

Review Article

Edible cutlery: An eco-friendly replacement for plastic cutlery

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Abstract

Plastic has become a significant threat to the entire ecological system, the daily utilization of plastic products has several beyond-description losses like air pollution caused by incinerating plastic, pollution of the marine environment and microplastics damaging internal organs of animals and indirectly harming humans by consuming the sea-food, meat and other products which rife with micro-plastic. This review aimed to assess the replacement of plastic usage with a better alternative, including studies on various types of cutlery, preparation of edible cutlery, therapeutical properties and the market of edible cutlery. They occur in everyday life, which compromises the standard of living. Plastic usage can be minimized with a better alternative, as complete eradication is not possible due to their consistent dependence and usage. So, a better substitute is cutlery made up of plant-based products like rice, sorghum, wheat, soy, and rice bran flour. The edible cutlery has biodegradable and eco-friendly properties and is the finest substitute for plastic cutlery. This cutlery can help change the system of unhealthiness into a better lifestyle by minimizing the health-associated risks such as cancers, endocrine disruption, and impaired immunity with exposure to leaching plastic packages which are used to store food items. It can help to achieve sustainable development goals (SDG) of United Nations Organisation i.e., ensure healthy lives and promote well-being for all at all ages (SDG-3) and take urgent action to combat climate change and its impacts (SDG-13), the ultimate aim of this paper was to reduce the usage of plastic and products made up of plastic.

Keywords: Biodegradable, Climate action, Carcinogenic, Good health, Well-being, Toxicity

INTRODUCTION

Edible cutlery is a plant-based product in which meals can be served or taken as a meal. It is generally recognized as EBO (eco-friendly, biodegradable and organic) as the product is made up of a mixture of flours. Since 2010, an Indian firm named Bakey's has been marketing edible cutlery as a commercial product (Reddy, 2016). During an in-flight meal, Hyderabad-based scientist Narayana Peesapaty in India spotted individuals scooping rice with a *khakra* rather than a plastic spoon. It inspired him to make a spoon out of flour (Das, 2016). The two major purposes for having edible cutlery as a replacement for plastic cutlery are biodegradability and eco-friendliness, as plastic is a considerable threat to both man-kind and nature. Various ingredients can be used to prepare edible cutlery, but some specific flours

give desired properties for the ultimate product. Other ingredients like rice flour, rice bran flour, soy flour, sorghum flour, etc. have their own nutritional benefits and can enhance the product's physico-chemical properties when mixed with other products. As plastic is a grave threat to the entire ecosystem, there is a considerable need to replace plastic cutlery with better alternatives like edible cutlery. Using plastics and the challenge of disposing of them is a major issue in our society today (Patil and Sinhal, 2018). As a result, plastics eventually find their way into our bodies as microplastics. According to some studies, plastics include a hazardous chemical called bisphenol A (BPA). BPA, a hormone-impersonating chemical, has been linked to various negative health impacts in children. This includes changed behaviour and obesity, reproductive abnormalities, cardiovascular alterations, and cancer (Schug

and Birnbaum, 2014). The edible cutlery consists of calcium, potassium, vitamin B, vitamin A, and rich fibre (Munir, 2017). As whole-grains are the primary ingredients, they promote health by preventing diseases like obesity, constipation, coronary heart disease (CHD) and other health-threatening diseases (Holl ander *et al.*, 2015).

NEED FOR REPLACEMENT OF PLASTIC CUTLERY

Every year, India generates 15 Mt of plastic waste, of which only one-quarter is recycled (United Nations Development Programme, 2018). Every year, 350 million tonnes of plastic are manufactured throughout the world. After steel and concrete, plastic was the third most prevalent human-made substance in 2017. If current manufacturing and waste management trends continue, nearly 12,000 Mt of plastic trash will end up in landfills or the natural environment by 2050 (Geyer *et al.*, 2017). When microplastics enter the body, it is critical to recognise that these impacts may harm biota, ecosystems, and human health (via inhalation, food ingestion, or skin). Many animal species, from huge mammals, birds, and fish to small zooplankton, mistake plastic for food and die as a result (De S a *et al.*, 2018). Only 9% of all plastic ever created has been recycled, while 6.3 billion tonnes of garbage never made it to a recycling plant and ended up in landfills and the ocean. Edible cutlery can help to replace plastic cutlery, and the main ingredient, sorghum gives the utensil properties like being able to withstand anything from hot soups to frozen desserts for about 15-20 minutes without disintegrating and being quite resilient and easily decomposable within 5 to 6 days (Natarajan *et al.*, 2019). Because plastics are amorphous in nature, they do not have a precise melting point, leading to food contamination. As a result, edible cutlery plays a critical part in the replacement of plastic silverware.

Environmental threat of plastic

Plastic is derived from the Greek word *plastikos*, which means "to mould into diverse shapes. Plastics consume around 4% of the world's oil and gas as feedstock, and about 3–4% is used to supply energy in their production. Because of their unique properties, such as light weight, low cost, durability, robustness, strength, corrosion resistance, thermal and electrical insulation, versatile fabrication and design capabilities, and the ability to easily be moulded into a variety of products, they are becoming increasingly popular (Hopewell *et al.*, 2009), and they have a wide range of applications (Thompson *et al.*, 2009). Despite their many benefits to human civilization, the materials employed in plastics have a number of disadvantages (Mwanza and Mbohwa, 2017). Toxic substances found in plastics

include di-(2-ethylhexyl) phthalate (DEHP), bisphenol A (BPA), poly halogenated chemicals, and heavy metals, all of which are harmful to human health (Halden, 2010). The bulk of these compounds have been proven to be easily immobilised in the environment, resulting in detrimental health consequences such as disturbance of the endocrine system (North and Halden, 2013). Plastic is a term that is frequently used to describe solid or semi-solid materials having varying degrees of flexibility, strength, harness, and other characteristics. Several additives such as plasticizers, carbon and silica etc. are used to increase the plastic's specialised qualities, durability, and strength. Coatings, paper, paperboard, plastic, and other polymers used in packaging or production equipment may contaminate food (Trasande *et al.*, 2018). Incineration and pyrolytic conversion of waste plastic release polyaromatic hydrocarbons, CO₂ (a greenhouse gas), and persistent organic contaminants such as dioxins into the environment (North and Halden, 2013). The main concern here is linking the types and amounts of additives found in plastics to absorption and accumulation by biological organisms (Andrady and Neal 2009). Plastic materials are a serious environmental problem due to their build-up and resistance to breakdown (Webb *et al.*, 2012). Despite the several benefits, they have a lot of disadvantages the minute it comes to handling waste (North and Halden, 2013). The plastics sector is crucial for foreign exchange profits, but the company's wastewater effluents are a major concern. Such wastewater effluents generate objectionable odours, damage surface and groundwater quality, and poison the soil, all of which indirectly or directly influence aquatic life and nearby humans' health (Ilyas *et al.*, 2018). Plastic waste may be disposed of in a variety of ways, including recycling, burning, and landfilling (Webb *et al.*, 2012). This is made worse by the fact that most plastics take a long time to degrade, making polluted soil unavailable for lengthy periods. For more than 20 years, plastic waste components appear to have been prevalent in landfills (Tansel and Yildiz, 2011). This is due to the limited oxygen supply in landfills; the surrounding environment is effectively anaerobic (Tollner *et al.*, 2011), and anaerobic settings reduce landfill degradation rates even more. Methane is released as a result of plastic breakdown (Royer *et al.*, 2018). Hazardous compounds such as when waste plastic is burned or pyrolytically converted releases polyaromatic hydrocarbons, CO₂ (a greenhouse gas), and persistent organic pollutants like dioxins into the atmosphere, causing global warming and pollution (Mwanza and Mbohwa, 2017). Plastics are the most often observed components in the ocean, and organic contaminants are found in high amounts in plastic particles. Nonylphenol (NP), polychlorinated biphenyls (PCBs), and organic pesticides including bi-

sphenol A (BPA), polycyclic aromatic hydrocarbons (PAHs), dichloro-diphenyl-trichloroethane (DDT), and polybrominated diphenyl ethers (PBDEs) are among the harmful substances found in marine plastic wastes (PBDEs) (Ilyas *et al.*, 2018). Endocrine disruption, breast cancer, neurobehavioral alterations, developmental impairment (hormonal imbalances, growth abnormalities, and neurological impairment), arthritis, cancer, DNA hypomethylation, and diabetes are all possible side effects (Zhou *et al.*, 2011).

Toxicity

Plastics are used to make items like water bottles, food containers, and receipts. Most of the plastic used daily consists of a harmful chemical known as BPA (Bisphenol A). BPA disrupts our endocrine system and normal hormonal function. Multiple studies have documented that BPA, as an endocrine-disrupting chemical, which leads to adverse health effects (Gore *et al.*, 2014). BPA has also been designated as a "chemical of concern" by the Canadian government, prompting measures to decrease BPA exposure among the most susceptible groups. PET (Polyethylene Terephthalate), the most widely used polyester plastic on the planet, with an expected lifespan of up to 5 decades (Pirillo *et al.*, 2021). The widespread dispersion and abundance of phthalates in the worldwide environment have resulted from their release during the production, use, and disposal of PVC items. Several studies have related to

obesity, cardiovascular illness, reproductive issues, and breast cancer (Cariati *et al.*, 2019). Plastics play an important role in climate change as it is non-biodegradable and harmful.

PRODUCTION OF EDIBLE CUTLERY

The production of raw materials that are used in edible cutlery has been listed in the Table 1. The main ingredient being used is paddy and sorghum. Sorghum has beneficial properties; when compared to rice, it uses 60 times less water to produce (Rashid, 2019). The crop can be grown in about all of the world's arable land (Munir, 2017). The Sorghum/Jowar produces 4.38 million tonnes with a yield of 1051 kilograms per hectare area (Tonapi, 2020) and Rice/Paddy produces about 112.91 million tonnes with a yield of 2578 kg/ha area (Skand *et al.*, 2020).

Varieties of cutlery

The cutleries are in wide varieties and various food manufacturing industries manufacture different types of cutleries like spoon, fork, plate and bowl etc. In many places of the globe the cutleries are manufactured as follows (Natarajan *et al.*, 2019). Peesapathy developed this enterprise in India and worldwide that makes edible tableware (spoons, forks, and even chopsticks) out of dried millets (jowar or sorghum), rice, and wheat. Sugu Company, based in Taiwan, makes edible plates

Table 1. Edible cutlery types and composition

Cutlery name	Raw Materials	Nutrients	Techniques/ Process	References
Edible Plate	Spinach Extract Rice Flour Sorghum Flour Sorbitol	Moisture – 2.57% Ash – 1.60% Crude fat – 1.72% Crude protein – 4.81% Crude fibre – 0.6% Detergent fibre – 3.40% (neutral) Detergent fibre – 1.64% (acid) Starch – 4.25% Flavonoids – 2.72% Carotenoids – 0.64mg Proteins – 1.06g Fat – 0.12g Mineral – 0.13g Fiber – 0.19g	Mixing, Kneading, Sheeting, Moulding, Baking, Cooling and Packing.	Sood and Deepshikha, 2018
Edible Spoon	Wheat Flour Sorghum Flour Rice Flour	Iron – 0.56mg Calcium – 2.43mg Carotene – 3.97mg Thiamine – 0.03mg Riboflavin – 0.01mg Niacin – 0.28mg Folic acid – 1.33mg	Mixing Kneading Moulding Baking Cooling and Packing	Rashid, 2019
Munch Bowls	Wheat Bran Wheat Flour Canola Seed Oil Salt Rooibos Tea	Energy – 380Kcal Protein – 3.5g Carbohydrates – 15.6g Total Sugar – 0.7g Saturated Fat – 0.1 Dietary Fibre – 4.5g Total Sodium – 71.1g	Preheating Mixing Sheeting Cutting Molding Baking Cooling and Packing	Poonia and Yadav, 2017

and other tableware, claiming to have invented the "world's first type of edible tableware" in 1986 as a solution to eliminating waste dinnerware. In Japan, a Japanese designer named Nobuhiko Arikawa of the Rice-Design firm produced edible dinnerware for the Orto Cafe. In addition, a couple of Belgian designers have created a new line of eco-friendly and appetising edible food containers. Helene Hoyois and Thibaut Gilquin, two teenage entrepreneurs, make containers out of potato starch, water, and oil. Co-founders of the Loliware firm in the United States expressed their concern for the environment and wanted to create a new type of environmentally friendly cup. The type of edible cutlery is classified in Table 1. The plates, spoons and bowls are intended to replace disposable plastic tableware.

Standard procedure of edible cutlery

Many components may be used to make edible cutlery, but sorghum flour (*sorghum bicolor*) and rice flour are two of the most common (*oryza sativa*) primary materials for manufacturing the cutlery help in maintaining the desired outcome and chemical parameters as Sorghum grain has almost the same amount of riboflavin and pyridoxine as wheat grain, but more pantothenic acid, nicotinic acid, and biotin (Morya *et al.*, 2017) which enhance the quality of the product. The production process involves basic operations. At first, both flours are mixed together with the addition of 10ml of water then the addition of sorbic acid and other ingredients takes place. The sorbic acid can be used as the best anti-fungal agent and added in droplet amounts along with

other ingredients, then kneaded well to form a fine dough. Later the dough is spread to make a fine sheet and the process like molding takes place with a pre-designed mold followed by cutting and baking of the product at a temperature of 166 °C for 10-15 minutes and then let it cool and packing it in an airtight package and store at a cool, dry place. Fig 1. clearly shows the systematic flow process of preparing edible cutlery. Thus, the dough can be free from mold and other spoiling microorganisms (Sood and Deepshikha, 2018).

Preservative

Sorbic acid is a naturally occurring chemical that has developed into the most frequently used food preservative on the planet, allowing the global food system to work. It is very effective against bacteria, moulds, and yeasts. This study looked at the effects of sorbates, a chemical preservative, on bakery food rotting fungus at different dosages, pH levels, and temperatures (Kumar *et al.*, 2015). The procedure for almost every cutlery is similar with varying temperature, time, raw materials, and other additives.

CULINARY USAGES

Some people prefer it to be taken in raw form and others like it to be taken with hot beverages like tea, coffee and soups. Edible spoons are also used in children's school baskets for having lunch. They are crispy and crunchy in nature, sometimes soggy when soaked for long periods in liquids. It has a shelf life of 2 years from

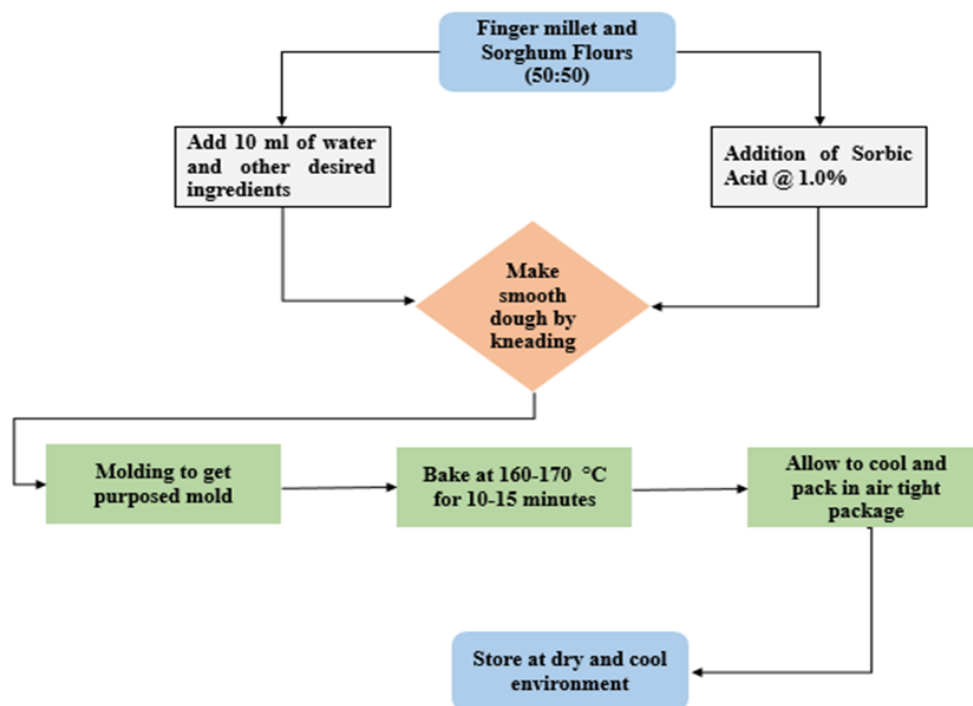


Fig 1. Schematic presentation of Unit operation of edible cutlery

the manufacturing date when it is stored in a dry and cool place (Natarajan *et al.*, 2019).

Household

From 2019 to 2025, the domestic application category is predicted to grow at the quickest rate of 9.0 %. People have been encouraged to use edible cutlery more frequently in their homes as a result of the increased use of edible cutlery in commercial locations (Kadam and Deshmukh, 2020). Parents of toddlers have embraced it as a healthier alternative to plastic spoons since the edible cutlery is made out of nutritious grains that are helpful to children. This product may be eaten like cookies with milk for a nutritious breakfast, increasing the demand for edible cutlery.

THERAPEUTIC PROPERTIES OF EDIBLE CUTLERY

The cutlery is a rich source of minerals, vitamins, carbohydrates, protein and fiber. It has mild sweetness and is more like a plain biscuit flavor. During conflicts and at disaster-prone places where food is scarce owing to a lack of resources, edible cutlery can be offered (Sood and Deepshikha, 2018). It is good in calories and nearly fat-free and diet-friendly. It consists of several nutritional content-like vitamins B1, B2, B3, B9, vitamin E and minerals like iron (Fe), and calcium (Ca) (Munir, 2017). They are also a good source of energy with the nutritional supplement. It fills the gut sufficiency feeling even after a small soup or a small hot beverage. Table 2 shows the comparison between edible cutlery and non-edible (conventional) cutlery. One can achieve good health and well-being by using edible cutlery.

The edible cutlery has specific nutritional and curative properties, while it consists of different types of raw materials like paddy and sorghum. Altogether they exhibit various health benefits such as anti-cancerous, anti-obese, anti-diabetic, and cardiovascular disease (Morya *et al.*, 2022).

Diabetes mellitus

Diabetes mellitus, commonly known as diabetes, is the most widespread health concerning issue in most of nations. The peaking of diabetes Type 2 across the world is significantly at an alarming rate. Importantly in India, it has prevalently reached 14.3% and there is a need for some significant approaches to Type 2 diabetes prevention (Kumari and Morya, 2021). Higher consumption of whole grains has been associated with a decreased risk of chronic illness (1–12), and the reduction appears to be considerable. Because lasting illnesses such as Type 2 diabetes (T2D), coronary heart disease (CHD), and hypertension are all expensive, the ability to lower chronic disease risk is critical. Whole grain diets lower LDL (low-density lipoprotein) cholesterol, blood pressure, and triglycerides while increasing

HDL (high-density lipoprotein) cholesterol (Kumari and Morya, 2021; Hollænder *et al.*, 2015). Sorghum is high in dietary fibre and has a low glycemic index, which aids in preventing and managing T2D in Indians. Lower magnesium consumption, lower total dietary fibre intake, or both were related to an amplified risk of diabetes (Weng *et al.*, 2012). The research study conducted by NIN (National Institute of Nutrition) and ICMR (Indian Council of Medical Research) collaborated with IIMR (Indian Institute of Millets Research) in Hyderabad in 2010 on sorghum-based foods under NAIP (National Agricultural Innovation Project). The project's findings showed that sorghum-based diets lower postprandial blood glucose levels, glycosylated haemoglobin, and a low glycaemic index (Prasad *et al.*, 2015).

Anti-obesity

Obesity has been related to an increased risk of practically every chronic illness, including diabetes, dyslipidemia, and mental illness. It significantly impacts stroke and cardiovascular disease risk, as well as several cancers and osteoarthritis (Hruby and Hu, 2015). Diets comprising foods with enhanced satiety properties may be advantageous for appetite control, long-term weight management (Hetherington *et al.*, 2013), and the prevention of obesity-related chronic illnesses.

Relieving constipation

Dietary fibre is widely known for relieving and preventing constipation, and several research articles, as well as methodical examinations and meta-analyses, have been published on the effects of organically produced dietary fibre on bowel movements (Watanabe *et al.*, 2018).

Anti-cancerous

Cancer is a terrible illness that affects people all around the world. Sorghum-based meals serve a useful purpose by supplying long-term phenolics that may help to prevent cancer (Chen, 2017). Sorghum-based foods have anti-carcinogenic potential that has been widely documented, and various research groups have demonstrated anti-cancer efficacy for polyphenol-rich sorghum (Khan *et al.*, 2021; Lee *et al.*, 2020).

Celiac disease

Celiac disease (CD) is an immune-mediated enteropathy of the small intestine caused by gluten consumption in genetically predisposed people. Celiac disease is still underdiagnosed in various areas, which can lead to serious health problems (Kumari and Morya, 2021). Currently, the only therapy for Celiac disease requires a gluten-free diet for the rest of one's life in order to enhance quality of life, relieve symptoms, and avoid resistant celiac disease, ulcerative jejunoileitis, small intestine adenocarcinoma, and lymphoma (Caio *et al.*,

Table 2. Comparison of edible vs. non-edible cutlery

Edible	Non-edible	References
Edibility- The cutlery is not only used for having a meal but cutlery itself can be taken as meal.	Edibility- All the cutleries are non-edible	Poonia and Yadav, 2017
Bio-degradable- The product can be degraded naturally within 5-6 days.	Nil	Natarajan <i>et al.</i> , 2019
Durable- The cutlery can last from months to years with a proper air tight packaging. For example, the edible spoon can last up to 2 years and it can be served in hot soups, salads, ice creams etc.	It can last for several years	Patil and Sinhal, 2018 Natarajan <i>et al.</i> , 2019
Nutritious- It can be nutritious and fulfils the daily body supplement as they are rich in dietary fibres and energy.	Nil	Sood and Deepshikha, 2018
Cost- Price of the product is cheaper when compared with metal cutlery.	Price of the product is some extent greater than edible cutlery.	Poonia and Yadav, 2017
Eco-friendly- Product ecologically friendly in nature. As the product doesn't affect any ecological parameters of environment.	Nil	Natarajan <i>et al.</i> , 2019
Reduction of wastage- It can help to minimize the global plastic cutlery wastage.	Nil	Natarajan <i>et al.</i> , 2019
Organic- It is made up of natural raw materials which is the reason for its organic nature.	Nil	Rashid, 2019
Preservatives- Depending upon the sources most of the products of edible cutlery doesn't consists preservatives.	Nil	Natarajan <i>et al.</i> , 2019
Alternative- It can be replacement for the plastic cutlery.	Nil	Patil and Sinhal, 2018
Market Growth- Many countries caught their eye on this trend and manufacturing industries may emerge within next few years in the field of food processing sectors and also trends in imports and exports globally which is beneficial for countries capital.	Nil	Rashid, 2019
Sustainable- Both the environment and economy can be benefitted with this product due to its sustainability.	Nil	Natarajan <i>et al.</i> , 2019

2019). Sorghum-based foods are considered a healthy diet for celiac disease sufferers since they contain no gluten (Pontieri *et al.*, 2013).

Coronary heart disease

Whole grain consumption has been linked to a decreased risk of coronary heart disease (Helnaes *et al.*, 2016). According to long-term prospective research, eating a balanced diet that includes fish, poultry, vegetables, fruits, and whole grains reduces the chance of getting a heart attack or stroke. Dietary fibre consumption has been related to a lower risk of CVD and coronary heart disease (CHD) in both men and women (Threapleton *et al.*, 2013).

MARKET OF EDIBLE CUTLERY

Edible cutlery has grown in popularity in both mature and emerging countries due to a rise in the number of customers who prefer vegan meals. People are more

likely to switch from disposable plastic cutlery to newly developed edible silverware (Patil and Sinhal, 2018). In this modern era, customer satisfaction is the most predominant factor of every industrialist, food manufacturer, B2B, or B2C business (Rashid, 2019). Edible cutlery made from sorghum could be viable as a substitute for single-use plastic cutlery that is wreaking havoc on the environment. One-time cutlery is in high demand in the United States. For example, purchases 40 billion plastic cutleries annually (Munir, 2017). The global demand for plastic cutlery is 640 billion dollars a year. In 2017, the market was valued at 2.62 billion dollars; by 2025, it is predicted to be worth more than 3 billion dollars. Another research released by National Geographic in 2018 found that half of the world's plastics are manufactured in Asia, with China accounting for 29% of the total manufacturing volume (Parker, 2018). The European Union recently decided to phase out single-use plastic spoons by 2020 (Welle, 2018). As a result, the cutlery reveals a large market opportunity for edible cutlery in many

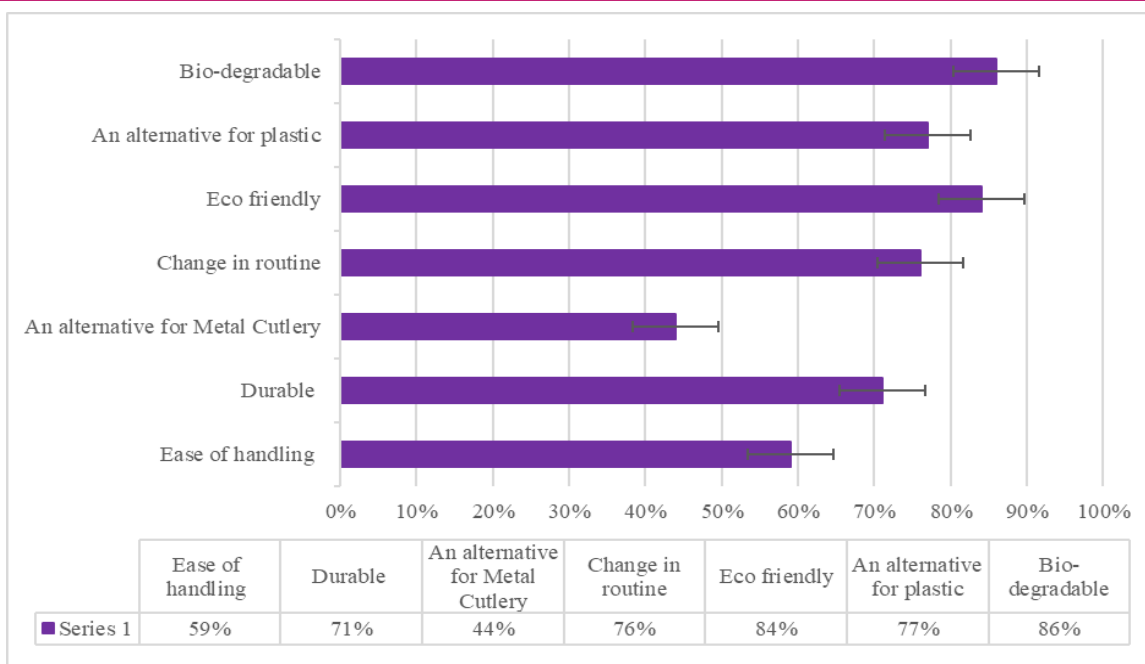


Fig. 2. Graphical representation of requirement of edible cutlery (Patil and Sinhal, 2018)

wealthy countries. The worldwide edible cutlery market was valued at \$24,860.0 thousand in 2018 and is predicted to reach \$56,970.4 thousand by 2026, with a CAGR of 11.1 percent between 2019 and 2026, according to the analysis. In 2018, the edible cutlery market was dominated by North America, with 41.8 percent of total sales (Dublin, 2020). Fig 2 is about the factors primarily responsible for the demand for edible cutlery.

Furthermore, the edible cutlery business has grown as a result of increased health consciousness and disposable cash. Other aspects that contribute to the market's development consist of the launch of innovative healthy flours and herbs by various industry members (Kadam and Deshmukh, 2020). Over the projected period, the growing usage of this product in the aviation sector, where steel items are regarded an unviable alternative, is likely to boost market expansion. The following is selected as a reference for the edible cutlery market since the US market is a well-known standard market among many nations.

Conclusion

There is a need for plastic alternatives or better solutions for people. As plastic is the biggest threat to mankind and the nature of the earth in the form of cancer, soil erosion, ocean toxicity and air pollution. Edible cutlery is a better replacement for plastic. Moreover, it can be cost-effective when the production of raw materials increases, helping the ultimate product to meet up the customer's economic expectations. The edible cutlery has qualities like biodegradability, eco-friendliness, edibility, and numerous health advantages to solve the

problem backdrop. Therefore, edible cutlery helps to achieve sustainable development goal 3 and 13. The qualities and advantages of the product can be enhanced and created with the assistance of the same will be identical. Hopefully, this product could be found as a replacement for plastic.

FUTURE PERSPECTIVES

Most people know the effects of plastic and its damage to the earth's ecosystem, but they need a change. The research should also be done to determine the materials with the least absorption capacity, as the cutlery may absorb the soups and liquids that are put into them. In addition, the shelf life of these materials is something that should be considered. Although the availability of edible cutlery is seen as very low, and its requirement has been increasing. It can be used in ice-creams, hot beverages, salads and sweets like *gulabjamun*, and *rasmalai*. Furthermore, because the tableware is edible, discarded tableware may provide food for soil microorganisms and insects. In such instances, it is vital to study the safety of such living species' eating (Natarajan *et al.*, 2019).

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Conflict of interest

The authors declare that they have no conflict of interest.

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