The possibility of using Ig Y-antibodies in immunotherapy

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Abstract. The importance of yolk antibodies (IgY) for their use in the diagnosis and treatment of human diseases is shown. The structural features of IgY compared to human immunoglobulins were studied. The disadvantages of obtaining hyperimmune sera from mammalian animals were revealed. A feature of IgY is its resistance to trypsin and chymotrypsin, which can contribute to more effective treatment of diseases. Data on optimization of the technology for obtaining yolk antibodies (IgY) from various bird species are presented. It is shown that 25-50 mg of highly purified immunoglobulin can be obtained from one bird egg. Obtaining immunoglobulins from eggs is more humane than using mammals for this purpose. Compared to ion exchange chromatography, gel chromatography, and ultrafiltration, the methods of precipitation with various chemicals (ammonium sulfate) were found to be simpler in terms of methodology. The results of electrophoresis revealed two types of proteins with a molecular weight of about 65 kDa and 30 kDa, which corresponds to the mass of the «heavy» and «light» IgY chains. Quail species Coturnix coturnix japonica as a producer of biological raw materials for the production of diagnostic immunoglobulins have great advantages over chickens (Gallus domesticus).

1 Introduction

The increasing resistance of pathogenic bacteria to antibiotics and the phage therapy of infectious diseases, which did not meet the high expectations, makes us think about using the old proven method of serotherapy for topical infections. Although the use of antibodies (immunoglobulins) in the treatment of bacterial infections in the twentieth century was replaced by antibiotics, serotherapy is still used in the treatment of those infections in which humoral immunity prevails (antitoxic, antiviral, antibacterial), as well as for the specific treatment of these diseases. In addition, specific antibodies are widely used for laboratory diagnostics of infections and for passive immunization (preventive serotherapy).

The purpose of the study. Based on the use of literature data and our own research, to study the possibilities of using so-called yolk antibodies for the diagnosis of topical diseases, as well as to evaluate the potential use of these antibodies in the therapy and immunoprophylaxis of topical diseases.

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2 Results

Eggs are an important source of nutrients in the diet of modern humans, providing up to 10% of the recommended daily intake of protein, 15% of vitamin B₂, 3% of vitamin E, 6% of vitamin A, and is also a source of saturated and polyunsaturated fatty acids, phospholipids. In the food industry, dry egg products are widely used as raw materials. The use of natural egg products significantly complicates the organization of production, dramatically increases the microbiological danger. The yolk is the most valuable part of the egg. The yolk accounts for up to 33% of the liquid content. The yolk contains approximately 60 calories, which is three times more than the protein. Egg yolk contains vitamins that are vital for the human body. Most of all vitamin E, D, B₉, B₁, B₂, B₁₂, A, F, K. The egg yolk contains more than 50 trace elements-phosphorus, calcium, iron, magnesium, sodium, potassium, sulfur and chlorine. In addition, the yolk contains proteins, lipids, carotenoids, lecithin and cholesterol. Another advantage of the yolk is that its nutrients are absorbed by the human body by 95%. Cholesterol is one of the important components of the cell membrane structures that determine its strength, elasticity, and permeability to various substances.

Modern researchers have dispelled the myths about the connection between the consumption of eggs and the development of cardiovascular diseases.

Modern equipment and flexible technological processes allow you to easily divide the egg into white and yolk and produce egg products in dry, liquid, chilled and frozen forms. Liquid products are filtered, pasteurized and packaged in aseptic packaging. Egg processing products retain their nutritional and energy value, all the vitamin complexes and nutrients contained in the egg. The egg yolk is also fermented before drying, which improves its emulsifying properties. Dry egg yolk is an indispensable product in baking, confectionery production, production of custards, sponge and shortbread dough, baby food.

As an example, the Russian enterprises ROSKAR and RUZOVO, where egg powder, dry egg white and dry egg yolk are produced, can be cited.

Antibodies from the yolk of birds have a number of characteristics that make them an attractive object for obtaining and using in immunochemistry:
- greater productivity;
- easy selection (egg collection instead of blood collection);
- small amount of antigen for immunization.

Yolk immunoglobulins have a local effect in the lumen of the stomach and intestines, blocking the receptors of microbial cells, thereby reducing the adsorption of microbes on the epithelial cells of the mucous membrane and inhibiting the reproduction of adsorbed microbial cells, weakening or preventing the development of the infectious process. The protection of the human body by antibodies is not new. Oral administration of antibacterial and antiviral antibodies (immunoglobulins) through infant formula has been found to be effective in preventing intestinal infections.

Quail eggs are quite easy to buy in any store, however, they are quite difficult to attribute to food in the traditional sense of the word. It is best and more accurate to position them as functional products (Food for Specific Health Use). They differ from dietary supplements in the presence of adaptogens in the physiological concentration that stimulate the body's defense systems (immune, antioxidant, antitoxic, etc.).

Quail eggs are rich in vitamins B₁ and A and minerals (iron and potassium). These eggs do not cause allergic reactions to egg weite, so they can be recommended for children. Despite the small size of quail eggs, their nutritional value is four times higher than that of chicken eggs. Chicken proteins do not contain this compound. Quail eggs contain more yolk than chicken eggs and have a more pronounced flavor. There is no doubt that quail eggs themselves can improve the functional state of the gastric and duodenal mucosa.
The problem of gastric ulcer and duodenal ulcer is currently not removed from the agenda. Previously, it was believed that the cause of this disease is a violation of the diet. In the 60s, stress was considered the cause of peptic ulcer disease. In 1983, Australian bacteriologists R. Warren and B. Marshall showed that in patients with peptic ulcer of the stomach and duodenum, bacteria resembling the wings of a gull (Helicobacter pylori) are found in the gastric mucosa. Currently, the World Health Organization (WHO) considers this microbe responsible for the occurrence of chronic gastric erosions, peptic ulcer disease, and even stomach cancer.

Eradication of Helicobacter pylori from the stomach, that is, etiotropic treatment, is very expensive and does not always give a positive result. An important measure in the treatment of stomach ulcers is a diet. For this purpose, dishes made from quail eggs help very well. However, if these birds are immunized (vaccinated) with a helicobacter antigen (vaccine), then after a while, antibodies (immunoglobulins) against Helicobacter appear in the yolk of quail eggs. Thus, you can "kill two birds with one stone" - a sick person receives dietary food in the form of dishes from quail eggs, in which there is a kind of neutralizer of Helicobacter.

If you vaccinate (immunize) birds, in particular, quails, with the Helicobacter antigen, then specific antibodies will accumulate in the egg yolks. In the human stomach, these antibodies will bind to the Helicobacter and neutralize them. When using a biological model of the Mongolian gerbil, it was found that this biotechnological complex (specific antibodies against Helicobacter pylori) prevents damage to the gastric mucosa caused by H. pylori and reduces the level of infiltration of lymphocytes and neutrophils. Thus, experimental gastritis caused by H. pylori, can be successfully cured by oral administration of these antibodies. Their immunological activity persists for 10 minutes at +60 °C, which suggests the possibility of pasteurization of the product. Fortification of food products with these antibodies will significantly reduce the level of H. pylori infection. Thus, anti-Helicobacter antibodies from quail immunized with H. pilori may potentially provide an alternative treatment for gastric and duodenal ulcers.

To obtain diagnostic immunoglobulins, it is most expedient to use the following methods.

2.1 Intranasal method

The antigen is pipetted into the nostrils of the birds. Before immunization, water is removed from the bird, it is allowed to drink after 1-2 hours. Antibodies can be detected as early as on the 8-10 day.

2.2 Subcutaneous method

The essence of the cutaneous method is that the antigenic material is rubbed into the feather follicles. 2-3 drops are applied to the bare surface of the skin with a stiff hair brush or a glass rod with a rough surface. One week after immunization, swelling of the feather follicles is observed, and antibodies are detected in the second week after immunization.

Puncture in the wing membrane.

A special applicator in the form of a two-pronged needle is used, which is immersed in antigenic material before immunization. The underwing membrane is pierced in the non-feathered place. The effectiveness of immunization is evidenced by a local inflammatory response.
2.3 Oral method

The oral method is used in the early morning hours, as the bird drinks a lot of water at this time. Skimmed milk powder (2.5 g per 1:1 of water) or sodium thiosulfate (16 mg per 1:1 of water) is added to the diluted (1:3) antigenic material. The birds are watered for 2 hours.

2.4 Cloacal method

The antigenic material is rubbed into the mucous membrane of the upper fornix of the cloaca with a special fluted glass spatula. On the 5-6 day after immunization, the reaction of the mucous membrane of the cloaca (edema and hyperemia) in 100 vaccinated chickens is taken into account. If a cloacal reaction is noted in 80% of chickens or more, it is considered that the immunization is satisfactory, if in a smaller number of chickens, then they are re-immunized.

2.5 Intraocular method

This is one of the most effective methods, since the application of the antigen is carried out in the immediate vicinity of the lymphoid organ - the Gardera gland (gland of the blinking membrane (glandula nictitans) - a paired exocrine gland in terrestrial (except for primates, including humans) and secondary aquatic vertebrates. The Harder's gland is associated with the existence of the nictitating membrane (third eyelid) and is located in the inner (medial) corner of the eye. It is necessary to inject antigen one drop to each bird, without touching the surface of the eye. It is imperative to keep the bird in this position for several seconds so that the antigen has time to be evenly distributed.

2.6 Intramuscular method

This method is used to immunize day-old chickens. The antigen is injected intramuscularly into the thigh area in a volume of 0.2 ml.

2.7 Spray method (coarse)

This method is used to vaccinate both day-old chickens and adult birds. The spray is used to distribute the antigenic material evenly over all chicks.

2.8 Aerosol method (finely dispersed)

The antigen is sprayed using special generators.

2.9 Subcutaneous method

The antigen is injected into the base of the neck. This zone has a definite advantage, since it is the cleanest in the bird. Stretching out the bird's neck, it is necessary to pull back the skin, slightly pulling the plumage, and pierce it in the drawn place.

2.10 Immunization in the pectoral muscles

Immunization in pectoral muscles as a type of intramuscular method. The needle is inserted into the middle part of the muscle to a depth of 0.3-0.5 cm at an acute angle towards the head.
with the introduction of the needle directed with the tip to the tail, it is possible to pierce the sternum and liver, which will lead to the subsequent death of the bird).

Birds do not have such a highly organized lymphatic system as humans. They have accumulations of lymphoid tissue scattered throughout the body, capable of actively responding to any antigenic stimulus. Lymphoid formations are presented in the form of centers of accumulation of medium and large lymphocytes or in the form of diffuse tissue infiltration by small lymphocytes. It should be noted that lymphoid formations are widely represented in the body of birds, mainly in connection with the digestive and respiratory systems. This strategy of placing immune cells is associated with a greater possibility of encountering a pathogenic agent.

Egg yolk antibodies have already been described in passive immunization with their oral (via mouth) ingestion in fortified foods to prevent intestinal infections such as those caused by enterotoxigenic \textit{E. coli}, \textit{Salmonella enterica} serovar, \textit{Typhimurium} and rotavirus. These studies have shown the potential benefits of using specific yolk antibodies. In addition, for the practical use of these yolk antibodies together with food or pharmaceutical materials, it is necessary to ensure their resistance to the action of acid and pepsin of gastric juice.

Preliminary results from this study suggest that yolk antibodies against \textit{H. pylori} obtained from immunized quails may provide a new approach to the management of helicobacteriosis in humans. However, many problems remain unresolved for clinical applications, such as the effect of the yolk antibodies themselves on the human body, the duration of the effect of these antibodies after discontinuation of use, etc.

Oral transmission of antibodies is the most appropriate option for the treatment of infections affecting the gastrointestinal tract. The immunity obtained by passive immunization lasts for a short period of time while the antibodies remain in the body, but it provides fairly rapid protection in acute diseases.

Usually, this type of therapy is carried out with human immunoglobulins and heterologous sera obtained from hyperimmunized animals, mainly horses. To prevent the death of the donor animal, it is recommended to take no more than 1\% of the blood volume from the body weight of the animal. Taking blood in large volumes can lead to the death of the animal [2, 9]. An alternative is to use birds as antibody donors.

As early as 1893, Fr. Klemperer examined the contents of the eggs of immunized chickens for the presence of antitoxin. It turned out that only in the yolk is detected antitoxin-specific antibodies that protected the experimental mice from death. However, for a long time this discovery remained little known. But when the welfare of laboratory animals became a serious ethical issue for the scientific community [2], his work on the non-invasive production of yolk antibodies became very significant.

The founder of the study of immunity in birds is the Russian researcher S. K. Dzerzhgovsky. One of the areas of his activity was the study of antitoxic immunity. In his work "On the question of the heredity of artificial immunity against diphtheria" (1901), he found out that only the yolk has "antitoxic properties", the protein did not contain "antitoxin" at all. The key point of the research was the conclusion of S. K. Dzierzhgovsky on the nature of yolk antibodies: "In the yolk, the bodies with antitoxic properties will belong to the globulins and generally have the same properties as in the serum". In the scientific literature, this immunoglobulin (Ig) is called IgY (from the English Yolk - yolk).

Using immunocytochemical and genetic methods, three classes of avian immunoglobulins were identified as homologues of mammalian IgM, IgA, and IgG [8, 10, 15]. The H and L chains of immunoglobulins are formed from repeating segments, each of which consists of 115 amino acids. They contain cysteine and tryptophan residues and a disulfide bridge within the domain that gives a functionally important tertiary structure to the immunoglobulin molecule. The domains (V-domains) in the terminal part vary greatly, and the formation of VH and VL domain pairs creates an antigen-binding site that determines the...
specificity of antibodies. This section contains the epitope (Fab fragment). Since the pairs of H and L chains connected by disulfide bonds form the main monomer block, two antigenic binding sites are formed.

Minor genetic variation is observed in the opposite region of the molecule, and these regions are called constant domains (CH or CL). H chains have 2-4 constant domain domains and one L-chain domain. The biological properties depend on the C-domains. They provide membrane transport, complement binding, and opsonization. The avian immunoglobulin molecule instead of the hinge region (HR) has a switching region with limited flexibility in the C1-C2 and C3-C4 domains. The more rigid structure of the IgY molecule compared to mammalian IgG gives IgY unique biochemical properties, such as the inability to precipitate in physiological salt concentrations.

When studying the structure of the IgY molecule of birds, there are also features in the nature of the destruction of the molecule under the action of proteolytic enzymes. Under the influence of papain protease, the molecule breaks down into Fab fragments and dialyzed peptides instead of the two Fab fragments and the Fc fragment obtained by the influence of papain on mammalian IgG. According to the literature, the homology of IGY with mammalian IgG is 30-35 %. The main difference between IgY and the mammalian homolog is the longer H chain in the molecule. The IgY molecule in birds does not have a genetically encoded hinge. Instead, there are "inclusion" zones with limited plasticity in the domain interfaces Cy 1-Cy 2 and Cy 3-Cy 4. The two branches are located so close that they prevent cross-linking of epitopes on large antigens. The Cst2 domain may have condensed during evolution and become a genetic hinge in mammalian IgG.

Phylogenetic studies have shown that in birds, the homologue of low molecular weight mammalian IgG is similar to both IgG and mammalian IgE. This avian isotype prevails in the blood serum, is produced after IgM in the primary reaction, and is the main isotype produced in the secondary reactions.

A special feature of IgY is its resistance to trypsin and chymotrypsin. In vitro experiments showed that after 8 hours of protease digestion, about 40 % of IgY molecules did not lose their functional activity. IgY is susceptible to degradation by pepsin in an acidic environment, but the addition of protectors (milk and egg white) helps protect IgY from acid degradation. The antibodies can be administered orally in various forms (egg powder). Eggs are an integral part of the human diet and are therefore easily perceived by the immune system. Therefore, immunotherapy based on IgY is low-toxic, however, it is contraindicated for people suffering from individual intolerance to egg white. Concerns about the possibility of digesting IgY in the mammalian gastrointestinal tract were dispelled by scientists who showed that 40 % of IgY molecules remain intact and functionally active. In addition, capsules with delayed release of immunoglobulins have been developed to protect antibodies from gastric digestion.

Therefore, yolk antibodies can be successfully used not only for the diagnosis, but also for the treatment of many diseases. Attempts are being made to use a new type of immunotherapy in surgical and therapeutic practice. The available literature describes cases of successful use of IgY for the treatment of influenza, intestinal infections. Attempts are being made to use IgY antibodies for the treatment of HIV infection. A method of Helicobacter eradication using IgY–antibodies not only against Helicobacter pylori antigens, but also against urease is described. IgY is also successfully used in dental practice.

The use of avian antibodies for the treatment and prevention of diseases of farm animals is described quite widely in the scientific literature. IgY drugs are supplied as feed additives for the prevention of infections of farm animals.

From one egg yolk of a chicken egg, you can get 25-50 mg of highly purified immunoglobulin. The introduction of antigenic material for the purpose of bird immunization is possible by more humane methods than when using mammals [2, 7, 8].
The egg yolk can be divided into plasma and a fraction of granules by diluting the whole egg with water or an aqueous solution of sodium chloride, followed by centrifugation. The plasma fraction is 77-81 % by weight of the dry matter of the yolk. The sediment obtained by centrifugation contains granules that made up 19-23 % of the dry matter mass.

The plasma fraction of chicken egg yolk contains about 25 % protein and about 73 % lipids. The protein component of the plasma fraction is 80 % of the mass of yolk proteins and contains low-density lipoprotein and water-soluble globular protein livetin. In chicken egg yolk, the granule fraction is about 20 wt.% of the egg yolk proteins and usually contains about 64 % of the proteins and 31 % of the lipids. The protein component of the granule fraction contains high-density lipoprotein, fosvitin, and low-density lipoprotein.

The term "high-density lipoprotein" (HDL) refers to a protein-lipid complex that is found in high concentrations in the yolk of bird eggs. HDL contains a protein with a hydrophobic pocket that holds the lipid component. HDL contains 75-80 % apoproteins and 20-25 % lipids. These lipids are represented by phospholipids (65 %), triglycerides (30 %) and cholesterol (5 %).

By ion exchange chromatography, two subgroups can be distinguished from the total mass of HDL: α- and β-HDL. α-HDL contains 6 times more sialic acid and 2 times more phosphorus than β-HDL. As a result, α-HDL has a higher acidity than β-HDL. Except for these differences, HDLs of both types have similar chemical compositions. HDL has a molecular weight of approximately 400 kDa, a diameter of about 7-20 nm, and a density of 1,12 g / ml. Unlike LDL, HDL does not have a spherical structure, but its pseudomolecular structure resembles that of globular proteins.

Low-density lipoproteins (LDL) are the main component of the egg yolk of chicken eggs, with a globular complex having a diameter of 17-60 nm and a density of 0,982 g/ml. LDL contains an inner core, mainly consisting of triglycerides and cholesterol esters, and a surface layer, which consists of phospholipids, cholesterol and apoproteins.

Apoproteins make up 11-17 % of the total mass of LDL, lipid components-83-89 wt.%. Lipids are 69 % phospholipids, 26 % - triglycerides and 5 % - cholesterol. LDL consists of two subgroups: LDL1 (10 * 106 Da) and LDL2 (3*106 Da). LDL1 represents 20 % of all LDL and contains twice as many proteins as LDL2. The chemical compositions of both types of LDL are similar. LDL proteins consist of 6 apoproteins. The proportion of the main apoprotein (130 kDa) is more than 70 %.

The second apoprotein represents about 20 % of apoproteins, its molecular weight is 15 kDa. Their isoelectric point is in the range from 6.5 to 7.3. LDL apoproteins contain about 40 % hydrophobic amino acids and are represented by a structure in the form of a random helix with a beta-folded configuration. Accordingly, they are highly hydrophobic and flexible molecules. LDL apoproteins are glycosylated by aspartic residues and contain 1,3 % hexose, 0,67 % hexosamine, and 0,38 % sialic acid.

3 Discussion

Different methods of IgY isolation can be divided into three main groups.

Deposition methods (deposition by various chemicals).

Chromatographic methods (ion exchange chromatography, gel chromatography).

Ultrafiltration

To isolate the immunoglobulins, ammonium sulfate was used because unlike ethanol and acetone, it is not flammable, is well dialyzed, and is less toxic. At the first stage of research, it is necessary to separate the ovoalbumins, which make up the protein shell from the yolk ball. The process of isolation of diagnostic immunoglobulins from egg yolks consisted of several stages.
At the first stage, the shell of quail eggs from the "blunt" side of the egg was opened with sterile scissors, the shell was cut off around the air chamber. The contents of the poultry egg were placed on a cloth made of filtering coarse dacron cloth or gauze, previously moistened with 0.9% isotonic sodium chloride solution or 0.01 M phosphate buffer solution (pH 7.2-7.4). With a light shake, the yolk was released from the protein without damaging its shell. The contents of the poultry egg were placed in a 9.6% solution of sodium bicarbonate (NaHCO₃) and kept in it until the protein was completely dissolved (usually 1-3 minutes), gently stirring. The dissolution of the protein was determined visually by the release of the surface of the yolk ball from the egg protein. The yolk balls were then separated from the solution using a gauze filter. If necessary, the above procedure was repeated several times. The yolk balls were washed with 0.85% sodium chloride solution and the yolk mass was extracted.

At the next stage, 5 volumes of distilled water were added to 1 volume of the yolk mass, thoroughly mixed and centrifuged for 30 minutes on a MLW k-80 centrifuge manufactured by Medizintechnik (Germany) at 2200 rpm. and a temperature of +12 °C. The supernatant was collected.

Then an equal volume of chloroform was added to the supernatant and thoroughly mixed for 30 minutes. Then they were centrifuged on a "MLW k24D" centrifuge manufactured by "Medizintechnik" (Germany) at 8000 rpm. and a temperature of +4 °C. The upper water phase contained Ig Y, the middle phase contained the coagulated components of the yolk, and the lower phase contained chloroform with the components of the yolk dissolved in it (fig. 1).

Fig. 1. Fractions of egg yolk emulsion after chloroform treatment and centrifugation (upper layer - aqueous phase with Ig Y, middle - aggregated protein, lower - chloroform with yolk components dissolved in it).

The upper water phase was selected and saturated with ammonium sulphate up to 50% by weight, and left for an exposure of 30 minutes in the refrigerator. Then they were centrifuged for 25 min. on a "MLW k24D" centrifuge manufactured by "Medizintechnik" (Germany) at 8000 rpm. and a temperature of +4 °C.

The supernatant was removed, and the precipitate was again resuspended to 1/10 of the original volume and re-precipitated with ammonium sulfate. Subsequently, they were centrifuged as described above. The supernatant was removed and the sediment was used for further studies.

To determine the degree of purity of the obtained preparations, electrophoresis was performed in a polyacrylamide gel in the presence of sodium dodecyl sulfate. In this case,
the proteins were in a solution containing a negatively charged detergent—sodium dodecyl sulfate. By binding to the hydrophobic regions of the protein molecule, this detergent caused the protein molecules to unfold into long, elongated chains. Complete removal of the protein shell, coagulation with 70% alcohol and treatment of the yolk with chloroform, followed by precipitation with ammonium sulfate to saturation of 50% by weight, provides a pure preparation of immunoglobulins.

The results of electrophoresis revealed two types of proteins with a molecular weight of about 65 kDa and 30 kDa, which corresponds to the mass of the "heavy" and "light" chains of Ig Y.

Significantly more diagnostic immunoglobulins can be obtained from the yolks of birds than from mammalian blood sera. In addition, Ig Y does not have a non-specific interaction with the components of mammalian blood serum, which is often manifested by a large number of false-positive serological reactions in humans.

The main source of raw materials for the production of immunobiological drugs are chickens (Gallus domesticus), but many people have allergic reactions to the protein of chicken eggs. In addition, chickens are often infected with various pathogens of bird diseases. The use of contaminated (most often oncoviruses) chicken embryos can cause the spread of viruses during vaccination.

Unlike chickens and other birds, the body temperature of quails is on average 2 °C higher and is 41-42 °C [6, 9]. For this reason, they are not sensitive to most pathogenic bacteria and avian viruses, which allows quail to be used as producers of biological raw materials and maintain the SPF (Specific Pathogen Free) status.

Comparing all the above data, we can conclude that quail as a producer of biological raw materials for the production of diagnostic immunoglobulins have the following advantages:

- the low body weight of the quail and the high egg productivity make it possible to place a significant number of individuals on small production areas;
- short period of puberty and oviposition does not depend on the season of the year;
- it is possible to maintain the SPF status;
- continuous and non-invasive production of raw materials (egg yolk mass) for the isolation of immunoglobulins;
- yolk immunoglobulins do not interact with the mammalian complement system and C-reactive protein.

4 Conclusion

The potential use of IgY for specific therapy and immunoprophylaxis of infectious diseases is shown as a feature of IgY is resistance to trypsin and chymotrypsin, which can contribute to more effective therapy of human infectious diseases. The technology for the production and purification of yolk antibodies (IgY) has been optimized. As IgY-producing birds, it is most appropriate to use quails of the Coturnix coturnix japonica species. Promising results of research on passive immunization indicate their beneficial effects on health. IgY technologies, even if they need further improvements and additions, will be of great importance for healthcare in the coming years around the world.

References

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