

SUMMARY

This disclosure describes a novel hetero-dimeric multi-specific format of multiple antibody variable domains comprising a core of two split variable domain pairs wherein both variable light domains and two cognate variable heavy domains are positioned in tandem on two separate protein chains, respectively, thereby driving hetero-dimerization of the two protein chains, wherein the core is formed by a first variable domain pair with specificity for human CD3 and a second variable domain pair with specificity for human serum albumin. Up to two additional binding domains, particularly antibody-based binding domains, such as scFv fragments, are fused to the amino- and/or the carboxyl-terminus of either protein chain, resulting in an up to hexa-specific hetero-dimeric protein. In addition to forming constructs that are stable and well expressed and that can be expected to exhibit a long half-life in plasma, it could surprisingly be shown that such constructs exhibit a different pharmacodynamic profile by showing slower T cells activation kinetics and reduced cytokine release, without compromising on their maximal target cell lysis capacity, when compared to a single-chain diabody (scDb) format comprising the identical CD3-binding domain and the same domain binding to the target antigen expressed on the target cells. Such reduced cytokine release at comparable effect size holds the promise for reduced adverse effects due to cytokine release and therefore for a favorable risk-to-benefit profile.

Thus, in one aspect the present disclosure refers to a hetero-dimeric protein comprising a first and a second single-chain protein,

wherein said first single-chain protein comprises a first amino acid sequence consisting of (from the N- to the C-terminus):

- (ia) a first VL domain,
- (iia) a first polypeptide linker, and
- (iiia) a second VL domain, and

wherein said second single-chain protein comprises a second amino acid sequence consisting of (from the N- to the C-terminus):

- (ib) a first VH domain,

- (iib) a second polypeptide linker, and
- (iiib) a second VH domain, and

wherein said first VL domain forms a first cognate pair of variable domains with specificity to a first target antigen with either said first or said second VH domain and said second VL domain forms a second cognate pair of variable domains with specificity to a second target antigen with the other of said VH domains, wherein one of said target antigens is human serum albumin and the other said target antigen is human CD3, wherein at least one of said first or said second single-chain protein further comprises

- (iv) at least one additional domain as third functional domain that is fused via a third polypeptide linker to said first or said second amino acid sequence wherein said functional domain is a proteinaceous domain having a predefined function, particularly an enzymatic activity or specific binding to a cognate ligand,

wherein each polypeptide linker consists of a chain of amino acid residues linked by peptide bonds, and

wherein said first and said second single-chain proteins do not comprise an immunoglobulin constant domain.

In a second aspect, the present disclosure refers to a nucleic acid sequence or two nucleic acid sequences encoding the first and the second single-chain proteins of the hetero-dimeric protein disclosed herein.

In a third aspect, the present disclosure refers to a vector or two vectors comprising the nucleic acid sequence or two nucleic acid sequences as disclosed herein.

In a fourth aspect, the present disclosure refers to a host cell or host cells comprising the vector or two vectors disclosed herein.

In a fifth aspect, the present disclosure refers to a method for producing the hetero-dimeric protein as disclosed herein comprising (i) providing the nucleic acid or the two nucleic acids as disclosed herein, or the

vector or two vectors as disclosed herein, expressing said nucleic acid sequence or nucleic acid sequences or said vector or vectors and collecting said hetero-dimeric protein from the expression system, or (ii) providing a host cell or host cells as disclosed herein, culturing said host cell or host cells, and collecting said hetero-dimeric protein from the cell culture.

In a sixth aspect, the present disclosure refers to a pharmaceutical composition comprising the hetero-dimeric protein as disclosed herein and a pharmaceutically acceptable carrier.

In one example, there is described the hetero-dimeric protein of the present disclosure for use in the treatment of a disease, particularly a human disease, more particularly a human disease selected from cancer, an inflammatory and an autoimmune disease, wherein at least one of said third, fourth, fifth, or sixth functional domain is able to specifically interact with a target of therapeutic relevance in the corresponding disease.

In another example, there is described a method for treating a patient suffering from a disease, particularly a human disease, more particularly a human disease selected from cancer, an inflammatory and an autoimmune disease, comprising administering to a subject an effective amount of the hetero-dimeric protein disclosed herein, wherein at least one of said third, fourth, fifth, or sixth functional domain is able to specifically interact with a target of therapeutic relevance in the corresponding disease.

Particular embodiments of the present invention are set forth in the appended dependent claims.

FIGURES

Figure 1 shows the SDS-PAGE analysis of the MATCH construct variants described in Table 2 under reducing and non-reducing conditions.

Figure 1 shows the dose response of the T-cell activation in the presence of target cells at different concentrations of MATCH and reference scDb molecules. Physiological concentrations of human serum albumin were added to the cell cultures after 5 h and 30 h of incubation.

Figure 3 shows the dose response of the T-cell activation in the presence of control cells at different concentrations of MATCH and reference scDb molecules.

Figure 4 shows a plot of the maximal activation of the T-cells induced by the MATCH and the scDb reference molecule normalized to the signal amplitude of the scDb at 5 h.

CLAIMS

1. A hetero-dimeric protein comprising a first and a second single-chain protein,
wherein said first single-chain protein comprises a first amino acid sequence consisting of (from the N- to the C-terminus):

- (ia) a first VL domain,
- (iia) a first polypeptide linker, and
- (iiia) a second VL domain, and

wherein said second single-chain protein comprises a second amino acid sequence consisting of (from the N- to the C-terminus):

- (ib) a first VH domain,
- (iib) a second polypeptide linker, and
- (iiib) a second VH domain, and

wherein said first VL domain forms a first cognate pair of variable domains with specificity to a first target antigen with either said first or said second VH domain, and said second VL domain forms a second cognate pair of variable domains with specificity to a second target antigen with the other of said VH domains, wherein one of said target antigens is human serum albumin and the other said target antigen is human CD3,

wherein at least one of said first or said second single-chain protein further comprises

- (iv) at least one additional domain as third functional domain that is fused via a third polypeptide linker to said first or said second amino acid sequence, wherein said functional domain is a proteinaceous domain having a predefined function, particularly an enzymatic activity or specific binding to a cognate ligand,

wherein each polypeptide linker consists of a chain of amino acid residues linked by peptide bonds, and

wherein said first and said second single-chain proteins do not comprise an immunoglobulin constant domain.

2. The hetero-dimeric protein of claim 1, further comprising
 - (v) a fourth functional domain that is fused via a fourth polypeptide linker to said first or said second amino acid sequence;
 - (vi) a fourth and a fifth functional domain that are fused via a fourth and a fifth polypeptide linker, respectively, to said first and/or said second amino acid sequence; or
 - (vi) a fourth, a fifth and a sixth functional domain that are fused via a fourth, a fifth and a sixth polypeptide linker, respectively, to said first and said second amino acid sequence.
3. The hetero-dimeric protein of claim 1 or 2, wherein said first polypeptide linker consists of from 5 to 20 amino acid residues, particularly from of 6 to 15 amino acid residues.
4. The hetero-dimeric protein of any one of claims 1 to 3, wherein said first single-chain protein and said second single-chain protein hetero-dimerize in a parallel orientation; or in an anti-parallel orientation, particularly wherein said first and said second polypeptide linker each consists of from 10 to 20 amino acid residues comprising between 40 and 60% charged residues, particularly from of 12 to 16 amino acid residues comprising 50% charged residues, in each case, wherein the two linkers are able to interact by forming interchain pairs of positively and negatively charged residues; particularly wherein the charged residues on one of said first and second linkers are exclusively positively charged residues, and the charged residues on the other of said first and second linkers are exclusively negatively charged residues, particularly wherein said first and second linkers are selected from SEQ ID NOs. 16 and 17.
5. The hetero-dimeric protein of any one of claims 1 to 4, wherein (a) said first VL domain (ia) and said first VH domain (ib) form a first cognate pair of variable domains with specificity to human serum albumin, and said second VL domain (iia) and said second VH domain (iib) form a second cognate pair of variable domains

with specificity to human CD3; or (b) said first VL domain (ia) and said second VH domain (iib) form a first cognate pair of variable domains with specificity to human CD3, and said second VL domain (iia) and said first VH domain (ib) form a second cognate pair of variable domains with specificity to human serum albumin.

6. The hetero-dimeric protein of any one of claims 1 to 5, wherein said third, fourth, fifth and/or sixth functional domains are independently selected from the list of: binding domains, toxins, enzymes, hormones, and signaling proteins; particularly wherein said third, fourth, fifth and/or sixth functional domains are independently selected from binding domains; particularly wherein said binding domains are independently selected from the list of: antibody-based binding domains, particularly scFv fragments, Fab fragments and single antibody variable domains, and binding domains based on alternative scaffolds, particularly ankyrin-based domains, fynomers, avimers, anticalins and binding sites being built into constant regions of antibodies.
7. The hetero-dimeric protein of any one of claims 1 to 6, wherein at least one of said antibody variable domains comprises CDR regions derived from a parental rabbit antibody, particularly wherein at least one of said antibody variable domains comprises human framework regions.
8. The hetero-dimeric protein of any one of claims 1 to 7, wherein said first single-chain protein and said second single-chain protein are cross-linked by at least one disulfide bond; particularly wherein said disulfide bond is formed between a first cysteine residue flanking said first or said second VL domain and a second cysteine residue flanking said first or said second VH domain; or wherein said disulfide bond is formed between a first cysteine residue comprised in a framework region of said first or said second VL domain and a second cysteine residue comprised in a framework region of said first or said second VH domain, particularly wherein said first cysteine residue is located at position 141 of said first or said second VL domain and said second cysteine residue is located at position 51 of said first or said second VH domain.
9. The hetero-dimeric protein of any one of claims 1 to 8, wherein said cognate pair of variable domains with specificity for human serum albumin comprises the three VL CDRs present in one of the VL protein sequence selected from SEQ ID NOs: 10,

12, and 14 in a human antibody VL framework, wherein the VL framework comprises Vk frameworks FR1, FR2 and FR3, particularly Vk1 frameworks, and a framework FR4, which is selected from a Vk FR4, particularly Vk1 FR4, and a Vλ framework 4, and the three VH CDRs present in one of the VH protein sequences selected from SEQ ID NOs: 11, 13, and 15 in a human antibody VH framework, particularly a VH3 framework, particularly wherein said cognate pair of variable domains with specificity for human serum albumin comprises a VL domain comprising at least positions 5 to 140, particularly at least positions 3 to 145, of a protein sequence selected from SEQ ID NOs: 10, 12, and 14, and a VH domain comprising at least positions 5 to 140, particularly at least positions 3 to 145, of a protein sequence selected from SEQ ID NOs: 11, 13, and 15, particularly wherein said cognate pair of variable domains with specificity for human serum albumin comprises a VL domain selected from SEQ ID NOs: 10, 12, and 14, and a VH domain selected from SEQ ID NOs: 10, 12, and 14.

10. The hetero-dimeric protein of any one of claims 1 to 9, wherein said cognate pair of variable domains with specificity for human CD3 comprises the three VL CDRs present in one of the VL protein sequence selected from SEQ ID NOs: 2, 4, 6 and 8 in a human antibody VL framework, wherein the VL framework comprises Vk frameworks FR1, FR2 and FR3, particularly Vk1 frameworks, and a framework FR4, which is selected from a Vk FR4, particularly Vk1 FR4, and a Vλ framework 4, and the three VH CDRs present in one of the VH protein sequences selected from SEQ ID NOs: 3, 5, 7 and 9 in a human antibody VH framework, particularly a VH3 framework, particularly wherein said cognate pair of variable domains with specificity for human CD3 comprises a VL domain comprising at least positions 5 to 140, particularly at least positions 3 to 145, of a protein sequence selected from SEQ ID NOs: 2, 4, 6 and 8, and a VH domain comprising at least positions 5 to 140, particularly at least positions 3 to 145, of a protein sequence selected from SEQ ID NOs: 3, 5, 7 and 9, particularly wherein said cognate pair of variable domains with specificity for human serum albumin comprises a VL domain selected from SEQ ID NOs: 2, 4, 6 and 8, and a VH domain selected from SEQ ID NOs: 3, 5, 7 and 9.

11. A nucleic acid sequence or two nucleic acid sequences encoding the first and the second single-chain proteins of the hetero-dimeric protein of any one of claims 1 to 10.
12. A vector or two vectors comprising the nucleic acid sequence or the two nucleic acid sequences of claim 11.
13. A host cell or host cells comprising the vector or the two vectors of claim 12.
14. A method for producing the hetero-dimeric protein of any one of claims 1 to 10 comprising (i) providing the nucleic acid sequence or the two nucleic acid sequences of claim 11, or the vector or the two vectors of claim 12, expressing said nucleic acid sequence or nucleic acid sequences, or said vector or vectors, and collecting said hetero-dimeric protein from the expression system, or (ii) providing a host cell or host cells according to claim 13, culturing said host cell or said host cells; and collecting said hetero-dimeric protein from the cell culture.
15. A pharmaceutical composition comprising the hetero-dimeric protein of any one of claims 1 to 10 and a pharmaceutically acceptable carrier.