Claims

1. A modified influenza H3 hemagglutinin (HA) protein comprising an amino acid sequence of a wildtype influenza H3 HA protein and comprising at least one amino acid substitution, said at least one amino acid substitution corresponding to position 382 of reference sequence SEQ ID NO: 92, and optionally corresponding to positions 384, 392 and/or 431 of reference sequence SEQ ID NO: 92.

2. The modified influenza H3 HA protein of claim 1, wherein:

the amino acid substitution corresponding to position 382 of reference sequence SEQ ID NO: 92 is to an alanine or a conserved substitution of alanine.

3. The modified influenza H3 HA protein of claim 1, wherein:

the amino acid substitution corresponding to position 384 of reference sequence SEQ ID NO: 92 is to a valine or a conserved substitution of valine;

the amino acid substitution corresponding to position 392 of reference sequence SEQ ID NO: 92is to an aspartic acid or a conserved substitution of aspartic acid; and/or

the amino acid substitution corresponding to position 431 of reference sequence SEQ ID NO: 92is to a methionine or a conserved substitution of methionine.

4. The modified influenza H3 HA protein of claim 2 or claim 3, wherein:

the conserved substitution of alanine is serine, glycine, threonine, cysteine, or valine;

the conserved substitution of valine is isoleucine, methionine, alanine, or threonine

the conserved substitution of aspartic acid is glutamic acid, glutamine, or serine; and

the conserved substitution of methionine is isoleucine, glutamine, valine or phenylalanine.

5. A nucleic acid encoding the modified influenza H3 HA protein of any one of claims 1 to 4.

6. A virus-like particle (VLP) comprising the modified influenza H3 hemagglutinin (HA) protein of any one of claims 1 to 4.

7. A method of producing an influenza virus like particle (VLP) in a plant, portion of a plant, or a plant cell, comprising:

a) i) introducing the nucleic acid of claim 5 into the plant, portion of the plant, or plant cell, and optionally further introducing a second nucleic acid encoding a proton channel protein, such as an influenza A subtype M2 protein; or

ii) providing a plant, portion of a plant, or plant cell comprising the nucleic acid of claim 5, optionally wherein the plant, portion of the plant or plant cell further comprises a second nucleic acid encoding a proton channel protein, such as an influenza A subtype M2 protein; and

b) incubating the plant, portion of the plant, or plant cell under conditions that permit expression of the influenza HA protein encoded by the nucleic acid, thereby producing the VLP, and optionally further incubating the plant, portion of the plant, or plant cell under conditions that permit expression of the proton channel protein encoded by the second nucleic acid, and

c) optionally harvesting the plant, portion of the plant, or plant cell, and purifying the VLP.

8. The VLP of claim 6, further comprising one or more than one lipid derived from the plant, portion of the plant, or plant cell, plant-specific N-glycans, modified N-glycans or a combination thereof.

9. A plant, portion of the plant, or plant cell comprising the nucleic acid of any one of claim 5.

10. A plant, portion of the plant, or plant cell comprising the HA protein of any one of claims 1 to 4 or the VLP of claim 6 or claim 8.

11. A composition for inducing an immune response comprising, an effective dose of the VLP of claim 6 or claim 8, and a pharmaceutically acceptable carrier, adjuvant, vehicle or excipient.

12. The VLP of claim 6 or claim 8, for use in inducing an immune response in a subject.

13. The VLP for use of claim 12, wherein the VLP is administered to the subject orally, intranasally, intramuscularly, intraperitoneally, intravenously or subcutaneously.

14. A method of increasing yield of production of an influenza virus like particle (VLP) in a plant, portion of a plant, or a plant cell, comprising:

a) i) introducing the nucleic acid of claim 5 into the plant, portion of the plant, or plant cell; or

ii) providing a plant, portion of a plant, or plant cell comprising the nucleic acid of claim 5; and

b) incubating the plant, portion of the plant, or plant cell under conditions that permit expression of the HA protein encoded by the nucleic acid, thereby producing the VLP at a higher yield compared to plant, portion of the plant, or plant cell expressing an unmodified influenza HA protein; and

c) optionally harvesting the plant, portion of the plant, or plant cell, and purifying the VLP.

15. An influenza H3 hemagglutinin (HA) protein comprising an amino acid substitution corresponding to position 382 of reference sequence SEQ ID NO: 92, wherein the amino acid substitution is to alanine or a conserved substitution of alanine.