Claims

1. A nutritional milk composition enriched in secretory Immunoglobulin A (IgA) antibodies, the composition comprising a bovine milk or colostrum base containing at least 0.2 g per liter of dimeric IgA with associated secretory component, wherein said IgA is immunologically specific to one or more predetermined pathogens prevalent in a target region, such that a single serving of the composition (250 mL) provides at least about 50 mg of functional sIgA capable of neutralizing the target pathogens.

2. The composition of claim 1, wherein the milk composition further comprises a lactose content of less than 1% by weight and a pH of approximately 6.6 to 6.8, thereby enhancing tolerance and stability while maintaining the natural organoleptic properties of milk.

3. The composition of claim 1, wherein the one or more predetermined pathogens are selected from the group consisting of: respiratory viruses, enteric viruses, bacterial respiratory pathogens, bacterial enteropathogens, and toxins associated with infectious disease, and wherein the IgA antibodies present are specific for antigens of those selected pathogens.

4. The composition of claim 1, wherein the composition is in a dried powder form obtained by low-temperature drying of the IgA-enriched milk, such that the secretory IgA retains at least 80% of its antigen-binding activity after reconstitution.

5. A method of producing a region-specific IgA-enriched milk product, comprising the steps of: (a) collecting epidemiological data indicative of prevalent infectious agents in a selected region, including at least public health case reports and wastewater pathogen analysis; (b) based on said data, selecting one or more pathogen-specific antigens corresponding to infectious agents showing elevated prevalence or outbreak status in the region; (c) immunizing one or more dairy animals with an immunogenic formulation comprising the selected antigens and an adjuvant that promotes mucosal Immunoglobulin A response, according to a schedule timed with the animals' lactation cycle; (d) after the immunizing step, obtaining milk from the immunized dairy animals during lactation; and (e) processing the obtained milk under conditions that preserve immunoglobulin functionality to produce the IgA-enriched milk product, wherein the product contains secretory IgA antibodies specific to the one or more selected pathogens.

6. The method of claim 5, wherein the epidemiological data in step (a) further comprises clinical laboratory isolate reports from healthcare facilities, and wherein step (b) includes computing a weighted incidence score for each candidate pathogen using the epidemiological data inputs and comparing said score to one or more thresholds to determine inclusion of the pathogen's antigen in the immunogenic formulation.

7. The method of claim 5, wherein the immunizing step (c) comprises administering to the dairy animals a prime vaccination and multiple booster vaccinations in the pre-parturition dry period (at approximately 8, 6, 4, and 2 weeks before expected calving), using a combination of aluminum salt adjuvant and a CpG oligonucleotide adjuvant, so as to induce high-titer antigen-specific IgA secretion in colostrum and milk .

8. The method of claim 5, wherein in step (e) the processing of the milk includes pasteurizing the milk at a temperature and time sufficient to ensure microbial safety (between about 63–72°C for 15–30 seconds) while retaining at least 70% of the IgA's antigen-binding activity, followed by rapid cooling and packaging of the milk product.

9. The method of claim 5, further comprising the step of testing the milk product for antibody titers specific to the selected pathogens and confirming that the IgA concentration meets or exceeds a predetermined potency threshold (0.2 g/L IgA or a neutralization titer ≥ a set value) prior to releasing the product for distribution.

10. The method of claim 5, wherein the dairy animals are cows and the immunogenic formulation of step (c) is polyvalent, containing antigens from a plurality of pathogens selected from viruses and bacteria that are currently of concern in the region, and wherein the method includes periodically updating the antigen composition of said formulation for subsequent immunizations based on newly collected epidemiological data, thereby dynamically matching the antibody profile in the milk to changing pathogen prevalence.

11. The method of claim 5, wherein if the epidemiological data indicates an emergent outbreak of a particular pathogen exceeding a critical threshold, the method further comprises performing an emergency immunization of the dairy animals with an antigen specific to said particular pathogen outside of the regular schedule, such that IgA antibodies against the emergent pathogen appear in the milk within about 2–4 weeks of outbreak detection.

12. A system for producing and delivering a pathogen-targeted immune milk product, comprising:

- a surveillance module configured to aggregate real-time disease prevalence data from multiple sources and to identify one or more high-threat pathogens in a geographical region;

- an antigen selection module operatively connected to the surveillance module, programmed to select corresponding antigen components when the prevalence data for a pathogen exceeds a predefined threshold;

- an immunization module comprising a vaccine preparation unit and means for administering vaccines to dairy livestock, adapted to immunize a population of dairy animals with the selected antigen components and adjuvants that induce secretory IgA production;

- a milk collection and processing module configured to collect milk from the immunized dairy animals and to pasteurize and/or preserve the milk under conditions that maintain antibody activity;

- wherein the system is arranged so that the collected milk contains a high level of IgA antibodies specific to the high-threat pathogens identified by the surveillance module, and further comprising a quality control unit that verifies antibody specificity and potency in the processed milk before the product is distributed.

13. The system of claim 12, wherein the surveillance module includes data inputs from public health databases for human cases, clinical lab networks, and at least one environmental sensor for wastewater analysis, and wherein the antigen selection module utilizes a weighted algorithm to prioritize pathogens by combining these inputs .

14. The system of claim 12, wherein the dairy livestock are housed in one or more controlled farm facilities, and the system further comprises a farm management subsystem that schedules immunizations, monitors animal health, and segregates immune milk from non-immunized milk, such that 100% of milk entering the processing module is traceable to immunized animals and meets predefined immunoglobulin criteria.

15. A method of enhancing mucosal immunity in an immunodeficient human subject, comprising orally administering to the subject a daily prophylactic dose of an IgA-enriched milk composition according to claim 1, wherein the subject is one who has low endogenous IgA levels or is otherwise immunocompromised, and wherein the secretory IgA antibodies in the administered composition provide passive immune protection at the subject's mucosal surfaces against pathogens prevalent in the subject's environment.

16. The method of claim 15, wherein the human subject has selective IgA deficiency as determined by an IgA diagnostic test (serum IgA below about 7 mg/dL), and the administering step comprises incorporating a serving of the IgA-enriched milk composition into the subject's daily diet, thereby reducing the frequency or severity of respiratory and gastrointestinal infections in the subject .

17. The method of claim 15, wherein the human subject is an elderly individual, an oncology patient undergoing immunosuppressive therapy, or a pediatric subject with recurrent infections, and the IgA-enriched milk composition contains antibodies targeting common community-acquired pathogens (including influenza virus, RSV, and rotavirus), such that regular consumption of the composition mitigates infection risk in the subject as part of an immune support regimen.

18. A method for identifying and providing targeted prophylactic nutrition to individuals with insufficient IgA-mediated immunity, comprising: (a) screening a population of individuals with a rapid immunoassay that detects IgA levels in a biological sample, to identify individuals having IgA levels below a normal reference range; (b) selecting the individuals identified in step (a) who are thus susceptible to recurrent mucosal infections; and (c) supplying to said selected individuals a nutritionally acceptable milk-based composition enriched with secretory IgA antibodies specific to one or more pathogens, in an amount effective to provide passive immunity and reduce infection susceptibility in the individuals.

19. The method of claim 18, wherein step (a) employs a lateral-flow fingertip blood test that qualitatively indicates low IgA by the absence of a test line , and wherein individuals identified as IgA-deficient are advised to consume the IgA-enriched milk composition of claim 1 on a regular basis as a compensatory immunoprotective measure.

20. The method of claim 18, further comprising collecting follow-up health data from the selected individuals during the period of consuming the IgA-enriched composition, and correlating consumption of the composition with incidence of infections, thereby demonstrating efficacy of the composition in providing protective immunity and allowing refinement of dosage or formulation for optimal benefit.

21. (Independent Method) A continuous method of enriching secretory Immunoglobulin A in a milk feedstream, comprising: (a) pumping raw or pasteurised milk at ≤0.5 bar trans-membrane pressure through a semi-permeable membrane having a molecular-weight cut-off of 8–30 kDa; (b) measuring IgA concentration in the retentate with an inline immunoassay or spectroscopic sensor at intervals of ≤60 s; (c) comparing each measurement to a predefined potency threshold of at least 0.20 g L^{-1} IgA; (d) automatically diverting retentate that fails to meet the potency threshold to a secondary utility stream; and (e) collecting retentate that meets or exceeds the threshold as an IgA-enriched product for human consumption.
22. (System) A processing skid comprising:• a tangential-flow filtration module with a membrane of claim 21; • an inline sensor configured to quantify IgA concentration in real time;• a programmable controller executing a feedback algorithm; and • a motor-actuated valve coupled to the controller, arranged to route flow either (i) to a pasteuriser when the sensed IgA concentration ≥ threshold or (ii) to a whey line when the concentration < threshold.
23. . (Software / Computer-readable medium) A non-transient computer-readable medium storing instructions that, when executed by a processor, (i) receive IgA titer data from the inline sensor, (ii) execute a proportional-integral-derivative control loop comparing said titer to the threshold, and (iii) transmit actuation signals to the valve of claim 22.
24. (Dependent) The method of claim 21 wherein diafiltration water is added to the feedstream to achieve a 3-to-5-fold concentration factor.

25. (Dependent) The method of claim 21 wherein zinc ions (0.3–0.8 mM) and trehalose (1–5 % w/v) are dosed inline downstream of the membrane to stabilise secretory component.
26. (Dependent) The system of claim 22 wherein the inline sensor is a fibre-optic immuno-photometer with a limit of detection ≤25 µg mL^{-1} IgA.
27. (Dependent) The method of claim 21 wherein milk temperature throughout steps (a)–(d) is maintained at ≤8 °C to preserve IgA bioactivity.
28. (Use claim) Use of the method of claim 21 in the manufacture of a nutritional composition of claim 1 having at least 70 % retention of antigen-binding activity after pasteurisation.