

Development of Sustainable and Compact Cutlery Solutions: Emphasizing Waste Reduction and Hygiene Maintenance in Uttarakhand.

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Abstract: The increasing reliance on plastic cutlery, driven by its affordability and convenience, has led to significant environmental and public health concerns. Whether used at food stalls or large gatherings, its widespread use contributes to pollution and waste management challenges. It is essential to analyze the root causes of this issue and develop sustainable alternatives that mitigate its impact. This study presents a work-in-progress of the underlying causes of excessive plastic use, particularly in hilly regions, and explores the potential for developing Eco-friendly compact cutlery. The proposed approach aims to maintain hygiene standards while enhancing waste management systems. The materials under consideration will be designed to be biodegradable and, in some cases, edible for roadside animals or easily Compostable in natural environments. The objective of this research is to contribute to environmental sustainability, with a specific focus on Uttarakhand, by addressing waste disposal challenges through the development of products that align with both human and ecological needs.

Keywords: Eco-friendly Design, Sustainability, Compact Design, Waste Management, Environmental Impact

Introduction

Plastics are one of the most convenient materials, but also among the most polluting. Due to their affordability and ease of use, it's no surprise that people continue to buy them. However, very few consider the environmental impact, such as how long plastics take to decompose or how waste should be managed. In India, whether it's food courts around campuses, while traveling, or staying in different places, people are constantly surrounded by plastic—and so are our roads. Yet hardly anyone takes the initiative to manage even a small part of the problem on their side. Our common mindset is, "Why should I do it? The government will take care of it." It's situations like these that reflect a larger issue. India faces a severe plastic pollution crisis, emerging as the world's largest plastic waste emitter, generating 9.3 million Tonnes annually [1]—approximately one-fifth of the global total. Much of this waste, including single-use plastics, is mismanaged, ending up in landfills or polluting the environment. While plastic is valued for its durability, these very properties make it an environmental hazard. Plastic cutlery, used for mere minutes, persists for centuries, accumulating in natural ecosystems such as rivers and mountains. The decomposition of plastics can take over 400 years, releasing toxins and endangering wildlife that mistakenly ingest them [2]. In parallel, the world grapples with a growing food waste crisis. Despite millions suffering from hunger, nearly one-third of all food produced globally is discarded each year. This not only exacerbates food insecurity but also contributes to severe environmental degradation. The root cause of these issues lies in human behavior, which is slow to change unless driven by a major crisis. Instead of waiting for a disaster to force action, a more proactive approach involves adopting sustainable materials and practices. By shifting towards eco-friendly alternatives, we can protect and nurture nature while creating a healthier environment for both humans and wildlife. It can help to support sustainable development goals (SDG) of United Nations Organization i.e., Ensure healthy lives and promote well-being for all at all ages (SDG-3), Ensure availability and sustainable management of water and sanitation for all (SDG-6), Ensure sustainable consumption and production patterns (SDG-12), Take urgent action to combat climate change and its impacts (SDG-13), Conserve and sustainably use the oceans, seas and marine resources for sustainable development (SDG-14), Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss (SDG-15).

1. Literature reviews:

The cutlery industry has undergone significant changes since the 1950s, both in terms of design and functionality. However, the most notable transformation occurred during the 1980s when environmental awareness began to shape consumer preferences. During this time, eco-friendly alternatives such as bamboo, wood, paper, and even edible cutlery gained popularity [3]. Simultaneously, the use of plastic cutlery became increasingly widespread, raising concerns regarding its long-term environmental effects, particularly related to disposal challenges. As of 2024, plastic cutlery continues to dominate the market, with plastic spoons expected to capture a market share of 56.6%. Within this, the food service industry, a major consumer of disposable cutlery, is projected to hold a significant 61.2% share. Furthermore, India is anticipated to experience a compound annual growth rate (CAGR) of 5.9% through 2034, surpassing countries such as the United States, Spain, China, and Thailand in terms of cutlery consumption [4]. These figures underscore the growing demand for disposable cutlery, highlighting the pressing need for sustainable solutions to address the mounting waste associated with plastic usage. One initiative

addressing the environmental crisis related to disposable cutlery is the non-profit organization Habits of Waste. Founded by Sheila Morovati in 2019, the organization encourages individuals to rethink their consumption patterns and reduce waste. Morovati advocates for cultural change, urging people to understand their collective power to influence environmental outcomes. "It's so embedded in our daily routine, it's so normal that we don't even see it," she states. Her goal is to create a new cultural norm, emphasizing that individual actions can collectively shift societal trends and reduce waste [5].

The impact of plastic cutlery on the environment is substantial. Following Newton's third law of motion 'for every action, there is an equal and opposite reaction' — the environmental consequences of choosing plastic products are severe. The following are some of the key effects of plastic tableware on the environment: Pollution of Waterways, Threat to Wildlife, High Carbon Footprint, Endangerment of Marine Species Degradation of the Environment, and most important is Health Risks: Daily use of plastic cutlery poses health hazards, including risks of kidney stones, liver and breast cancer, reduced sperm count, and hormonal imbalances, Microplastics found in human bodies, etc [6]. The growing consumption of single-use plastics, particularly in

India, exacerbates these environmental issues. In 2023, India produced approximately 9.46 million tonnes of plastic waste, with 43% of this waste categorized as single-use plastics, including cutlery, bags, and packaging. This alarming statistic reflects the scale of the issue and the urgency of addressing the environmental and health consequences of plastic waste. Activists and environmentalists have called for stronger policies and better enforcement to curb plastic consumption. At the same time, several companies are exploring sustainable alternatives, such as biodegradable and reusable packaging options [7]. While plastic cutlery remains a major concern, alternative materials such as bamboo, stainless steel, and edible cutlery are emerging as potential solutions. Bamboo, a rapidly growing plant, has gained attention for its sustainability.

However, its increasing popularity raises concerns about overharvesting and the potential destruction of natural habitats if not managed responsibly. Stainless steel, on the other hand, has its own set of challenges due to the energy-intensive processes required for its extraction and production. Despite this, metal cutlery has a longer lifespan, which can help reduce the need for frequent replacements and the consumption of resources in the long run [8]. In addition to plastic, other major players in the disposable cutlery market include Huhtamaki, Dart Container, Pactiv Evergreen, Solia AS, TrueChoicePack, Eco-Products, Fuling, BioPak, Georgia-Pacific, D&W Fine Pack LLC, Anny's Plastic Tableware, Tair Chu Enterprise Co., BKS Plastics, Swantex, and Karat by Lollicup [9]. In summary, the rise in disposable cutlery use, especially plastic, has raised significant environmental and health concerns. While plastic continues to dominate, there is a growing push for alternatives such as bamboo and stainless steel, each with its own benefits and drawbacks. The continued efforts of organizations like Habits of Waste and the exploration of biodegradable solutions offer hope for a more sustainable future in the cutlery industry. However, stronger policies and greater consumer awareness are crucial in addressing the environmental crisis and reducing the dependence on plastic.

2. Methodology

The study employs the design thinking process along with the Double Diamond framework to analyze current trends in materials usage and user preferences. Analytical methods were applied to assess insights, user personas, mapping, ergonomics, and pain points, which provided the basis for the development of the project. The design process involved extensive research into user behavior and material trends, allowing for the creation of a sustainable solution that meets both functional and environmental needs.

2.1 Brainstorming

The initial phase of the research involved brainstorming the product concept. The insights gathered were categorized into three key areas: identifying the target users, analyzing the product's characteristics, and evaluating its interaction with the environment. This structured approach aimed to ensure a comprehensive understanding of the product's impact and feasibility.

2.2 Data Collection and Analysis

The first stage of the Double Diamond design process [10], 'Discover,' focuses on gathering insights and understanding the existing landscape. Both primary and secondary data were collected, with observations and insights documented accordingly. The data collection was conducted in and around

the college campus to ensure relevant and contextual findings. This phase involved extensive environmental observations to analyze how the product interacts with its surroundings. Before identifying potential problems, it was crucial to establish a thorough understanding of the product by addressing the 5Ws: Who are the users? What is the purpose of the product? When is it used? Where is it commonly utilized? Why is it needed? By systematically exploring these aspects, a strong foundation was built for the next phases of the design process.

Primary data was gathered through interviews, surveys, and observations to analyze the interaction between the product, users, and the environment. Users provided insights into the challenges they face while using the product, particularly in hostel settings, where space constraints are a significant concern. Additionally, hygiene issues related to cutlery used in mess facilities emerged as a common worry among respondents. For solo travelers, a prevalent habit of using and discarding cutlery was observed. This raised an important question regarding the environmental impact of disposal practices—whether the materials decompose naturally or contribute to pollution. These insights serve as a foundation for evaluating the need for sustainable, space-efficient, and hygienic alternatives. As part of the secondary research, a market study was conducted to understand current trends, future forecasts, and available alternatives in the industry. This research explored various hybrid cutlery options, sustainable materials, and emerging innovations in the market. Additionally, a competitive brand analysis was performed to assess existing players, their product offerings, and market positioning. These insights provide a comprehensive understanding of the industry landscape, helping to identify gaps and opportunities for innovation. Stakeholder mapping (Ref.Fig.1), to gain a deeper understanding of how and where cutlery is utilized across various sectors. This process helps identify key stakeholders, their roles, and their interactions within the supply chain, usage, and disposal of cutlery. By analyzing these connections, the study aims to determine critical touchpoints for innovation, sustainability, and user engagement.



Fig.1: Stakeholder mapping

3. Product Development & Prototyping:

The process of product creation involved extensive data collection and analysis, leading to the development of mockups and prototypes.

The focus was on generating innovative ideas and solutions to address the defined problem of plastic cutlery waste. Various spoon designs were explored, prioritizing multi-functionality, compactness, and sustainability. Concepts included: Foldable or collapsible spoons for portability, Hybrid designs integrating fork and spoon functions,

Edible or biodegradable spoons made from agro-waste materials, and Modular designs that allow attachment to different handles for adaptability

3.1 Sustainable Material

As highlighted in the introduction, identifying the best alternatives to conventional plastic cutlery is crucial in addressing global challenges such as plastic pollution and food waste. One promising solution is the utilization of agro-waste as a sustainable raw material for producing biodegradable and edible cutlery. This approach not only minimizes waste but also provides an eco-friendly disposal method, benefiting both the environment and wildlife. By integrating such innovative materials, the study aims to contribute to a more sustainable and circular economy. Agro-waste materials such as rice hulls, soybean meal, distiller's grains, beet pulp, almond hulls, brewer's spent grains, peanut meal, onion skins, pea pods, corn cobs, peanut shells, sugarcane bagasse, pineapple waste, coconut shells, and others (Ref.Fig.2) offer a sustainable alternative for cutlery production [11].



Fig.2: Utilization of Agro-waste as a sustainable raw material.

These materials are easily disposable and, in some cases, can serve as a food source for roadside cattle in need. Utilizing such waste not only promotes eco-friendly disposal but also supports a circular economy by repurposing agricultural byproducts effectively. Understanding the standard dimensions of various spoon types across different brands is essential for design and usability considerations. Ergonomic measurements play a crucial role in ensuring

comfortable and efficient use of cutlery, minimizing strain on the hands, wrists, and arms. Well-designed cutlery enhances grip, reduces the risk of repetitive stress injuries, and improves the overall dining experience, particularly for individuals with physical limitations or special needs. To understand the practical aspects of ergonomic measurement,

experiments and practical assessments were conducted. A comprehensive dataset was collected, referencing the book: "Indian Anthropometric Dimensions for Ergonomic Design Practice" [12]. This data provided valuable insights into human hand dimensions, grip strength, and comfort parameters, enabling the design of ergonomically optimized cutlery for diverse user needs.

3.2 Prototyping Mockup

Prototype mockups (Ref. Fig.3-5) were made from paper to understand how much length, height and width will be ergonomically appropriate and from where to give bend or curve for a comfortable holding. With mockups we can compare and understand which model is easy to use, will adapt, where to add adjustments so that we can observe and gather insights on how the users will use or communicate with the product.

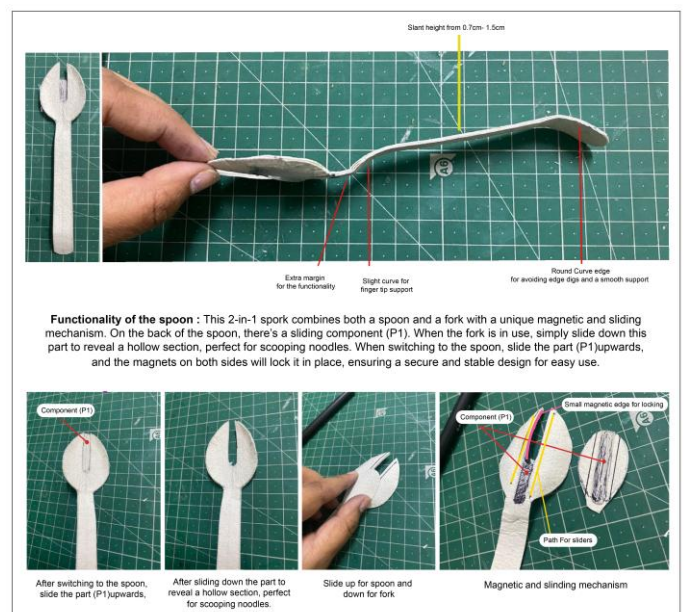


Fig.3: Prototype mockup 1



Fig.4: Prototype mockup 2



Fig.5: Prototype mockup 3

These prototype mockups were put through user testing, where target users interacted with the designs (Ref.Fig.6) and provided feedback and valuable insights to improve the product. Some users shared important thoughts regarding durability, strength, and potential for multiple uses. While some were in favor of the product, they expressed concerns about proceeding with production due to potential negative properties that could arise in the future. Based on the insights gathered, further adjustments were made to the product, which was then retested accordingly.

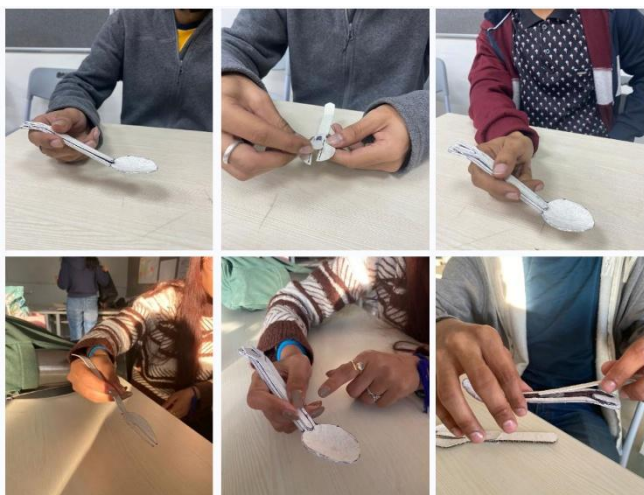


Fig.6: Prototype mockups were tested by users to gather insights based on observations and usage preferences.

To gain a deeper understanding of the design, mockups were created using materials such as MDF, acrylic sheets, and HIPS sheets (Ref.Fig.7). These materials were explored and tested to gather additional insights into the product's feasibility and performance.



Fig.7: Materials exploration such as MDF, acrylic sheets, and HIPS sheets

Ensuring a comfortable grip while handling the cutlery is essential for its long-term performance, along with maintaining an aesthetically pleasing design. Additionally, the product's environmental impact from production to usage is a key consideration. The interaction of the product with various elements aims to strike a balance between innovation and sustainability.

4. Conclusion:

This project introduces a product that promotes environmental sustainability and hygiene while serving as a functional, edible alternative for animals. Its versatility positions it as a viable long-term solution for reducing waste and encouraging eco-friendly practices in the food service industry. Implementing such solutions can contribute positively to both environmental and social well-being. Although the project is still in progress,

with mockups being developed from agro-based materials, the preliminary steps taken mark a promising direction. As we continue to explore the decomposition rate and environmental impact, the potential for sustainable alternatives becomes increasingly clear. This research not only contributes to eco-friendly innovation but also opens doors for future advancements in biodegradable material development, bringing us one step closer to a greener, more responsible future.

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