the modified O^6-alkylated guanine derivatives incorporated into oligodeoxyribonucleotides for use as of chemical probes for labelling AGT, again to facilitate detecting the levels of this enzyme in cancer cells to aid in research and in chemotherapy. Two types of variant AGT substrates and an assay for AGT in which it is labelled with biotin (the same as that described in DE 199 03 895 A) are disclosed. In addition, the use of these O^6-alkylated derivatives in the directed evolution of the AGT is suggested.

Summary of the Invention

Broadly, the present invention relates to a further use of O^6-alkylguanine-DNA alkyltransferase (AGT) in a method of labelling, and optionally subsequently manipulating and/or detecting, a protein or peptide of interest in a system in which a fusion of the protein or peptide and AGT is contacted with a labelled substrate so that the AGT transfers the label from the substrate to the AGT fusion, thereby allowing the labelled AGT-protein fusion to be manipulated and or detected by virtue of the transferred label. This contrasts with the prior art uses of assays for measuring AGT levels in which the AGT is not present as a fusion protein.

Accordingly, in a first aspect, the present invention provides a method which comprises contacting a fusion protein comprising protein of interest and an O^6-alkylguanine-DNA alkyltransferase (AGT) and a substrate having a label so that the AGT transfers the label so that it is covalently bonded to the fusion protein. After transfer of the label to the fusion protein, the method may additionally involves the further step of detecting and/or manipulating the labelled fusion protein.

In one embodiment, the present invention provides a method of labelling a fusion protein comprising protein of interest and an O^6-alkylguanine-DNA alkyltransferase (AGT), the method comprising contacting the fusion protein with a substrate having a label so that the AGT transfers the label so that it is covalently bonded to the fusion protein.

In some embodiments, the method comprises one or more

further steps, for example detecting and/or manipulating the labelled fusion protein.

In a further aspect, the present invention provides a method of detecting a fusion protein comprising protein of interest and an O^6-alkylguanine-DNA alkyltransferase (AGT), the method comprising contacting the fusion protein with a substrate having a label so that the AGT transfers the label so that it is covalently bonded to the fusion protein and detecting the protein construct using the label.

In a further aspect, the present invention provides a method of manipulating a fusion protein comprising protein of interest and an O^6-alkylguanine-DNA alkyltransferase (AGT), the method comprising contacting the fusion protein with a substrate having a label so that the AGT transfers the label so that it is covalently bonded to the fusion protein and manipulating the fusion protein using a physical and/or chemical property introduced by the label to the fusion protein.

In some embodiments of this aspect of the invention, the method may comprise detecting the protein construct using the label.

In a further aspect, the present invention provides a method of immobilising a fusion protein comprising protein of interest and an alkylguanine-DNA alkyltransferase (AGT) on a solid support, the method comprising contacting the fusion protein with a substrate having a label which is attached or attachable to a solid support, wherein the AGT transfers the label so that it is covalently bonded to the fusion protein which thereby

is attached or can be subsequently attached to the solid support. In embodiments of the invention in which the label is not initially attached to the solid support, the method may involve the further step of contacting the labelled fusion protein with the solid support so that it becomes immobilised on the solid support. In this preferred embodiments of this aspect of the invention, the label may be covalently attached to the solid support, either when the label is transferred or in a subsequent reaction, or may be one member of a specific binding pair, the other member of which is attached or attachable to the solid support, either covalently or by any other means (e.g. using the specific binding pair of biotin and avidin or streptavidin).

In a further aspect, the present invention provides a method to label AGT fusion proteins both *in vivo* as well as *in vitro*. The term *in vivo* labelling of a AGT fusion protein includes labelling in all compartments of a cell as well as of AGT fusion proteins pointing to the extracellular space. If the labelling of the AGT fusion protein is done *in vivo* and the protein fused to the AGT is a plasma membrane protein, the AGT part of the fusion protein can be either attached to the cytoplasmic or the extracellular side of the plasma membrane. If the labelling is done *in vitro*, the labelling of the fusion protein can be either performed in cell extracts or with purified or enriched forms of the AGT fusion protein.

In a further aspect, the present invention provides a method of determining the interaction of a candidate compound or library of candidate compounds and a target substance or library of target substance. Examples of compounds and substances include ligands and proteins,

drugs and targets of the drug, or small molecules and proteins. In this method, the protein of interest fused to the AGT comprises a DNA binding domain of a transcription factor or an activation domain of a transcription factor, a target substance or library of target substances is linked to the other of the DNA binding domain or the activation domain of the transcription factor, and the label is a candidate compound or library of candidate compounds suspected of interacting with the target substance(s).

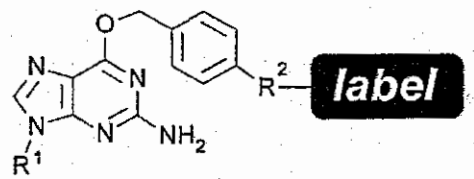
In preferred embodiments, the method may further comprise transferring the candidate compound or library of candidate compounds to the AGT protein fusion and contacting the AGT fusion protein(s) labelled with the candidate compounds and the target substance(s) so that the interaction of a candidate compound joined to the AGT fusion protein and a target substance activates the transcription factor. The activated transcription factor can then drive the expression of a reporter which, if the method is carried out in cells, can be detected if the expression of the reporter confers a selective advantage on the cells. In some embodiments, the method may involve one or more further steps such as detecting, isolating, identifying or characterising the candidate compound(s) or target substance(s).

In the present application, the O^6-alkylguanine-DNA alkyltransferase or 'AGT' has the property of transferring a label present on a substrate to one of the cysteine residues of the AGT forming part of a fusion protein. In preferred embodiments, the AGT is an O^6-alkylguanine-DNA alkyltransferase, for example human O^6-alkylguanine-DNA alkyltransferase which is described in

Pegg et al 1995 and references therein. However, other alkylguanine-DNA alkyltransferases are known, e.g. murine or rat forms of the enzyme described in Roy et al., 1995, which can be employed in the present invention provided that they have the property defined above. In the present invention, O^6-alkylguanine-DNA alkyltransferase also includes variants of a wild-type AGT which may differ by virtue of one or more amino acid substitutions, deletions or additions, but which still retain the property of transferring a label present on a substrate to the AGT or the protein or peptide with which it forms a fusion. Other variants of AGTs may be chemically modified using techniques well known to those skilled in the art. AGT variants may be produced using protein engineering techniques known to the skilled person and/or using molecular evolution to generate and select new O^6-alkylguanine-DNA alkyltransferases.

In the present invention, the reference to the protein part of the fusion protein with the AGT is intended to include proteins, polypeptides and peptides of any length and both with and without secondary, tertiary or quaternary structure. Examples of applications of the present invention are provided below.

In the present invention, the labelled substrate is preferably a labelled benzylguanine substrate, and more preferably is an O^6-benzylguanine derivative. An example of such a derivative is an O^6-benzylguanine derivative that is derivatised at the 4-position of the benzyl ring with the following general formula:



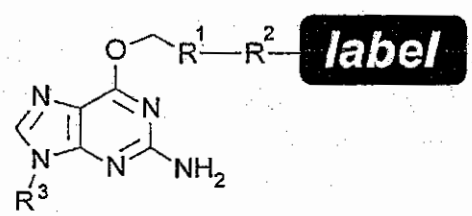
wherein:

R^1 is a proton, a β-D-2'-deoxyribosyl, or a β-D-2'-deoxyribosyl that is part of an oligodeoxyribonucleotide, preferably having a length between 2 and 99 nucleotides;

R^2 is a linker group, for example a flexible linker such as a substituted or unsubstituted alkyl chain, a polyethylene glycol; and

label is a molecule responsible for the detection and/or manipulation of the fusion protein as described herein.

Examples of modified O^6-benzylguanine derivatives suitable for use in accordance with the present invention are provided in Figure 1. Further, the present inventors have found that the AGT can tolerate a considerable degree of flexibility in the identity of the substrate, allowing a wide range of substrates to be used with the following general formula:



wherein:

R^1 is a group accepted by AGT, allowing the AGT to transfer the label to the AGT-protein fusion, for example a substituted or unsubstituted alkyl chain, a substituted or unsubstituted cycloalkyl group with a ring size between three and ten carbons, a substituted or

unsubstituted heterocycle with a ring size between three and ten carbons, a substituted or unsubstituted aromatic heterocycle with a ring size between three and ten carbons;

R^2 is a linker group, for example a flexible linker of varying length such as a substituted or unsubstituted alkyl chain or a polyethylene glycol; and

R^3 is a proton, a β-D-2'-deoxyribosyl, or a β-D-2'-deoxyribosyl that is part of an oligodeoxyribonucleotide, preferably having a length between 2 and 99 nucleotides; and

label is a molecule responsible for the detection and/or manipulation of the fusion protein as described herein.

The label part of the substrate can be chosen by those skilled in the art dependent on the application for which the fusion protein is intended. Examples of labels include:

(1) A spectroscopic probe such as a fluorophore, a chromophore, a magnetic probe or a contrast reagent;

(2) A radioactively labelled molecule;

(3) A molecule which is one part of a specific binding pair which is capable of specifically binding to a partner. Such specific binding pairs are well known in the art and include, for example, biotin, which can bind to avidin or streptavidin;

(4) A molecule that are suspected to interact with other biomolecules;

(5) A library of molecules that are suspected to interact with other biomolecules;

(6) A molecule which is capable of crosslinking to other biomolecules as known to those skilled in the art [Nadeau et al., 2002];

(7) A molecule which is capable of generating hydroxyl radicals upon exposure to H_2O_2 and ascorbate such as a tethered metal-chelate [Hori et al., 2002]; *check last draft*

(8) A molecule which is capable of generating reactive radicals upon irradiation with light such as malachite green [Jay et al. 1999];

(9) A molecule covalently attached to a solid support, where the support may be a glass slide, a microtiter plate or any polymer in general known to those proficient in the art;

(10) A nucleic acid or a derivative thereof capable of undergoing base-pairing with its complementary strand;

(11) A lipid or other hydrophobic molecule with membrane-inserting properties.

(12) A biomolecule with desirable enzymatic, chemical or physical properties;

(13) A molecule possessing a combination of any of the properties listed above.

By way of example, embodiments of the present invention will now be described in more detail with reference to the accompanying figures.

Brief Description of the Figures

Figure 1: A) Mechanism of O^6-alkylguanine-DNA alkyltransferase; B) Structure of O^6-benzylguanine; C) General structure of O^6-benzylguanine derivatives used in the examples; D) General scheme for labeling of AGT fusion proteins, X being the protein fused to AGT; E) Structures of AGT substrates used in the examples. The

sequence of the oligonucleotide (22mer) is: 5'-GTGGTGGGCGCTGXAGGCGTGG-3' where X = ***BG-Bt***.

Figure 2: Western blots after labelling of AGT fusion proteins in vivo. A) Western-Blot of total cell extract of *E. coli* expressing Pep-hAGT with and without ***BG-Bt*** in the medium. A streptavidin-peroxidase conjugate is used to detect biotinylated proteins. The band at 20 kD corresponds to a protein that is biotinylated in *E. coli* in the absence of ***BG-Bt***. B) Western-Blot of total cell extract of yeast expressing a hAGT-DHFR-HA fusion protein with and without ***BG-DIG*** in the medium. An anti digoxigenin-peroxidase conjugate is used to detect digoxigenin-labelled proteins.

Figure 3: HEK 293 cells incubated with ***BG-AcFc*** and analyzed by fluorescence and light microscopy. It can be seen that the fluorescence accumulates in the nucleus of the cell. This is the expected result, as it is know that hAGT is located in the nucleus [Ali et al., 1998]. The third picture is an overlay of the images obtained from fluorescence and light microscopy.

Detailed Description

The following applications of the present invention are provided by way of examples and not limitation. The method disclosed herein is generally applicable to a range of applications and is capable of specifically and covalently labelling fusion proteins with (1) labels which are capable of sensing and inducing changes in the environment of the labelled fusion protein and/or (2) labels which aid in manipulating the fusion protein by the physical and/or chemical properties specifically introduced by the label to the fusion protein. The

method disclosed herein can be used to label AGT fusion proteins both *in vivo* and *in vitro*.

The present invention is based on the realisation that specific attachment of a label to a desired protein could be carried out by constructing a fusion protein between that protein of interest and taking advantage of the mechanism of an O^6-alkylguanine-DNA alkyltransferase such as human DNA repair enzyme O^6-alkylguanine-DNA alkyltransferase (hAGT). This enzyme irreversibly transfers the alkyl group from its substrate, O^6-alkylguanine-DNA, to one of its cysteine residues (Figure 1). A substrate analogue that rapidly reacts with hAGT is O^6-benzylguanine, the second order rate constant being approximately 10^3 sec^{-1} M^{-1} (Figure 1). We have shown that substitutions of O^6-benzylguanine at the C4 of the benzyl ring do not significantly affect the reactivity of hAGT against O^6-benzylguanine derivatives. This enables the use of O^6-benzylguanine derivatives that have a label attached to the C4 of the benzyl ring to covalently and specifically attach the label AGT fusion proteins *in vivo* or *in vitro* (Figure 1D). The labelling is independent of the nature of the fusion protein.

If the labelling is done *in vivo* or in cell extracts, the labelling of the endogenous AGT of the host is advantageously taken into account. If the endogenous AGT of the host does not accept O^6-benzylguanine derivatives or related compounds as a substrate, the labelling of the fusion protein is specific. In mammalian cells (human, murine, rat), labelling of endogenous AGT is possible. In those experiments where the simultaneous labelling of the endogenous AGT as well as of the AGT fusion problem poses a problem, previously described AGT-deficient cell

lines can be used [Kaina et al. 1991]. In general, the present invention can be employed in all applications of the technique were the covalent and specific attachment of a label to a AGT fusion protein is used to monitor or influence the behaviour of the AGT fusion protein or is used to manipulate the AGT fusion protein by virtue of the introduced label. Examples of applications for the use of this technology follow.

1) The label as a spectroscopic probe or reporter group

The use of a labelled AGT substrates, such as O^6-benzylguanine derivatives, where the substrate carries a detectable label which can be transferred to the AGT, such as a fluorophore, a chromophore, a magnetic probe, a radioactively labelled molecule or any other spectroscopic probe, allows the present invention to be used to specifically and covalently attach the detectable label to the AGT fusion protein, either in a cell, on the surface of a cell (*in vivo*) or *in vitro*. This allows the detection and characterization of the AGT fusion protein *in vivo* or *in vitro*. The term *in vivo* includes labelling in all compartments of a cell as well as of AGT fusion proteins pointing to the extracellular space. The method can be compared to the applications of the green fluorescent protein (GFP) which is also genetically fused to the protein of interest and allows its investigation in the living cell. The disadvantage of GFP and its mutants is that it is principally limited to the use of the natural occurring fluorophore.

2) The label as a tag to detect and isolate AGT fusion proteins

The use of AGT substrates, such as O^6-benzylguanine derivatives, which are labelled with an affinity tag such

as biotin allows the present invention to be used to transfer an affinity tag to the AGT-protein fusion, thereby allowing the fusion protein to be bound by a binding partner of the affinity tag. By way of example, the addition of AGT substrates labelled with an affinity tag such as biotin to cells (bacterial or eukaryotic) expressing an AGT fusion protein, or to the cell extracts of such cells or to purified AGT fusion proteins, will lead to the covalent modification of the fusion protein with the affinity tag. This will then allow the isolation of the fusion protein using the interaction between the affinity tag and its binding partner, e.g. in the case of biotin, immobilized avidin or streptavidin. If the label is linked to the AGT-protein fusion via a linker containing a cleavable bond, such as a disulfide bridge, or if the linker is photocleavable, the AGT fusion protein can be released from the affinity tag after its isolation.

3) The label as of source of reactive radicals

AGT substrates, such as O^6-benzylguanine derivatives, can be used to introduce labels into AGT-protein fusions which are capable of generating reactive radicals, such as hydroxyl radicals, upon exposure to an external stimuli. The generated radicals can then inactivate the AGT fusion proteins as well as those proteins that are in close proximity of the AGT fusion protein, allowing the study the role of these proteins. Examples of such labels are tethered metal-chelate complexes that produce hydroxyl radicals upon exposure to H_2O_2 and ascorbate, and chromophores such as malachite green that produce hydroxyl radicals upon laser irradiation. The use of chromophores and lasers to generate hydroxyl radicals is also known in the art as chromophore assisted laser

induced inactivation (CALI)[Jay et al. 1998]. CALI is a method that is used to specifically inactivate certain proteins within a cell in a time-controlled and spatially-resolved manner and which is based upon the spatial neighbourhood of a chromophore and a protein. Upon laser irradiation the chromophore generates hydroxyl radicals, which inactivate all proteins within and only within about 0.1 nm of the chromophore. So far, the chromophore is brought in the spatial neighbourhood of the protein of interest by microinjecting chromophore-labelled antibodies specific to the protein of interest. In the present invention, labelling AGT fusion proteins with chromophores such as malachite green and subsequent laser irradiation would allow to inactivate the AGT fusion protein as well as those proteins that interact with the AGT fusion protein in a time-controlled and spatially-resolved manner. The method can be applied both *in vivo* or *in vitro*.

In a similar manner, AGT fusion proteins can be labelled with tethered metal-chelates and the AGT fusion protein and those proteins that interact with the AGT fusion protein can be inactivated in a specific manner upon exposure to H_2O_2 and ascorbate. The method can not only be used to study the function of an AGT fusion protein or those that are in close proximity of the AGT fusion protein, but also to identify those proteins that are in close proximity of a AGT fusion protein. Here, proteins which are in close proximity of the AGT fusion protein can be identified as such by either detecting fragments of that protein by a specific antibody, by the disappearance of those proteins on a high-resolution 2D-electrophoresis gels or by identification of the cleaved protein fragments via separation and sequencing

techniques such as mass spectrometry or protein sequencing by N-terminal degradation.

4) The label as a ligand mediating protein-protein interactions

The use of labelled AGT substrates, such as O^6-benzylguanine derivatives can be used to transfer a ligand to the AGT-protein fusion. This allows binding partners of the ligand, such as proteins, to bind to the AGT-protein fusion. For example, where the label is a ligand which is capable of binding to a binding partner, contacting such a substrate with a AGT fusion protein will lead to specific attachment of the ligand to the fusion protein. If the ligand binds to another protein Y and the dimerization of the protein Y with the labelled AGT fusion protein leads to a biological function or a measurable signal, the biological function or the measured signal depends on the addition of the AGT substrate carrying the label. A specific example would be the use of AGT substrates and AGT fusion protein in the so-called three-hybrid system described by Ho et al., 1996, to regulate gene expression with small molecules. In this case, AGT is fused to the DNA-binding domain of a transcription factor. A protein Y, such as FKBP that binds a ligand, such as FK506, is fused to the activation domain of a transcription factor. Supplying the cells with the AGT substrate that carries the ligand, in this example FK506, will lead to the formation of a functional transcription factor and gene expression.

5) The label as a drug or biological active molecule whose target is unknown

The use of O^6-benzylguanine derivatives or related AGT substrates that carry a label and where the label is a

drug or a biological active small molecule that binds to an yet unidentified protein Y. Here the goal would be to identify the target protein Y of the biological active molecule. In this case, AGT is fused to the DNA-binding domain of a transcription factor. A cDNA library of the organism which expresses the unknown target protein Y is fused to the activation domain of a transcription factor. Adding the O^6-benzylguanine derivatives or related AGT substrate that carry a label and where the label is the drug or the biological active small molecule will lead to the formation of a functional transcription factor and gene expression only in the case where this molecule binds to its target protein Y present in the cDNA library and fused to the activation domain. If gene expression is coupled to a selective advantage, the corresponding host carrying the plasmid with the target gene Y of the drug or bioactive molecule can be identified.

6) The label as a library of small molecules to identify molecules that bind to the protein Y

The use of O^6-benzylguanine or related AGT substrates that carry a label and where the label is a library of chemical molecules: Here the goal would be to identify small molecules that bind to a protein Y under in vivo conditions, which might be a potential drug target. In this case, AGT is fused to the DNA-binding domain of a transcription factor. The target protein Y is fused to the activation domain of a transcription factor. Adding a library of small molecules attached as label to a O^6-benzylguanine derivative will lead to the formation of a functional transcription factor and gene expression only in the case where the label (i.e. the small molecule) binds to its target protein Y fused to the activation domain. If gene expression is coupled to a selective

advantage, those molecules of the library leading to the growth of the host can be identified.

7) The use of BG derivatives to immobilize AGT fusion proteins and/or to create protein arrays of AGT fusion proteins

The use of O^6-benzylguanine derivatives or related AGT substrates carrying a label and where the label is covalently attached to the surface of a carrier or where the label is a molecule that can be bound non-covalently by another molecule that is itself attached to the surface. An example for the latter approach is where the label is biotin and the molecule attached to the surface is streptavidin or avidin. Possible examples for a carrier would be either a glass side, a microtiter plate or any functionalized polymer. The immobilization of the AGT substrate via its label allows the subsequent immobilization of a AGT fusion protein on the carrier by the transfer of the label to the fusion protein. Spotting (different) AGT fusion proteins in a spatially resolved manner on the carrier allows the creation of protein arrays.

8) The label as a cross-linker to detect proteins that interact with the AGT fusion protein

The use of O^6-benzylguanine derivatives or related AGT substrates which carry a label and where the label is a molecule that can cross-link to other proteins. Examples of such cross-linkers are molecules containing functional groups such as maleimides, active esters or azides and others known to those proficient in the art and described in Nadeau et al., 2002. Contacting such AGT substrates with AGT fusion proteins that interact with other proteins (*in vivo* or *in vitro*) can lead to the covalent

cross-linking of the AGT fusion protein with its interacting protein via the label. This allows the identification of the protein interacting with the AGT fusion protein.

Examples

The following examples are set forth so as to provide those of ordinary skill in the art with a complete disclosure and description of how to practice the invention, and are not intended to limit the scope of the invention.

Example A: Covalent labelling of AGT fusion proteins in E. coli

The following example, the labelling of Pep-hAGT in *E. Coli* using ***BG-Bt***, demonstrates the feasibility of covalently labelling hAGT fusion proteins in *E. coli*. The sequence of the peptide fused to the N-terminus of hAGT (yielding Pep-hAGT) is (in single letter code) MHHHHHHSSA followed by the first amino acid of hAGT, a methionine. Liquid cultures of XL-1Blue *E. coli* cells containing a pET-15b (*Novagen*) based expression vector encoding hAGT with an N-terminal fusion peptide, i.e. Pep-hAGT, were grown to an optical density OD_{600nm} of 0.6. Expression of Pep-hAGT was induced by adding IPTG to a final concentration of 1 mM. At the same time ***BG-Bt*** was added to a final concentration of 10 µM and the bacteria were incubated for 2h at 37°C. Cells were harvested by centrifugation and the pellet washed twice to remove access ***BG-Bt***. A re-suspended aliquot of cells was analysed by Western Blotting. Biotinylated proteins were detected using a streptavidin-peroxidase conjugate (*NEN*) and a chemiluminescent peroxidase substrate (*Renaissance reagent plus, NEN*) (Figure 2).

Example B: Covalent labelling of AGT fusion proteins in yeast

The following example demonstrates the feasibility of covalently labelling hAGT fusion proteins in yeast. Here, a hAGT-DHFR-HA fusion protein is biotinylation in yeast using ***BG-Bt***. The fusion protein is constructed on the DNA level using standard molecular biology procedures. In short, the stop codon of hAGT is replaced by codons for the amino acids RSGI, which are then followed by the codon for the first amino acid of DHFR from mouse, a Met [Nunberg et al., 1980]. The codons for the linker between hAGT and DHFR also encode for a Bgl II site, its DNA sequence being AGATCT. To construct the fusion between DHFR and the HA tag, the stop codon of DHFR is replaced by a codon for the first amino acid of the HA-tag [Kolodziej, 1991]. The HA-tag is followed by a stop codon. A culture of L40 yeast cells, containing the the expression vector p314AK1 in which the hAGT-DHFR-HA protein is under control of the p_{cup1} promoter, was grown to an OD_{600} of 0.6. Expression of hAGT-DHFR-HA was induced by adding $CuSO_4$ to a concentration of 100 µM and ***BG-Bt*** was simultaneously added to a concentration of 10 µM. Aliquots were taken after 2.5h and 5h and cells harvested by centrifugation. The pellet was washed twice to remove remaining ***BG-Bt***. After lysis of the yeast cells by freeze/thaw cycling the cell extract was analysed for the presence of biotinylated hAGT-DHFR-HA fusion protein using an ELISA. In short, the biotinylated hAGT-DHFR-HA was immobilized in streptavidin-coated microtiter wells and detected by using an antiHA-antibody (*Babco*) as a primary and an antimouse-HRP conjugate (*Sigma*) as a secondary antibody (Figure 1) [Kolodziej, 1991]. The ELISA was developed using the peroxidase substrate ABTS and the signal

(absorbance) measured at OD_{405nm}. The signal for the in vivo biotinylated hAGT-DHFR-HA fusion protein was at least fivefold above background. The background signal was defined as the OD_{405nm} of cell lysates obtained from cells treated exactly as above but omitting the addition of ***BG-Bt***.

Example C: Covalent labelling of hAGT fusion proteins in yeast

The following example demonstrates the feasibility of covalently labelling hAGT fusion proteins in yeast. Here, the hAGT-DHFR-HA fusion protein is labelled with digoxigenin in yeast using ***BG-DIG***. The construction of the hAGT-DHFR-HA fusion is described in example B. A culture of L40 yeast cells containing the expression vector p314AK1 in which the gene of a hAGT-DHFR fusion protein is under control of the p_{cup1} promoter was grown to an OD_{600nm} of 1.2. Expression of the hAGT-DHFR fusion protein was induced by adding $CuSO_4$ to a concentration of 100 µM and ***BG-DIG*** was simultaneously added to a concentration of 20 µM. After 2h cells from 1 ml of shake-flask culture were harvested by centrifugation. The pellet was washed three times with medium to remove remaining ***BG-DIG***. After lysis of the yeast cells by freeze/thaw cycling the cell extract was analysed for the presence of digoxigenated hAGT-DHFR fusion protein by Western blotting. Digoxigenated proteins were detected using an anti-digoxigenin-peroxidase conjugate (*Roche*) and a chemiluminescent peroxidase substrate (*Renaissance reagent plus, NEN*) (Figure 2).

Example D: Covalent labelling of hAGT fusion proteins in human cell lines

The following example demonstrates the feasibility of labelling AGT fusion proteins in mammalian cells. Here, endogenous hAGT in human cells (HEK 293) is labelled with fluoresceine using ***BG-AcFc***. HEK 293 cells were incubated with 5 µM ***BG-AcFc*** in PBS for 5min. The acetylated fluoresceine derivative ***BG-AcFc*** is cell-permeable and non-fluorescent but can be expected to be hydrolysed rapidly within the cell to yield the fluorescent ***BG-Fc***. The cells were then washed by changing the PBS to remove any access substrate ***BG-AcFc*** and incubated in PBS for 20 min. Images were then taken with a confocal fluorescence microscope (Ext. 492 nm; Em. 510 nm). As a control experiment, the HEK 293 cells were treated as above but incubated prior to addition of ***BG-AcFc*** overnight with O^6-benzylguanine (1 µM). This should inactivate the endogenous hAGT and therefore prevent the accumulation of the fluorescence in the nucleus. As expected, no accumulation of fluorescence in the nucleus was observed when the cells were preincubated with O^6-benzylguanine. To independently confirm that the hAGT accepts ***BG-Fc*** as a substrate, recombinant Pep-hAGT (10 µM, as described in example A was incubated with 100 µM ***BG-Fc*** at 25°C in 50 mM Tris-Cl, 10 mM DTT, 1mM EDTA, 200 µg/ml BSA, 10% Glycerol, pH 7.4 for 10 minutes, followed by addition of 900 µl PBS (phosphate buffered saline: 137 mM NaCl, 2.7 mM KCl, 10 mM Na_2HPO_4, 1,8 mM KH_2PO_4, pH 7.4). Separation of excess substrate ***BG-Fc*** was achieved by gel filtration on a NAP™-10 Column (Pharmacia) according to the supplier's instruction. The Pep-hAGT was then characterized in a standard fluorescence spectrophotometer. The sample was excited at 222, 238 and 490 nm, respectively and showed maximal emission at a wavelength of 523 nm, verifying that the protein was

labelled with fluoresceine. A solution of 20 nM ***BG-Fc*** in PBS was measured as reference. The substrate's emission wavelength is 519 nm (excitation at 237, 323 and 490 nm respectively).

Example E: Covalent labelling of AGT fusion proteins in cell extracts

To demonstrate that fusion proteins with AGT can be directly labelled and manipulated (here immobilized) in cell extracts the following N- and C-terminal fusion proteins with hAGT proteins were constructed via standard molecular cloning procedures and cloned into a yeast expression vector:

(i) V5-NLS-B42-hAGT, where V5 stands for V5 epitope, NLS for SV40 large T antigen nuclear localization sequence and B42 stands for an artificial transcriptional activator B42 [Ma et al. 1987]. The last codon of the B42 transactivation domain is followed by the 21 amino acid sequence ASKKGTELGSTTSNGRQCAGIL. The last three codons include a Eco RI site for the C-terminal cloning of the hAGT to B42. A Not_SI site is the C-terminal restriction site for the hAGT, whose sequence includes a stop codon;

(ii) hAGT-HA-Ura3, where Ura3 stands for the yeast enzyme orotic acid decarboxylase and HA stands for the Ha epitope. Here, the stop codon for the hAGT is replaced by RS linker followed by the first amino acid of the HA-tag. The HA-tag is directly followed by the Ura3 gene;

(iii) hAGT-DHFR-HA, where DHFR stands for the mouse dihydrofolate reductase and HA stands for the Ha epitope. Construction see example B; and

(iv) SSN6-hAGT, where SSN6 stands for a yeast repressor of DNA transcription [Schultz et al. 1987]. Here, the stop codon of hAGT is replaced by codons for

the amino acids RSGSG, which are then followed by the codon for the first amino acid of SSN6 of yeast, a methionine.

The expression of all genes were controlled by the p_{CUP1} promoter. L40 yeast cells containing an expression vector encoding for one of the fusion protein were grown to an OD of 0.6 and expression of the fusion protein was induced by adding $CuSO_4$ to a concentration of 100 µM. Aliquots (2 ml) were taken after 5h and cells harvested by centrifugation. After lysis of the cells by freeze/thaw cycling the yeast extract was incubated with ***BG-Bt-oligo*** (10 pmol) for 20 min at room temperature, leading to biotinylation of the fusion protein. Subsequently, the suspension was transferred into a streptavidin-coated microtiter plates (*Roche molecular biochemicals*) and incubated for 1h. After extensive washing of the well with PBS, the immobilized fusion protein was detected using either an antiHA-antibody (*Babco*) or an antihAGT-antibody (in the case of the SSN6-hAGT-fusion protein) as a primary and an antimouse-peroxidase conjugate (*Sigma, #A4416*) as a secondary antibody and subsequent incubation with the peroxidase substrate ABTS using standard biochemical procedures. In all cases, the signal which was measured as the OD_{405nm} was at least five-fold above background. Background was measured for each fusion protein by omitting the addition of ***BG-Bt-oligo*** to the cell extracts.

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Claims:

1. A method to be performed outside the human or animal body which comprises contacting a fusion protein comprising protein of interest and an O^6-alkylguanine-DNA alkyltransferase (AGT) with a substrate having a label so that the AGT transfers the label so that it becomes covalently bonded to the fusion protein, and wherein the label is a spectroscopic probe, an affinity tag, a first member of a specific binding pair which is capable of specifically binding to the second member of the specific binding pair, or a molecule which is a solid phase or is attached to a solid phase or is attachable to a solid phase.

2. The method according to claim 1, further comprising detecting the fusion protein using the label.

3. The method according to claim 2 which comprises detecting the labelled fusion protein in an *in vitro* system.

4. The method according to claim 3, wherein in the *in vitro* system, the labelling is carried out in cell extracts or with purified or enriched forms of the fusion protein.

5. The method according to claim 2, comprising detecting the labelled fusion protein in an *in vivo* system.

6. The method of claim 5, wherein the *in vivo* system is cells.

7. The method of claim 6, further comprising the initial step of transforming the cells with an expression vector comprising nucleic acid encoding the fusion protein linked to control sequences to direct its expression.

8. The method according any one of the preceding claims, further comprising manipulating the labelled fusion protein using a property introduced by the label to the fusion protein.

9. The method according to any one of the preceding claims, wherein the protein of interest is fused to the N- or the C-terminus of the AGT.

10. The method according to any one of the preceding claims, wherein the O^6-alkylguanine-DNA alkyltransferase is human O^6-alkylguanine-DNA alkyltransferase.

11. The method according to any one of the preceding claims, wherein the O^6-alkylguanine-DNA alkyltransferase is murine or rat O^6-alkylguanine-DNA alkyltransferase.

12. The method according to any one of the preceding claims, wherein the O^6-alkylguanine-DNA alkyltransferase is a mutant O^6-alkylguanine-DNA alkyltransferase having an amino acid sequence differing from human, rat or murine O^6-alkylguanine-DNA alkyltransferase by one or more amino acid substitutions, deletions or additions , but which retains the property of transferring a label present on a substrate to the AGT-protein fusion.

13. The method according to any one of the preceding claims, wherein the label becomes covalently bonded to a cysteine residue of the fusion protein.

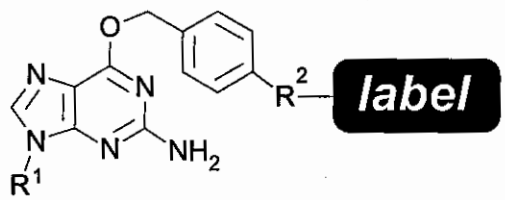
14. The method according to any one of the preceding claims, wherein the labelled substrate is incorporated into a nucleic acid molecule.

15. The method according to claim 14, wherein the nucleic acid molecule is an oligonucleotide between 2 and 99 nucleotides in length.

16. The method according to any one of the preceding claims, wherein the labelled substrate is a benzyl guanine substrate.

17. The method according to claim 16, wherein the benzyl guanine substrate is substituted with the label at position C4 of the benzyl ring.

18. The method according to claim 16 or claim 17, wherein the labelled benzyl guanine substrate is represented by the general formula:



wherein:

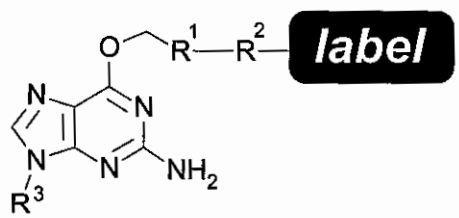
R^1 is a proton, a β-D-2'-deoxyribosyl or a β-D-2'-deoxyribosyl that is part of an oligodeoxyribonucleotide;

R^2 is a linker group; and

label represents a spectroscopic probe, an affinity tag, a first member of a specific binding pair which is capable of specifically binding to the second member of the specific binding pair, or a molecule which is a solid phase or is attached to a solid phase or is attachable to a solid phase, for use in detecting and/or manipulating the fusion protein.

19. The method according to claim 18, wherein the linker group R^2 is a substituted or unsubstituted alkyl chain or a polyethylene glycol.

20. The method according to claim 18 or claim 19, wherein the labelled benzyl guanine substrate is represented by the general formula:



wherein:

R^1 is a group accepted by AGT allowing the AGT to transfer the label to the protein fusion;

R^2 is a linker group;

R^3 is a proton, a β-D-2'-deoxyribosyl, or a β-D-2'-deoxyribosyl that is part of an oligodeoxyribonucleotide; and

label represents a spectroscopic probe, an affinity tag, a first member of a

specific binding pair which is capable of specifically binding to the second member of the specific binding pair, or a molecule which is a solid phase or is attached to a solid phase or is attachable to a solid phase, for use in detecting and/or manipulating the fusion protein.

21. The method according to claim 20, wherein R^1 is a substituted or unsubstituted alkyl chain, a substituted or unsubstituted cycloalkyl group with a ring size between three and ten carbons, a substituted or unsubstituted heterocycle with a ring size between three and ten carbons, or a substituted or unsubstituted aromatic heterocycle with a ring size between three and ten carbons.

22. The method according to claim 20 or claim 21, wherein the linker group R^2 is a substituted or unsubstituted alkyl chain or a polyethylene glycol

23. The method according to any one of claims 18 to 22, wherein the oligodeoxyribonucleotide has a length between 2 and 99 nucleotides.

24. The method according to any one of the preceding claims, wherein the label is a spectroscopic probe.

25. The method according to claim 24, wherein the spectroscopic probe is a fluorophore, a chromophore, a magnetic probe or a contrast reagent.

26. The method according to claims 1 to 23, wherein the label is an affinity tag.

27. The method according to claim 26, wherein the affinity tag is biotin, avidin or streptavidin.

28. The method according to claim 26 or claim 27, wherein the affinity tag is linked to the fusion protein via a cleavable linker so that the fusion protein can be released from the affinity tag.

29. The method according to claim 26 or claim 27, wherein the affinity tag is linked to the fusion protein via a photocleavable linker so that the fusion protein can be released

from the affinity tag.

30. The method according to claims 1 to 23, further comprising immobilising the fusion protein by contacting the fusion protein with a labelled substrate which is attached or attachable to a solid support, wherein the AGT transfers the label so that it becomes covalently bonded to the fusion protein and the labelled fusion protein is thereby attached or can be subsequently attached to the solid support.

31. The method according to claim 30, wherein the label is not initially attached to the solid support, and the method comprises the further step of contacting the labelled fusion protein with the solid support so that it becomes immobilised on the solid support.

32. The method according to claim 30 or claim 31, wherein the label is one member of a specific binding pair, the other member of which is attached or attachable to the solid support.

33. The method according to claim 32, wherein the specific binding pair are biotin and avidin or streptavidin.

34. The method according to claim 30, wherein the label is covalently attached to the solid support by the transfer of the label or in a subsequent reaction.

35. The method according to any one of claims 30 to 34, wherein the label is linked to the fusion protein via a cleavable linker so that the fusion protein can be released from the label after immobilisation on the solid support.

36. The method according to any one of claims 30 to 34, wherein the label is linked to the fusion protein via a photocleavable linker so that the fusion protein can be released from the label after immobilisation on the solid support.

37. The method according to any one of claims 30 to 36, wherein the method comprises immobilising a plurality of proteins of interest on a solid support.

38. The method according to claim 37, wherein the proteins of interest are

immobilised on the solid support in an array.

39. The method of claim 38, wherein the array comprises a plurality of spatially resolved locations.

40. The method according to any one of claims 30 to 39, wherein the solid support comprises a glass or a polymer.

41. The method according to any one of claims 1 to 23, wherein the label is a first member of a specific binding pair.

42. The method according to claim 41, further comprising contacting the fusion protein with molecule comprising the second member of the specific binding pair.

43. The method according to claim 41 or claim 42, wherein the interaction or binding of the first and second members of the specific binding pair generates a detectable result.

44. The method according to any one of claims 41 to 43, wherein the first and second members of the specific binding pair are a first and second protein, an antibody and antigen, an enzyme and substrate or a ligand and receptor.