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Innovative Technologies for Edible Utensils: A Sustainable Alternative to Single-Use Plastics

Jayshree Majumdar*, Sreeja Mitra, Deepanjan Das, Apurba Sarkar, Srijani Majumdar, Subhra Saha

Department of Food Technology, Guru Nanak Institute of Technology

Corresponding author email: jayshree.majumdar@gnit.ac.in

Abstract- The increasing concern over single-use plastic waste has led to the development of edible utensils as sustainable alternatives. These utensils not only reduce environmental pollution but can also provide additional nutritional benefits. Recent innovations combine food science, materials technology, and smart design to improve strength, stability and consumer acceptability. This paper highlights key innovative technologies for the production of edible utensils and their potential applications in sustainable food systems.

Keywords- edible utensils, innovative technology, plastics, sustainability.

I. INTRODUCTION

Edible utensils are used as eco-friendly alternatives to single- use plastics, by reducing waste they offer functional and nutritional benefits. Advance technologies and natural ingredients enhance their rigidity, durability, and biodegradability, making them a sustainable step toward a plastic free future. Although the characteristics of plastic cutlery are hard to replicate, the requisite therefore is to act responsibly towards the environment and innovate a sustainable alternative to plastic cutlery, which are eco-friendly, inexpensive, sustentative and often times nutritious. Globally, countries are coming up with new and better strategies to decrease the usage of plastic cutlery, thereby taking steps in reducing global plastic waste influx. (1).

II. INNOVATIVE TECHNOLOGIES

1. Extrusion and baking technology

The versatility of extrusion allows for the creation of a diverse array of novel and intriguing ingredients and cuisines. It can also provide long-lasting, safe, nutritious, and affordable foods that are customized to meet the unique requirements of each consumer. In order to improve, reengineer, innovate extrusion processing methods (2). The mechanical strength and water resistance of carbohydrate and protein are improved through extrusion, which modifies their structures. (3)

Recent research has shown that the nutritional value and texture of extruded products are enhanced by cereal mixtures and legumes. In addition to addressing environmental concerns, these innovations

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underscore the potential of extrusion and baking technologies to develop utensils that offer safe, practical, and nutritious serving options. Edible implements have the potential to become mainstream solutions for sustainable food service systems through ongoing research. (4)

2. Hydrocolloid Gelation Technology

Hydrocolloid gelation is a sustainable method for making the edible, biodegradable utensils like spoons, bowls from polysaccharides such as alginate, agar and carrageenan (5 a). Some of the Gelation properties are:

a. Seaweed Hydrocolloids & Gelation: Alginate forms elastic, water insoluble gels with calcium ions through the overall integrity in the gelation (5 b). Agar produces thermo-reversible, transparent gels on cooling these materials (5 c). Combining these with starch, proteins or gums improve elasticity and load bearing strength of utensils (6 a).

b. *Heat Resistance, Biodegradability & Nutrition*: As the alginate is stable in boiling water and agar up to 85 degree C, so the utensils withstand heat and also in high temperature (5 d). From the characteristics they can be chemically fortified. So edible utensils made by drying and coating with 1-3% hydrocolloid +starch + glycerol, are best for rigidity and water resistance power (6 b).

3. Protein crosslinking technology

Plant Proteins like (Soy, Pea, Chickpea) have the ability to film forming, break down naturally and nutritious benefits. When it heated with natural binders, it improves crosslinking, strength, water resistance.

a. Plant Proteins Incorporated with Natural Binders:

- *Soy Protein:* It has amino acids, that help form strong flexible films. These films resist water and oil. It is renewable, making it eco-friendly and affordable (7 a).
- *Pea Protein:* It is low in allergens and forms soft yet strong films after crosslinking. It is good for making utensils that are safe and easy to produce in large scale (8).
- *Chickpea Protein:* It is easy to digest, forms stable films. It can hold antioxidants, helping protect food. It is also biodegradable and cost friendly (9).

b. Strong, High Protein Utensils with Good Bite Strength**;** These plant proteins add protein to the utensils, making them healthy nutritional choice. Also, natural binders and heat help create durable structures, that don't break easily and resist moisture. Moreover, the protein structure holds together well, so the utensils can manage pressure from biting without falling apart (7 b).

4. 3-D Food Printing

3-D printing is a process of making three-dimensional objects using additive processes where layers are laid down in succession to create a complete object. Additive manufacturing refers to the technology of producing a final three-dimensional product by depositing thin layers of material upon each other. A variety of materials can be utilized, including metals, plastics, resins, rubbers, ceramics, glass and concretes. Most commercial 3-D printers use a computer-aided design to translate the design into a three-dimensional object. The design is then used by the 3-D printer to deposit the layers of material.

It is being considered in the food sector due to its multiple advantages such as personalized nutrition, customized food designs, simplifying the supply chain and broadening of the available food material. 3-

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D food printing has excellent advantages in low volume food fabrication of customized items in food services. It helps in delivering the food with visual aesthetic and most importantly good taste. (10)

5. Nano-Composite Reinforcement

Nanocellulose, nano starch and protein nanofibers reinforce edible utensils to make them strong, eco-friendly.

A. *Nanocellulose:* It derived from plant fibres or food waste. It improves strength, water resistance, barrier properties. It is renewable and also extend utensils lifespan (11 a).
B. *Nano starch:* It's created from tiny starch particles. It improves structural integrity and 3D printability. It enhances nutrient enrichment, food freshness (11 b).
C. *Protein Nanofibers:* It's synthesized from plant proteins. It forms lightweight, biodegradable layers. When it combined with natural oil, it boosts antioxidant properties and makes the utensils versatile (7 c, 11 c).

6. Edible Coating and Multilayer Technology

Edible Coating & Multilayer Technology is used in fruits and vegetables which mainly focuses on inhibition of texture modification, moisture barrier & antimicrobial properties. The edible coating includes single layer coatings & lipid-based coatings (12). In the preparation of the multilayer packaging, edible coating is mostly applied to the food products which increases the shelf life, physical quality & appearance of the product (14). Edible film coating with beeswax-in-water emulsion were stabilized with cellulose nanofibrils which has a droplet diameter around 10 micrometers (15).

The edible films produced from hydrolyzed collagen & cocoa butter & plasticized with sucrose which has many mechanical properties such as water vapor permeability & opacity. The cocoa butter films were easily manageable & flexible where sucrose reduces the tensile strength, where hydrolyzed collagen increased above 15%. It also provides a shiny coating to the utensils which looks attractive (16). Starches are used to form edible films as it has been used to form self-supporting films which caste by aqueous solution (17).

The starch improves the filming properties without the increasing any cost of production, it also provides modified packaging which increases the shelf life of the utensils (18). The films have good acceptable sensory characteristics as well as physical characteristics and are low in cost (20).

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Fig.1. Edible Coating: (a) Beeswax (b) Cocoa Butter (c) Starch Film

7. Plant Fiber Reinforcement

Plant fibres such as banana fiber, wheat bran, rice husk are valuable and very important in the case of making edible utensils due to their high strength, low cost, and biodegradability (21 a).

a. Fibers with Binders: Banana fiber from banana pseudo stems, enhances high utensils strength, improves their durability; where rice husk is naturally lightweight, enhances the texture and strength of the edible utensils when mixed with starches, gums and proteins (21 b). Also, another plant fiber, wheat flour, contains gluten, acts as a natural binder and adds dietary fibres, with showing their low glycemic index (22 a).

b. Mechanical Strength & Sustainability: So, from the above advantages it can be added that reinforcing utensils with agricultural by products not only improves the strength and stability, but also supports a circular economy by reducing waste. This method decreases the product cost through local source, aids dietary fiber, promotes gut health when consumed and promotes eco-friendly, alternative choices to plastics (22 b).

8. Smart Edible Utensils

Out of concern for environmental pollution and the harm that people's intake of plastic does to their health, many start-ups have developed cutting-edge utensil that is edible and biodegradable. In addition to being edible, it also has qualities that make it nutritional and acceptable for consumption. Numerous distinctive characteristics of utensils derived from plant proteins and fibers include affordability, lightness, availability and biodegradability. (23)

Recently, the assimilation of pH-sensitive natural pigments into biopolymers has shown promising prospects. Unlike synthetic pigments, which have potential safety problems due to migration, natural pigments have negligible toxicity levels both to humans and the environment and some even possess nutritional and pharmacological properties. It has various advantages like biocompatibility, availability, biodegradability, stability and minimum toxicity. Hence, we can use natural pigments like

III. APPLICATIONS

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a. *Restaurants and Catering:* Edible utensils work as an eco-friendly serving option, to reduce plastic pollution, to enhance the dining experience and even to add nutritional value to meals.
b. *Events and Festivals*: They are an innovative concept that are aiming to reduce environmental impact of disposable plastic utensils. As the world grapples with the pressing issues of plastic waste and sustainability, edible utensils are offering a promising solution to the growing problems of single-use plastic utensils.
c. *Healthcare:* Innovative technologies for nutrient-fortified edible utensils in healthcare involves to enrich plant-based materials like grains, pulses and vegetables with vitamins, minerals and antioxidants for the creation of personalized nutritional supplements for patients.
d. *Space Mission and Defense:* Their key application is in space missions and defense, where edible utensils are offering a sustainable, dual-use solution by providing both food and packaging without the generation of waste, which is critical in environments where waste disposal is quite challenging.

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