SUMMARY

Provided herein are adjuvants, vaccine formulations comprising the adjuvants, methods of making the adjuvants and methods of using the adjuvants and vaccine formulations. In particular, chitosan and an antigen may be cross-linked using an aldehyde.

In one aspect, there is provided a vaccine comprising an adjuvant composition and an antigen,

wherein the adjuvant composition comprises a carbohydrate linked to chitosan to form a Schiff base,

wherein the carbohydrate is an open-ring mannose moiety,

and wherein the vaccine is formulated for administration in food or drinking water.

In one aspect, there is provided a use of the vaccine formulation as disclosed herein in the manufacture of a medicament for enhancing the immune response of a subject to an antigen.

In one embodiment, a composition comprising 0.5% to 2% of an aldehyde cross-linked chitosan and an antigen is provided. The final concentration of aldehyde in a vaccine composition is less than 0.5%.

In another embodiment, an adjuvant composition comprising a carbohydrate linked to chitosan to form a Schiff base is provided. The adjuvant may be combined with an antigen. The carbohydrate may be mannose.

In yet another embodiment, vaccine formulations are provided. Vaccine formulations may include the adjuvants provided herein and an antigen. The antigens may be proteins or microbial in nature, suitable microbes include bacteria, yeast, or other fungi, eukaryotic parasites and viruses and may be attenuated, recombinant, killed or otherwise inactivated.

In still another embodiment, methods of making the adjuvants and vaccine compositions are provided herein. The chitosan is dissolved in a solution of acetic acid, and an antigen is added to the dissolved chitosan. Finally the antigen and chitosan are combined with

We claim:

1. A vaccine comprising an adjuvant composition and an antigen,
   wherein the adjuvant composition comprises a carbohydrate linked to chitosan to form a Schiff base,
   wherein the carbohydrate is an open-ring mannose moiety,
   and wherein the vaccine is formulated for administration in food or drinking water.
2. The vaccine of claim 1, wherein the Schiff base is not reduced.
3. The vaccine of claim 1, wherein the Schiff base is reduced.
4. The vaccine of any one of claims 1-3, further comprising an enhancing molecule.
5. The vaccine of claim 4, wherein the enhancing molecule is saponin, toll-like receptors, the B subunit of a bacterial toxin, bacterial toxins, CpG motifs, liposomes or monophosphoryl lipid A.
6. The vaccine of claim 4, wherein the enhancing molecule is tetanus toxoid, cholera toxin B subunit, heat labile enterotoxin B subunit, or tripolyphosphate.
7. A vaccine of any one of claims 1-6, wherein the antigen comprises a microbe.
8. The vaccine of claim 7, wherein the microbe is *Salmonella, Escherichia, Shigella, Bordetella, Clostridium, Mycoplasma, Staphylococcus, Streptococcus, Bacillus, Influenza*, or *Eimeria*.
9. The vaccine of claim 7 or 8, wherein the microbe is inactivated or killed.
10. The vaccine of claim 9, wherein the microbe is killed using formaldehyde, glutaraldehyde or formalin.
11. Use of the vaccine formulation of any one of claims 1-10 in the manufacture of a medicament for enhancing the immune response of a subject to an antigen.
12. The use of claim 11, wherein the immune response includes an enhanced antibody response as compared to administering the vaccine without an adjuvant.
13. The use of claim 12, wherein the enhanced antibody response is an enhanced secretory IgA antibody response as compared to administering the antigen without an adjuvant.
14. The use of any one of claims 11-13, wherein the subject is a mammal or poultry.
15. The use of any one of claims 11-14, wherein the route of administration is subcutaneous or oral.

16. The use of any one of claims 11-15, wherein the vaccine formulation is administered in the food or drinking water.