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Popular Article

Edible Vaccines: A Novel Strategy for Global Health and Disease Prevention

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Introduction

Global health continues to be seriously threatened by infectious diseases, especially in underdeveloped nations with scant access to medical facilities and resources. Numerous infectious diseases have been successfully fought off via vaccines, which have also helped relieve the strain on healthcare systems and saved countless lives. Traditional vaccination strategies have played a critical role in the eradication or control of many illnesses around the world. However, the traditional methods of vaccine production, distribution, and administration frequently encounter difficulties due to factors including expense, the necessity for a refrigerated supply chain, and needle-based delivery techniques. These difficulties emphasize the urgent requirement for novel approaches that can get beyond these restrictions and strengthen international immunization campaigns.

Edible vaccines are a revolutionary advancement in the discipline of immunization that has recently come to prominence. This innovative approach uses plant's natural ability to deliver vaccines, providing a promising and potentially significant way to overcome the drawbacks of traditional vaccines.

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The notion behind edible vaccines is to produce vaccine antigens using plant or plant-based technologies. Edible vaccines represent a ground-breaking concept where plants, such such as fruits, vegetables, or other food crops, are genetically engineered to produce specific antigens or proteins found in pathogens. Researchers can take advantage of plants inherent capacity to make proteins by genetically modifying plants to express particular antigens. Individuals can consume the resulting edible plant tissues, such as fruits or leaves, to trigger the desired immune response against the pathogen of interest (Fig 1). Consuming these genetically altered plants stimulates the immune system of the body, causing an immunological response that offers protection against the intended disease. This innovative system not only offers a needle-free and more patient-friendly way to administer vaccines, but it also has the potential to completely alter how the world fights illness. Particularly in distant places and settings with limited resources, this non-invasive and simple form of delivery could greatly increase vaccine coverage. Several plant species have been explored as potential hosts for edible vaccines, including banana, tomato, potato, and lettuce, among others. Each plant species has distinct advantages in terms of simplicity of cultivation, scalability, antigen expression stability, and safety.

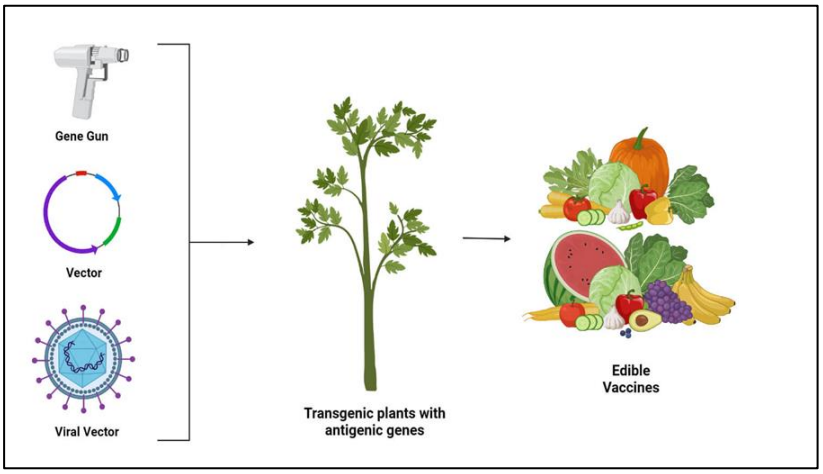

Figure no. 1: Edible Vaccines

Edible vaccines have a number of other intriguing qualities in addition to being simple to administer and scalable. It is not necessary to transport or store them in a cold chain because they can be kept at ambient temperature. In areas without a dependable infrastructure for refrigeration, this capability is especially beneficial. Additionally, the use of platforms based on plants for production lowers the price of producing vaccines, potentially lowering the cost and increasing access to vaccines for underprivileged communities.

However, several challenges must be addressed to realize the full potential of edible vaccines. Regulatory issues, public acceptance, and worries about allergenicity, stability, and effectiveness are some of these difficulties. Before edible vaccinations can be widely used, thorough scientific

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investigation, clinical trials, and strict regulatory restrictions will be required to guarantee their safety and effectiveness.

Our aim to provide a comprehensive overview of the concept of edible vaccines and their potential to revolutionize global health and disease prevention. The current level of research and development in the field will be examined, with a prominence on effective applications, persisting difficulties, and potential future developments. By focusing attention on this cutting-edge tactic, our aim to encourage additional study, cooperation, and funding into edible vaccines as a way to enhance global health outcomes and combat infectious illnesses on a larger scale.

Concept of Edible Vaccines

Edible vaccines represent a revolutionary approach to vaccination, utilizing plants as vehicles for delivering vaccines. Edible vaccines involve genetically modifying plants (GMOs) to produce specific antigens or proteins from pathogens. When these GMOs are consumed, they stimulate an immune response in the body, leading to the production of protective antibodies. Essentially, the plants themselves become the vaccine, potential to overcome various challenges associated with traditional vaccines, such as the need for injections, cold chain storage, and costly production methods. Edible vaccines are a revolutionary form of immunization that use plants as carriers of particular antigens. Here is a brief description of edible vaccinations along with a comparison to traditional vaccines (Table 1).

Table no. 1: Comparison of edible vaccines and traditional vaccines

Aspect	Edible Vaccines	Traditional Vaccines
Administration	Oral administration	Injection
Stability	Enhanced stability, less dependence on refrigeration	Require strict refrigeration and storage conditions
Accessibility	Improved accessibility, local cultivation possible	May face boundaries in resource-limited areas
Production	Can be produced using agricultural practices	Difficult manufacturing processes
Development & Regulation	Require research, safety assessments, and regulatory approval	Require research, safety assessments, and regulatory approval
Cost-effectiveness	Potentially lower production costs	Can be expensive due to complex processes

Engineering Edible Vaccines

To create edible vaccines, scientists introduce specific genes into the plant's genome,

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instructing it to produce the ideal antigen. Commonly used plant systems include tobacco, potatoes, bananas, tomatoes, and lettuce. These plants are selected based on their ability to express high levels of the antigen and their compatibility with large-scale cultivation.

Mode of action of edible vaccines

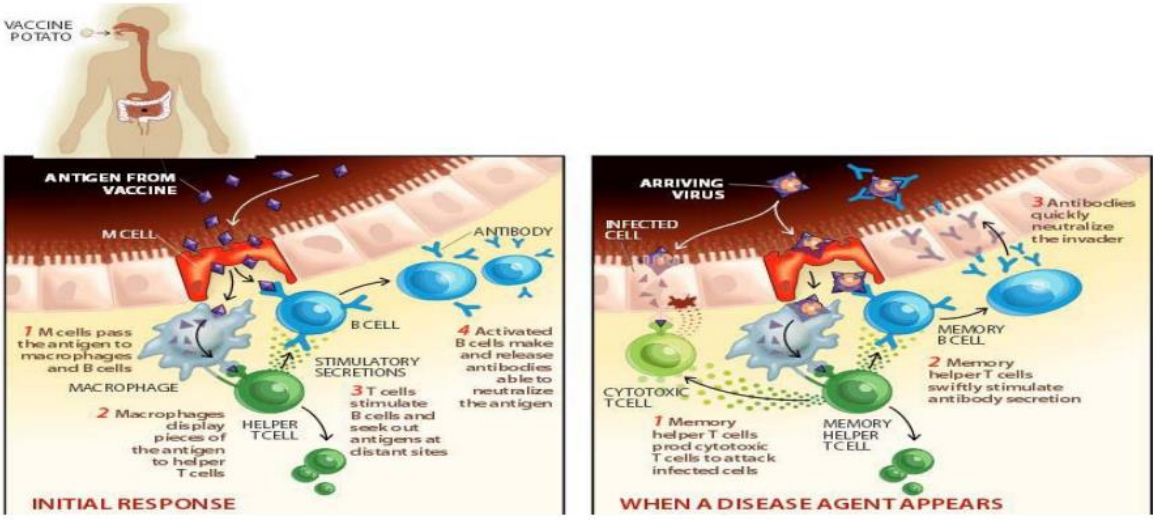

Figure no. 2: Mechanism of action; Food-based vaccinations made from potatoes (Jan *et al.*, 2016).

Since the urogenital, respiratory, and gastrointestinal tracts are practically all human infections primary entry points into the body, they almost all invade at mucosal surfaces. Mucosal immunity is the body's first and main line of defense. Because oral vaccinations can produce mucosal immunity, antibody-mediated immune response, and cell-mediated immunological response, they are the most effective method of mucosal immunization. Due to the thick outer wall of the plant cell, orally administered antigen-containing plant vaccines do not get hydrolyzed by gastric enzymes. Antigen-containing transgenic plants function by bioencapsulation, which involves an exterior hard cell wall, before being hydrolyzed and released in the intestines. When Payer's patches and gut-associated lymphoid tissue (GALT) are exposed to the released antigens, M cells in the intestinal lining pick them up. These are then transmitted to macrophage and local lymphocyte populations, producing memory cells, local IgA response, serum IgG, and IgE responses that quickly balance the onslaught by the actual infectious agent (Fig 2).

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Safety and Regulation

The safety of edible vaccines is of paramount importance. Regulatory agencies thoroughly evaluate these vaccines to ensure their efficacy and safety before they can be approved for human use. Extensive studies are conducted to assess potential risks associated with allergenicity, unintended effects on the environment, and gene flow between genetically modified plants and their wild relatives.

Potential Applications

a) **Infectious Diseases:** The development of edible vaccines promises hope for the treatment of infectious diseases such rotavirus, cholera, hepatitis B, and malaria (Table 2). Edible vaccines, which may offer greater protection against infections that commonly enter through the mouth, directly target the mucosal immune system in the gut.

Table no. 2: A list of plants that have been investigated as potential sources of edible vaccines, along with the disease or infectious agent they are linked to and the antigen expressed:

Plant	Disease or Infectious Agent	Antigen Expressed
Alfalfa	Newcastle disease virus	Newcastle disease virus F protein
Banana	Hepatitis B virus	Hepatitis B surface antigen (HBsAg)
Carrot	Foot-and-mouth disease virus	Foot-and-mouth disease virus VP1
Lettuce	Human papillomavirus	Human papillomavirus L1 protein
Maize (Corn)	Escherichia coli	Heat-labile enterotoxin (LT)
Potato	Cholera toxin	Cholera toxin subunit B
Rice	Rotavirus	Rotavirus VP6 protein
Soybean	Hepatitis C virus	Hepatitis C virus core protein
Tobacco	Norwalk virus	Norwalk virus capsid protein
Tomato	Rabies virus	Rabies virus glycoprotein

b) **Animal Health:** Edible vaccines also have applications in veterinary medicine. They can be used to immunize livestock against diseases, reducing the economic losses and public health risks associated with infectious animal diseases.

c) **Cancer Vaccines:** Researchers are investigating the utility of ingestible vaccinations in the treatment and prevention of cancer. Inducing an immune response against cancer cells may be achievable by producing tumor-specific antigens in plants.

d) **Birth control:** TMV administration results in the production of a protein called ZB3 protein, which is present in Mousezona pellucida and is proficient of blocking mouse egg fertilization because of the resultant antibodies.

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Challenges and Future Outlook

Despite the substantial potential of edible vaccines, there are still a number of difficulties. Public acceptance, legal restrictions, problems with intellectual property, and the requirement for extensive manufacturing and distribution are a few of these. The public, regulatory agencies, lawmakers, and scientists will need to work together to overcome these hindrances.

Conclusion

A feasible and cutting-edge approach to improving global health and disease prevention is the use of edible vaccinations. This method, especially in resource-constrained places, offers many benefits by administering vaccinations through edible plants, including simplicity of administration, lower cost, enhanced stability, and expanded accessibility. The challenges associated with traditional vaccine distribution systems, such as the necessity for a cold chain and injections, may be solved with edible vaccines. They are a flexible weapon for combatting different infections because they can also be modified to target particular diseases. However, more investigation and development are required to ensure the efficacy, safety, and regulatory acceptance of edible vaccines. This innovative approach, if successfully applied, might revolutionize vaccination programmes, especially in developing nations, and help eradicate or control infectious illnesses on a worldwide basis. This pioneering method represents a huge advancement in the ongoing campaigns to safeguard populations worldwide from deadly diseases.

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