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Sprayable double-stranded RNA accelerated future foods safety

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Introductıon

The non-transgenic approach of Spray-Induced Gene Silencing (SIGS), which relies on spray application of Double-Stranded Rna (dsRNA) to induce RNAi, has come to prominence due to its safety and environmental benefits in addition to its wide host range and high target specificity. Recently, the SIGS based dsRNA has been applied in precise disease or pest control to enhanced food safety. dsRNA technology could enable the creation of functional foods with tailored nutritional profiles for potential development of functional foods. It also is innovative applications in food processing and preservation, which has shown promise non only in preharvest crop protection, but postharvest grain storage for novel solutions for stored-product safety. Here, we simplified the progress or opinion of those aspects for foods safety.

Precision Disease of Pest Control for Enhanced Food Safety

The application of dsRNA will be rapidly degraded in the environment-usually within a few days-leaving virtually no residues on agricultural products, resulting its environmental friendliness and better than chemical pesticide. A 2020 Organization for Economic Co-operation and Development (OECD) report concluded that dietary intake of RNA molecules, including dsRNA, poses no health risk to humans or vertebrates, revealing dsRNA safety for human. As the core component of RNA interference (RNAi), dsRNA can precisely silence genes that are essential to pests or pathogens, thereby suppressing their growth or reproduction. Compared with conventional pesticides, dsRNA, based on the DNA sequence specificity, offers high specificity of targeting only the intended pest or pathogens, leaving non-target organisms largely unaffected. It has been reported in successful protection of various plants such as Arabidopsis, tobacco, grapes, citrus, tomatoes, wheat, barley, and rice for excluding nematodes, root worms, whiteflies, psyllids, aphids and moths. It can also prevent the invading of fungi, including Fusarium graminearum, Botrytis cinerea, and Fusarium oxysporum, as well as viruses, including cucumber mosaic virus, tomato leaf curl virus, and potato virus in tobacco, lettuce, peach, citrus, grape, apple, chili, zucchini, tomato, wheat, barley, and rice. Although few reports were detected in the animal protection using dsRNA, it's possible to wipe out the disease in the surface of large livestock, such as cattle and goats, or feedding them specific materials embedding dsRNA. Until now, The U.S. Environmental Protection Agency (US-EPA) has approved the commercial use of Ledprona, an RNA pesticide containing dsRNA, for controlling the Colorado potato beetle. Kenya has authorized an RNAi cassava variety resistant to cassava brown streak virus, significantly improving local food security.

Potential Development of Functional Foods

dsRNA technology could enable the creation of functional foods with tailored nutritional profiles for specific goals. Silencing or enhancing specific plant genes to boost levels of vitamins, minerals, or other beneficial compounds for nutrient fortification. Designing foods that address specific dietary needs, such as hypoallergenic products for personalized nutrition. It has been proved that external dsRNA downregulates anthocyanin biosynthesis-related genes and affects anthocyanin accumulation in Arabidopsis and Solanum lycopersicum [1-2]. Foliar application of dsRNA targeting endogenous potato (Solanum tuberosum) isoamylase ISA1-3 confers the promotion of amylopectin biosynthesis, which can be made for easily digestible food, especially for old people [3]. In the future, it's possible to produce foods with multiple functions, based on the multiple functional genes.

Innovations in Food Processing and Preservation

Future applications of dsRNA may extend beyond the field into processing and shelf-life technologies. dsRNA can target key

genes of spoilage microorganisms to inhibit their growth in the fruits or other foods in the sold and extend their shelf-life. This application can reduce the chemical additives to meet consumer demand for cleaner labels by replacing traditional preservatives. The similar application method in the food preservation has been reported in a few research, such as, the fresh cut potatoes, soaking in dsRNA StPPO solution, had lower browning index compared to the control group, and the polyphenol oxidase enzyme activity in the tissue was lower, indicating that the application of dsRNA StPPO can inhibit the expression of potato polyphenol oxidase StPPO gene and effectively control the phenomenon of fresh cut browning [4].

Novel Solutions for Stored-Product Pest Management

Stored commodities (grains, nuts, etc.) frequently suffer from insect infestations, and conventional phosphine fumigants are losing efficacy due to rising pest resistance. dsRNA can overcome resistance by silencing genes responsible for insect resistance to phosphine, restoring the effectiveness of existing fumigants. This application provides eco-friendly alternatives and reduces reliance on traditional fumigants and lower environmental contamination risks. The successful sprayable dsRNA happened in protecting stored rice grains from the lesser grain borer (Rhyzopertha dominica), which showing significant insecticidal activity, with 72% mortality observed after ingestion of grains stored for 60 days post-treatment, compared to 90% mortality in freshly treated grains [5].

Future Challenges and Outlook

Despite its promise, widespread adoption of dsRNA in the food sector must address several hurdles. Prolonged dsRNA use could drive the evolution of resistant pests or pathogens, necessitating diversified control strategies, which needs rigorous resistance management. Besides, agencies such as EFSA (EU) and EPA (USA) need to finalize risk-assessment guidelines specific to RNAi-based foods and implement regulatory frameworks. Moreover, public perception, consumer acceptance and understanding of RNAi technology will significantly influence market uptake.

Conclusion

dsRNA holds transformative potential for the future food industry, particularly in precision agriculture, food-safety enhancement, functional-food creation, and environmentally responsible storage management. As the technology matures and regulatory frameworks solidify, dsRNA is poised to become a key enabler of safer, more efficient, and more sustainable food production systems.

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