CHAPTER II

REVIEW OF LITERATURE

The review of literature pertaining to the study entitled **"Sustainable Solutions: Edible Millet Tableware as a Substitute for Single-Use Cutleries in the Food Service Sector**" is presented in the following headings,

2.1 Single Use Plastics (SUP) in Packaging – The Path Traversed

2.2 Single Use Cutleries in Food Service Sectors - Short-Term Convenience, Long-Term Environmental Cost

2.3 Edible and Ecofriendly Cutlery – A Sustainable Solution

2.4 Millet: Versatility, Products, and Properties

2.5 Edible Flower: A Nutritional and Therapeutic Wonders

2.6 Millet and Edible Flower-based Products

2.1 SINGLE USE PLASTICS (SUP) IN PACKAGING – THE PATH TRAVERSED

In food service sector, packaging plays a vital role in maintaining the food quality, enhancing the visual appearance, convenient, protection, and delivering product information to consumers about the packed food item. Nowadays, most of the food packaging were made of synthetic polymers that poses environmental challenges due to its non-biodegradable nature, that led to pollution from manufacturing process and generate rapid waste (Ncube *et al*., 2020). Utilization of plastic has emerged popularity in a short duration in different aspects in food industries from packaging to displaying of food products. Single-use plastics (SUP) provided better protection and preservation at low cost whereas only used for a short time which has a life cycle less than few hours to few months, that resulted in a throw away culture and posing negative impacts on environment and human health (Dey *et al*., 2021). The European Union's Directive (EU) 2019/904 of the European Parliament and its Council describes SUP as materials that were used once, or for a short period, before being thrown away. The definition of SUPs is further comprehended as, products that have been made entirely or partially of plastic but were not designed to be used multiple times, and being returned to the manufacturer for re-entering the market. Cutlery, plates, straws and stirrers, food and beverage containers, cups

for beverages, packets and wrappers, and plastic bags were the major SUPs utilized in day-to-day life. The main purpose of the implementation of the directive is to prevent and reduce the impact of plastics on the environment (Dybka-Stępien *et al*., 2021; Regulation EU 2019/904 of the European Parliament and Council of 5 June, 2019).

The pervasive use of SUP has fostered a global throwaway culture, especially in the food packaging industry, where convenience, low cost, and durability have driven their widespread adoption. This trend has resulted in a significant escalation of plastic waste generation, posing severe environmental threats to marine ecosystems and biodiversity (Kabir *et al.,* 2022; Chen *et al.,* 2021). Leal Filho *et al.* (2021) found that production of SUP and its waste become the international concern that affects the natural environment and usage of SUP was increased during COVID-19 pandemic due to increased online purchase and food-based e-commerce websites. SUPs will never disappear or degrade, instead it thickens and fragments, affects life on land and below water that hinders to achieve Sustainable Development Goals (SDGs).

The United Nations Environment Programme (UNEP) estimates that approximately 300 million tons of plastic waste were generated annually, with only 9 per cent being recycled, 12 per cent incinerated, and a staggering 79 per cent accumulating in landfills or the natural environment (UNEP 2021)**.** Since 1950, global plastic production has skyrocketed from 1.5 million tons to around 370 million tons by 2019. Asia leads with 51 per cent of production, followed by NAFTA countries (19%) and Europe (16%). Continuation of current trend may lead to accumulation of plastic litter in landfills and natural ecosystems that could reach 12 billion tons by 2050. The persistence of plastic waste due to its non-biodegradable nature, including items like disposable bowls, exacerbates these challenges and underscores the urgent need for sustainable alternatives that can replace conventional plastic products and reduce the environmental footprint of SUPs (Kumar *et al.,* 2021; Godfrey *et al.,* 2019).

The larger portion of SUP are manufactured using polypropylene, polyethylene, polystyrene, terephthalate, poly vinyl chloride along with fillers, colorants and stabilizers that fragments due to chemical, biological or environmental elements and gradually enters into food chain and living system (Akhtar *et al*., 2023; Dey *et al*., 2021; Sana *et al*., 2020). SUPs degraded slowly and fragmented into pieces into secondary microplastics (less than 5 mm sized particles) which is found in freshwater in lakes and rivers and also in drinking water. Among microplastics, 52 per cent is found as fragments and 29 per cent and 19 per

cent are as films and spheres, respectively which is detected in South and North Pacific and North Atlantic oceans that causing negative impacts on the ecological system (Dayal *et al*., 2024; Chen *et al.,* 2021). Marine SUP pollution consists of both macro (>5 mm), microplastics (0.1μm to < 5 mm) and nanoparticles (<0.1 μm) that becomes the global concern that pose greater threat to marine organisms, affects micro algal growth and human health. The common SUP collected during coastal cleanups consists of bottles, grocery bags, bottle lids or caps, food wrappers, straws, stirrers and foam take-way containers which are all part of food service sectors (Dayal *et al*., 2024; Akhtar *et al*., 2023).

Microplastics migration from SUP to food material is an important factor as it causes heavy metal toxicity, additive contamination that causes health hazards (Dey *et al*., 2021). The migration of microplastics into food items can decrease nutritive value, safety and organoleptic properties due to the leaching of harmful chemicals. Endocrine-disrupting compounds like phthalates, Bisphenol A, dioxins, fillers, plasticizers in used in SUP affects the hormonal balance, homeostasis, reproduction, development and behavioural process in human body (Muzeza *et al*., 2023). A study by Li *et al*. (2022) found that microplastics are inhaled by humans from the environment that leads to respiratory disorders and further causes oxidative stress, cytotoxicity, and inflammation. It remains in lung fluid for upto 180 days that increase the risk of chronic lung issues. Yan *et al*. (2021) found that microplastics and nanoparticles damages the intestinal epithelial barrier that causes inflammatory bowel disease. It also changed the stress-related genes or microRNA deregulation causing early signs of cancer (Tiwari *et al*., 2023). The rising concern for the potential migration of harmful substances, such as additives and monomers, from plastic into food products that leads to significant socio-political push toward developing innovative packaging materials. The global awareness of plastic pollution has sparked a shift in consumer behaviour towards sustainable practices (Walker *et al*., 2021).

2.2 SINGLE USE CUTLERIES IN FOOD SERVICE SECTORS - SHORT-TERM CONVENIENCE, LONG-TERM ENVIRONMENTAL COST

The global overproduction of single-use cutleries particularly in food consumption, coupled with increasing awareness of their environmental and health impacts, has driven significant changes in the use, production, and waste management. Efforts to mitigate these issues include banning plastic cutlery, plates, stirrers, and beverage containers,

reducing the consumption of single-use products like cups and food containers, and promoting separate collection systems through deposit-refund schemes. Additional strategies involve raising public awareness about the environmental harm caused by polymers, implementing product labelling by highlighting its ecological impact, introducing extended producer responsibility in waste management (a mandatory provision in waste management rules, 2026 of Indian act), and developing eco-friendly alternatives such as cutlery from natural materials. It is a collective and sustainable measure to reduce the reliance on single-use plastics (Dybka-Stępien *et al*., 2021; Chowdhury *et al*., 2021).

Spoon is the first cutlery used by humankind, that is made from natural sources such as wood, animal bones or seashells. The first recorded evidence of spoon was developed in England far back in the year 1259 which was not used for eating, but often used to represent wealth and influence in ceremonies. In, 18th century, forks and knives for consuming food were also added. Silver was the most common metal for cutlery, before the advent of stainless steel. Stainless steel cutleries were chosen over other metal cutleries, as it is easy to maintain, non-reactive and durable. Then, the introduction of plastics into the market made its availability very simple and at the same time, the cost of cutlery also decreased with a lot of variations and sizes, such as, cups, bowls, spoons, forks, knives, etc. The price of stainless-steel cutlery today is much higher than plastic or edible cutlery. The use of single-use plastic cutleries and the issue of disposing them is a major problem that is currently to be addressed (Kabir *et al*., 2022). In 21st Century, food service sector faces huge challenge as the take-away culture has been increased and mass utilization of single-use cutleries were in food-truck festivals, barbecues and picnic spots. The requirement is enormous in aviation catering and dietary catering where ready-to-eat convenience food has been increased (Dybka-Stępien *et al*., 2021).

Banning of single use cutleries, mandating the cost, decreasing the consumers purchase, changing the customers attitude were the steps taken to reduce the usage. Many countries have banned the usage of SUP including single use conventional cutleries to stop landfills and ocean litter. According to Plastic Waste Management Amendment Rules, 2021, Ministry of Environment, Forest and Climate Change, India has banned the production and usage of SUP below 75 to 120 microns for bags, stirrers, glasses and cutlery (fork, spoon, knives, straw, trays, wrapping film) in India from July,2022.

Few regulations like European Commission regulations (EU 10/2011 and EU10/2016), Food Safety and Standards Authority of India regulations in 2018 and 2020 (packed drinking water), and IS9845 were regulating the potential hazards of toxic contaminants migrated from food packaging material. European Food Safety Authority has allowed an overall migration of 60 mg kg^{-1} for the food and 10 mg kg^{-1} for the material. Food Safety Standards Authority of India, 2018 suggested that migration limit of 60 mg/kg or 10 mg/dm^2 and the migration from the packaging material should not be exceeded.

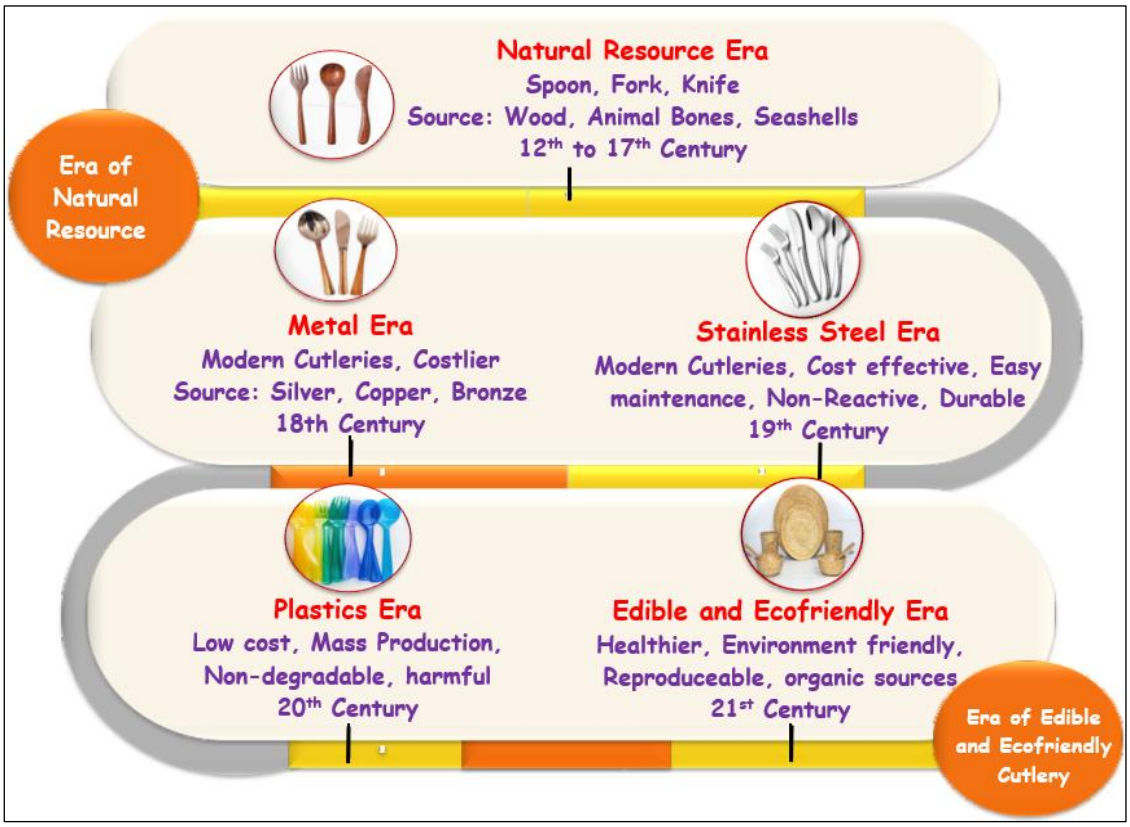

Figure 1

Emerging History of Cutleries – Past to Current Scenario

*(Chowdhury *et al*., 2021; Kabir *et al*., 2022)

The harmful effects of single-use plastic cutleries need to be tackled by sustainable alternatives like edible and ecofriendly cutlery and crockery. It has emerged as a smart and promising eco-friendly option to address environmental concerns. Its biodegradability and potential to mitigate plastic waste make it a sustainable choice to beat plastic pollution. Edible and ecofriendly cutlery also provide a potential for innovation and entrepreneurship opportunities and a field to be explored more.

2.3 EDIBLE AND ECOFRIENDLY CUTLERY – A SUSTAINABLE SOLUTION

Edible cutlery is a promising environmentally friendly alternative to SUP that provided a sustainable, biodegradable, eco-conscious alternative with potential nutritional benefits and an innovative solution to a cleaner, greener future. Edible cutlery and crockery were gaining widespread popularity with a growing demand worldwide for ecofriendly alternatives. Nowadays a large number of manufacturers increased the focus on producing enumerable innovative products that helps in the reduction of plastic waste. It serves as an ecofriendly substitute for SUP and a sustainable choice during travel as it can be consumed along with the food which can be in the form of wraps or food containers. It is important to label allergic information to ensure safety and sustainable secondary packaging should be used to pack the edible wraps, cutlery and crockery (Narvekar *et al*., 2022).

Edible cutlery is an innovative idea that the cutlery can be eaten along with the food and few manufacturers had developed cutleries from different sources and large-scale commercialization should be focused more. The market for plastic cutlery is increasing 30 per cent annually that reach the landfills and cause pollution. Edible cutlery exhibited the same properties of SUP disposable cutlery and it has the degradable property and enhance the health (Mukherjee & Raju, 2023). Srivastava *et al.* (2024) highlighted that the edible cutlery provides a sustainable, biodegradable, and customizable alternative to plastic utensils, offering both environmental and nutritional benefits. This innovative solution supports the growing demand for eco-conscious practices, combining convenience with functionality to promote a cleaner, greener future.

In 2019-2020, China has prohibited the single-use cutleries in online food delivery and started green nudges, which decreased the use of single-use cutleries (He *et al*., 2023). Few manufacturers have produced edible cutlery and crockery. Sugu company form Taiwan produced biodegradable tableware and cutlery; Karatt Bakery Café, Orto Café, Honest has manufactured plates, bowl, chopstick from edible and seaweed sources; Poland based company, Bioterm developed wheat bran tableware; Notpla, a United Kingdom based company produced edible water capsules from seaweeds; Loliware, Marriot Hotels, Pernod Richard has developed straws and films from seaweed and milk casein; Munch Bowls, a Mexican company manufactured bowl from bran and Poilane from France developed edible utensils from cracker cookies. In Indian based companies were also developed different edible and ecofriendly cutlery, spoons from cereals with different

flavours by Bakeys, cups from cereals with added flavours by Attaware, spoons and cutleries from edible flour by Trishula, India (Chowdhury *et al*., 2021)

Numerous research focused on formulating cutleries from bamboo and corn cob which were ecofriendly but not edible. Edible cutlery is an ecofriendly alternative that replaces single-use conventional cutleries and reduce the negative footprints of SUP on environment. Edible cutleries and crockeries were natural and biodegradable that eliminates waste disposal system. It can be consumed at the end of the meal and versatile to hold a wide range of hot or cold food items without compromising functionality. Several studies have explored the development of edible cutlery and bowls using various ingredients; however, certain limitations persist. Kabir *et al*. (2023) formulated edible cutlery from rice, wheat and sorghum that becomes soggy in 30 minutes and 25 to 33 per cent of biodegradation within 24 hours. The researcher also recommended that the manual approach is less preferable and flavours can be added to enhance the sensory attributes of the developed cutlery. Iqbal *et al.* (2022) produced edible spoons, forks, and bowls using rice, sorghum and other millet flour but it lacks in textural and functional properties. Mandal & Antarkar (2024) formulated a composite cutlery made from finger millet, pearl millet and sorghum with added flavours were developed and exhibited good sensory attributes for 30 days with good nutrient profile that uplifts the health of community. Rajendran *et al*. (2020), optimized cutleries made with 52.10% wheat flour and 26.18% barnyard millet flour, withstands 25 minutes in cold water, 15 minutes in hot water, and degrades within 5 days.

Jaspal *et al*. (2024) stated that the development of multi-millet edible bowls from little, kodo, and barnyard millet flours offers a promising, environmentally conscious alternative to traditional plastic-based bowls and its biodegradable properties is an added advantage. Thagunna *et al.* (2023) formulated cutlery using water, wheat flour, finger millet, rice flour, water, jaggery, oil, and salt in varying amounts by manual method that exhibited, 31.59 % of water absorption rate and completely biodegraded within 5 days. Molu *et al.* (2024a), formulated cutleries from maize and wheat flour exhibited good sensory attributes and textural properties. Mukherjee & Raju (2023) formulated tablespoon from wheat, foxtail millet, and roasted bengal gram with skimmed milk powder, beetroot extract as functional additive and the researchers confirmed that it enhances the nutritional status as part of daily diet.

Rishi *et al.* (2024) developed an edible bowl from finger millet, rice, and wheat flour with cinnamon powder, that exhibited strong flavour, sogginess within 15 minutes, and a lack of reproducibility due to manual moulding. Similarly, Siddiqui *et al.* (2023) standardised an edible spoon using mosambi peel, sago powder, and gum arabic, but reported poor sensory attributes and reproducibility challenges. Nehra *et al*. (2024) developed a bowl from finger millet flour, refined flour, jaggery, xanthan gum, and brewer's spent grain, and found to be soggy in less than 15 minutes and lacks reproducibility due to manual moulding. Dordevic *et al.* (2021) standardised an edible spoon from grape seed flour, proso millet, wheat flour, xanthan and palm oil and sensory evaluation or exposure tests were not conducted. Matheswari & Arivuchudar (2024) formulated a composite cutlery from whole wheat flour, rice bran powder, dehulled chickpea flour, groundnut cake powder, beetroot pomace, apple pomace, and molasses with a shelf life of 120 days. Vyshali *et al*. (2022) developed biodegradable cutleries from fruit core (jackfruit, pineapple) along with jackfruit seed flour and found that jack fruit is highly acceptable with better nutrients and its shelf life or textural properties were not analysed.

The need to enrich edible cutlery with medicinal plants shows a growing trend due to its added health benefits. The main challenge in incorporating medicinal plants in edible cutlery is the bulk sourcing of raw materials as some medicinal plants might be available limited or only cultivated in specific regions, that affect the consistent supply chain. Overharvesting of medicinal plants and biodiversity loss due to its over exploitation should also be considered and avoided. The structural integrity, texture, taste, and durability of the edible cutlery should be focused and balanced while formulating and few medicinal plants might cause allergies or adverse reactions among certain people that may compromise safety of the end product. The consistency of the edible cutlery formulations with medical plants should be standardised to ensure quality, reproducibility and to enhance the nutritional content and sensory attributes for consumer acceptance. The cost of medicinal plants incorporated edible cutlery could be higher than conventional SUP and standardising a cost-effective and affordable eco-friendly cutlery is a challenging research area (Srivastava *et al*., 2024).

The limitations of the past literature including manual molding, lack of reproducibility, poor sensory attributes, and insufficient testing of functional properties is addressed in the present research to formulate a scalable solution in the field of edible and

sustainable tableware. The present research focused on formulation, standardisation and characterisation of edible millet tableware from pearl millet and sorghum to replace single use cutleries in food service sectors. It is formulated to withstand various food items at different temperature including hot soups to cold desserts without compromising the structural integrity, sensory attributes and nutritional value. It can be consumed along with the packed food and degrades easily if discarded or thrown away that eliminates the necessity for conventional system for non-biodegradable waste collection or disposal.

2.4 MILLET: VERSATILITY, PRODUCTS, AND PROPERTIES

2.4.1 Background of Millets

Millets were a group of small edible seeds belong to the *Poaceae* family and a staple food for many people from ancient period due to its nutritional benefits and gluten free nature. Millets were the powerhouse of various nutrients and bioactive compounds including, carotenoids, phenolic acids, flavonoids, lignin and beta-glucan. The consumption of millets is increasing in the recent years and considered as an alternative to rice and wheat. The cultivation of millets has drastically increased globally due to its potential health benefits and sustainable production practices. It grows in adverse climatic conditions and known for its resistance to drought conditions and resistant to insects that cause only minimal damage to the grain. Millets can be broadly divided into two categories, namely, major millets that include sorghum (*Sorghum bicolor*) and pearl millet (*Pennisetum glaucum*) and minor or small millets consist of finger millet (*Eleusine coracana*), proso millet (*Panicum miliaceum*), foxtail millet (*Setaria italica*), kodo millet (P*aspalum scrobiculatum*), barnyard millet (*Echinochloa spp*.) and little millet (*Panicum sumatrense*) (Bajpai & Ravichandran, 2023; Chen *et al*., 2021).

Different names were coined to millets according to the growing regions of India and the world. Millets exhibited rich nutritional profile, taste, and it is an ideal choice to formulate food products in daily diet. Many countries in Asia and Africa utilize millets as an important food ingredient to develop various processed foods such as bread, porridge, fermented and non-alcoholic beverages, sweets, snacks, and instant mixes than consuming it in raw form. European and North American countries use millet as a gluten-free ingredient in ready-to-eat food products. The use of millet in processed foods not only increased their market value but also created opportunities to promote their nutritional benefits to a wide range of consumers (Sunil *et al*., 2024).

In several parts of India, millets were cultivated for the food, feed, and fodder for livestock that promote a sustainable agriculture practice. Millets were considered as good source of energy, particularly in drylands that also provide essential micronutrients and phytochemicals to enhance health and reduce the health risk. It also exhibited superior antioxidants that scavenge the free radicals with numerous therapeutic properties (Sunil *et al*., 2024). Globally, about 820 million people suffer from severe hunger and malnutrition. India exhibited 29.1 per cent of the Global Hunger Index in 2022 and positioned 107th rank. Malnutrition could be overcome by proper consumption of food items, including millets, as it is a sustainable and cost-effective staple food. It provides numerous micronutrients, including zinc, iron, folic acid and β-carotene that can be supplemented to overcome malnutrition (Biradar *et al*., 2024). Millets also contributed to reducing climate change by reducing carbon footprint as it requires less water for cultivation when compared to other staple food items like rice and wheat. It is also known as "Nutri-cereals and Shree Anna" due to the rich source of nutrients and as a staple food for the Indian population.

2.4.2 Cultivation and Production of Millets

Farmers cultivate larger quantities of major millets as compared to minor millets in India and the highly cultivated area is the northeastern part, including Manipur, Meghalaya, and Nagaland. It can easily adopt to diverse soil and climatic conditions. The growing season is between June to November, and the most suitable soil type for cultivation is well-drained loamy soil. It requires a warm temperature of 20°C to 35°C for germination and is susceptible to frost. Millets can be grown with less rainfall and the average rainfall requirement is around 450 mm for major millets and 350 mm for minor millets (Sachan *et al*., 2023).

India has the largest area under millet cultivation, followed by Niger which is cultivated in 312.44 lakh hectares globally. Uzbekistan has the highest millet yield per hectare, followed by Switzerland. The flexibility of millets to adapt to shorter growing seasons, a wide range of temperatures, moisture regimes, and input conditions makes them valuable and affordable. Since, it increases the conversion of carbon dioxide into oxygen, which is also an advantageous C4 crops. Millets have the ability to support food and nutritional security as a nutritious food in daily diet and its low-cost production lead to increased cultivation area (Bajpai & Ravichandran, 2023).

Millets are cultivated in 93 countries worldwide and the highest producers are Asia, Africa and Europe. In 2012 to 2022, India is the highest producer of millet and Niger exhibited a strong decline in Millet production. Azerbaijan, Mexico, Turkey and India are the highest millet producing countries. India is the largest producer of rice, wheat, and other cereals and the cereals production was around 297.5 million tons in 2019-2020. Production and productivity of rice, wheat, maize and other dominant crops have been increasing due to the advanced technology, which replaced the production and productivity of other important crops such as minor millets. Maharashtra, Rajasthan, and Karnataka are the leading producer of states in India. In the year 2023-2024, Rajasthan is the highest producer of Bajra with 44.9 per cent, Karnataka produced 62.4 per cent of Ragi, Madhya Pradesh and Uttarakhand produced 34.26 per cent and 13.98 per cent of minor millets, respectively. The cost of the millets can be attributed to general price inflation, and the cost of inputs like seeds, fertilizers and labour (Banerjee *et al*., 2024; Hariprasanna, 2023).

According to Agricultural and Processed Food Products Export Development Authority (APEDA), the total millet production in the year 2024 in India, is 1538 Mil MT in the area of 12.19 Mil ha and the largest produced states were Rajasthan followed by Karnataka, Maharashtra, Uttar Pradesh, Haryana, Gujarat, Madhya Pradesh, Tamil Nadu, Andra Pradesh and Uttarakhand and the major millets were highest produced followed by minor millets.

2.4.3 Consumption Pattern of Millets

Millets exhibited a sharp decline in consumption due to the preference for rice and wheat is due to ease of preparation, shorter cooking times and available through Public Distribution System (PDS). Factors like longer cooking times, lack of value-added products, poor storage, inadequate or costlier modern processing techniques, and weak marketing strategies reduced the millet consumption. The consumption of millets fell in both rural and urban areas, with rural households showing a steeper decline between 1977–78 and 2011–12. Consumption of millets exhibited the highest drop (97.62%) in rural areas, including jowar, ragi, and bajra, while urban consumption also declined notably for sorghum, bajra, and ragi. Recently, millet consumption is rising due to growing awareness of their nutritional and health benefits. Efforts should focus on developing value-added products, increase awareness, and improve the market access to increase consumption pattern of millets (Sukumaran Sreekala *et al.,* 2023).

Governments and industries were increasingly focusing on millets for their role in addressing climate change, malnutrition, and health issues like diabetes. Prashanthi & Reddy (2023), stated that, millet production and consumption have declined over the years, while rice and wheat consumption has increased, contributing to a rise in lifestyle disorders. A survey of 15,139 individuals across seven major Indian cities found that health concerns (28%) were the top reason for millet consumption, followed by weight loss (15%) and taste preference (14%). The main barriers for consumption of millets are the lack of millet use at home (40%) and dislike of taste (22%). Millet consumption can be enhanced by, developing tastier products, raising awareness of its health benefits, and its availability across all regions (Kane-Potaka *et al*., 2021).

Millets is a staple food in Asia and Africa, valued for its dietary fiber, micronutrients, and phytochemicals. A study by Priya *et al.* (2024) examined the millet consumption pattern among 100 adults in Chennai and found that 41 per cent consumed millets, once to thrice in a week for its nutritional and health benefits. Most respondents found millets as an affordable food ingredient and preferred to consume in the form of kali, kanji, pongal, upma, and biscuits, often combining with pulses in preparations like pongal and kichidi. Finger millet is the most commonly consumed millet across all income groups. Consumers expressed a positive attitude towards millets and emphasized the need for ready-to-cook and ready-to-eat millet products such as dosa batter, noodles, flakes, breads, and beverages to promote health and convenience. Millets, being nutritionally rich and resilient to severe weather, should be promoted as part of the diet. This can be achieved by providing millets through PDS at affordable prices and implementing a holistic approach to raise awareness about their benefits in society.

2.4.4 Processing and Nutritional benefits of Millets

Millets can be consumed in different forms and processing increase the variety and enhance the shelf life rather than in its raw forms. Minimal processing of millets is required, including husk removal and conventional processing improve the digestibility, shelf-life, and nutritional quality. The consumption of millet can be increased by formulating convenient products with better acceptability and shelf life. The common processing of millets is soaking, germination, malting, decortication, flaking, fermentation, grinding, roasting and microwave heating. The processing methods were aimed to improve nutritional quality and reduce the anti-nutritional factors. The non-thermal techniques such as cold plasma and ultrasound were used in millet processing to preserve the release

bioactive compounds, reduce antinutrients and also decrease the microbial growth and currently which is done in a small scale. The different processing techniques increased the bioavailability and absorption of nutrients and decreased the effect of antinutritional factors. Processing of millets could increase the total phenolic content (TPC) and total flavonoid content (TFC) especially in the germinated form whereas dehulling of millets lead to reduction in TPC and TFC (Sunil *et al*., 2024; Gowda *et al*., 2022).

Millets were nutrient-rich grains packed with vitamins, minerals, proteins, amino acids, and dietary fiber, making them a healthy alternative to rice and wheat. Millet aids in promoting weight loss, and easy to digest due to their low gluten content. Millet consumption is gaining popularity as one of the best grain due to its nutrient content and health benefits. Health benefits of millets included, anti-inflammatory effect, inhibition of platelet aggregation and antiviral activities, and reducing the risk of cancer were shown by dietary fibre and phenolic compounds (Sachan, *et al*., 2023; Maurya *et al*., 2023). Inclusion of millets in daily diet could reduce the risk of certain diseases including celiac, cardiovascular, type 2 diabetes, gastrointestinal cancers, and nutrition deficient disorders. The consumption rate and demand of millets have been increased in the recent years due to the awareness of its potential health benefits on par with other cereals. The processing techniques applied in the formulation of millet products also decides the amount of nutrients and bioactive compounds present in the end product (Sunil *et al*., 2024).

The bioactive compounds in millets hold a promising potential beyond their basic nutrition, creating a pathway to develop functional and nutraceutical-based products with extensive health benefits. Soaking, germination, roasting and similar processing methods of millets showed an increase in bioactive compounds such as antioxidants, polyphenols and also exhibited an increase in dietary fibres, vitamins, and minerals, contributing to various physiological benefits in humans. Nutrient content and bioactive compounds in millet plays an important role in product development in the food and pharmaceutical industries, and improves the health of the consumers. The presence of diverse bioactive compounds and its multifaceted health-promoting properties, make the millets for formulating innovative, value-added millet-based products. Developing millet products with good texture, appearance, shelf life, convenience, and economical cost can promote the consumption of millet. Adaptation of novel processing and value-addition technologies to create a better-quality diet and improve the bioavailability of micronutrients may

protect human health from poor diet-based and modern lifestyle diseases (Latha Ravi & Rana, 2024; Sunil *et al*., 2024).

2.4.5 Pearl Millet and Sorghum – A Sustainable source for Edible and Ecofriendly Tableware

2.4.5.1 Pearl millet

Pearl millet (*Pennisetum glaucum* (L.) R. Br.) is the sixth most important cereal crop after rice, wheat, maize, barley and sorghum. It is widely grown on 30 million ha in the arid and semi-arid tropical regions of Asia and Africa, accounting for almost half of the global millet production. Pearl millet production is affected by climate change which directly influence the biophysical factors such as plant and animal growth along with the various areas associated with food processing and distribution. Pearl millet exhibited nutritionally superior in micronutrients namely, iron and zinc that reduce malnutrition and hidden hunger (Satyavathi *et al*., 2021). Among all the millets, pearl millet is a regular crop that provides a staple food especially for the people in semi-arid tropical regions of Asia and Africa (Biradar *et al*., 2024).

Pearl millet is a good source of dietary fibre, protein, magnesium, B vitamins, zinc, potassium, phosphorous and other health promoting compounds and the presence of anti-nutritional factors may reduce the absorption of micronutrients **(**Bello *et al*., 2022). Complex carbohydrates in pearl millet had a low glycaemic index that is suitable for individuals with diabetes or aids in reducing blood sugar levels and gluten-free nature made it as a viable alternative for individuals with celiac disease or gluten intolerance. Pearl millet exhibited better textural and water-holding capacities that can be used in various food applications such as baking, extrusion, and fortification. Various techniques such as, milling, dehulling, fermentation, and roasting, were used to enhance the digestibility, sensory attributes, and overall nutritional quality. Processing methods can also reduce antinutritional factors and increase the bioavailability of minerals. Incorporating pearl millet into diets and food products can enhance nutritional profiles, particularly in regions where malnutrition and micronutrient deficiencies prevail (Meena *et al*., 2024).

Pearl millet is the rich source of protein, dietary fibre and carbohydrates; and the presence of protein is comparable with other cereals and dietary fibre promotes digestive health and reduces the risk of chronic cardiovascular disease and diabetes due to its low glycemic index. It is also a good source of micronutrients including B complex vitamins,

iron, zinc, magnesium and phosphorous that aids in physiological properties and promote overall well-being. It also exhibits phenolic compounds, flavonoids, and tannins that acts as a potential functional food (Biradar *et al*., 2024; Nibhoria *et al*., 2024). The bioactive compounds like hydroxybenzoic and hydroxynamic acid derivatives present in pearl millet aid in weight management, reducing chronic diseases and improves the health status and plays an important role in multigrain and gluten free food products (Tanwar *et al*., 2025; Rotela *et al*., 2021).

Pearl millet is also called as poor man's bread and consumed in various forms including chapathi, gruel, porridge and dessert. It is considered as the cheap source of protein and minerals. It is a raw material in the production of lactic acid and alcoholic fermented beverages (Eduru *et al*., 2021). Primary processing of pearl millet includes wetting, dehulling, milling and secondary processing like fermentation, malting, extrusion, flaking and roasting and popping as done to produce value added products and ease the consumption pattern. It also reduced the antinutritional properties, ease digestion and increases the shelf life. Non-thermal processing including cold-plasma, ultrasound, UV irradiation, high pressure processing, pulsed electric field is also done that improved the nutritive content and shelf stability of the value-added products (Mundassery *et al*., 2024; Eduru *et al*., 2021). Due to the conventional and modernized processing techniques, pearl millet is consumed in different forms including, 'uji' and 'dolo' were the traditional fermented beverages, extruded products including chips, crisps and also included in bakery products for its gluten-free nature. The development of ready-to-eat millet products has also increased that satisfy the nutritional requirement of daily diet (Nengparmoi *et al*., 2024).

The need for reformulating the diet with nutri-dense millets is increasing due to its vital nutrients that enhances the health of general population and reducing chronic disorder (Jindal *et al*., 2023). Consuming pearl millet as staple food could reduce malnutrition which can be consumed in many forms due to the conventional and modern techniques. Thus, pearl millet is the next-generation crop holding the potential of nutritional richness and the climate resilience and efforts must be targeted to develop nutritionally dense hybrids/varieties with high tolerance to drought using different omics approaches (Satyavathi *et al*., 2021).

2.4.5.2 Sorghum

Sorghum (*Sorghum bicolor*), is a prevalent crop in the *Gramineae* family that is highly cultivated in Africa, Asia, Australia, and America. Its flexibility in accommodating divergent climatic conditions and soil type contributes to its status as a pivotal staple food for millions of people worldwide (Mbulwe & Ajayi, 2020). Sorghum is commonly classified into four major categories such as sweet sorghum, grain sorghum, forage sorghum and biomass sorghum (Tanwar *et al*., 2023).

Sorghum is the fifth most cultivated and produced crop globally and contributed a major part in agricultural economy. It is a resilient crop (C3 crop) grown in diverse conditions and require fewer resources including water and fertilizers. It contributes to global security, serve as a human food and animal feed and also a bioenergy source due to the its resilient nature. (Lee *et al*., 2021; Sunoj *et al*., 2020; Habyarimana *et al*., 2020).

The edible portion of sorghum consists of pericarp, endosperm, germ and testa. The germ is rich in lipids, fat-soluble vitamins, particularly B-complex, and essential minerals whereas non-starch polysaccharides, phenolic acids, tannins, phenolic compounds and carotenoids are present in the pericarp and testa, while the endosperm exhibited starch, protein, B complex vitamin and minerals. It is a rich source of carotenoids and polyphenols that showed antioxidative, anti-inflammatory and anti-cancer properties. The sorghum variety cultivated as a kharif crop exhibited a diverse phenolic profile as compared to other cereal grains and its gluten-free nature increased the consumption pattern among people in US and Mediterranean region. It is an underutilized cereal grain that exhibited better nutritional profile, and exhibited numerous functional properties (Tanwar *et al*., 2023).

The phenolic compounds of sorghum were phenolic acids, 3-deoxyanthocyanidins, and condensed tannins which is similar to other cereals like maize and wheat. The highest phenolic compound is present in its bran. It also exhibited a superior flavonoid content (including apigeninidin, apigeninidin 5-glucoside, luteolinidin, luteolinidin 5-glucoside, and 3-deoxyanthocyanidins) which provide unique colour and taste of sorghum. The biosynthetic pathway in sorghum grains lead to the accumulation of 3-deoxyanthocyanins flavonoid compounds that is responsible for the yellow colour which is present in most varieties of sorghum grains (Pontieri *et al.*, 2022). The presence of flavonoids increased the health and reduce inflammation by influencing the pathogenic process. The presence of phenolic compounds, and flavonoids make sorghum as a functional ingredient in

manufacturing different food items including snacks to pastries and beverages may be along with cereals or as substituting cereals (Ghinea *et al*., 2021).

A study investigated the impact of germination (72 h) of sorghum on physicochemical, protein solubility, in vitro protein digestibility, antinutrient, antioxidant, and structural properties. Germination of sorghum showed that a reduction in crude protein, fat, fibre, and ash content which significantly improved the antioxidant property, total phenolic content, and total flavonoid content, also increased in vitro protein digestibility and Fe^{2+} chelating activity. Antinutritional factors such as phytic acid and tannin were reduced after germinating millets. Structural analyses (XRD and FTIR) revealed that modifications in crystalline and molecular structures, while scanning electron microscopy showed disrupted starch granules in germinated flour. The findings also suggested that, germination enhances the functional and nutritional properties of sorghum flour, making it more suitable for various applications in food products (Singh *et al*., 2024).

2.5 EDIBLE FLOWER: A NUTRITIONAL AND THERAPEUTIC WONDERS

Edible flowers have been used as infusions in earlier period and currently there is a growing interest in its extracts for their superior nutritional value and potential phenolic compounds and is used in modern therapy (Rivas-García *et al*., 2021). Edible flowers include 97 families, 100 genera and 180 species. In the past, several species such as rose (*Rosa* spp.), calendula (*Calendula officinalis*), saffron (*Crocus*), violets (*Viola odorata*), dandelion (*Taravacum officinale*) and breaded elder (*Sambucus nigra*) were usually used. Nowadays, chrysanthemum (*Chrysanthemum coronarium*), daylily (*Hemerocallis fulva*), lilac (*Syringa vulgaris*), mint (*Mentha* spp.), nasturtium (*Tropaeolum majus*), pansy (*Viola x wittrockiana*), rose (*Rosa* spp.) and tulip (*Tulipa* spp.) were becoming increasingly popular. The dry matter of edible flowers is a source of major constituents such as carbohydrates, proteins and lipids, as well as vitamins, minerals and low molecular phytochemicals (Chensom *et al*., 2020). The three main parts of flowers were pollen, nectar and petals. Pollen is a source of carbohydrates, proteins, lipids, carotenoids and flavonoids. Nectar contains sugars, proteins, lipids, and also abundant in organic acids, phenolic compounds, alkaloids and terpenoids. In contrast, petals are rich in vitamins, minerals and antioxidants (Skrajda-Brdak *et al*., 2020).

The existence of edible flowers has attracted attention in various corners of the world. The attractive colours and shapes, exotic aroma, and delightful taste make edible

flowers very easy to attain. Moreover, they also provide health benefits for consumers due to the unique composition and concentration of antioxidant compounds in the matrices. The bioactive compounds and their functional properties from edible flowers were necessary to diversify the usage and reach broader consumers. Edible flowers can be applied to a variety of needs as food components. Edible flowers can be consumed directly, pre-cooked or merely used as a garnish because their diverse colours were visually appealing. Nowadays, the use of edible flowers for food and beverages appears to be in demand as the population requires a healthy diet to endorse their immunity in face of a global pandemic (Prabawati *et al*., 2021). With the growing interest in healthy lifestyle, functional foods have become popular and recurrent in the human diet. Consequently, the global market niche has been expanding constantly, and its innovation is being stimulated. Functional food is defined as food products that incorporate or enhance ingredients that offer health benefits, in addition to nutritional values, modulating bodily functions, which can improve the immune response or decrease the risk of diseases and comorbidities (Jadhav *et al*., 2023). The market value of packed edible flowers is 90.5 USD million from 2022 to 2026 and an annual increase of 4.2 per cent to 4.40 per cent is expected (Pires *et al*., 2023).

Edible flowers have a high phenolic compound and poses antioxidant property, antibacterial property, anticancer property, anti-inflammatory property that enhances the metabolic disorder and reduce oxidative stress-related diseases (Rivas-García *et al*., 2021). The main bioactive compounds, such as phenolic acids and flavonoids in some edible flowers have specific functional properties. Phenolic acids, including chlorogenic acid, gallic acid, *p*-hydroxybenzoic acid, and *p*-coumaric acid, while flavonoids such as flavones, flavonols, flavanones, and anthocyanins that poses the antioxidant properties that prevent the degenerative diseases such as antidiabetic and cardiovascular disease (Prabawati *et al*., 2021).

97 families, 100 genera, and 180 species of edible flowers were used globally and many flower based vegetables, such as broccoli, cauliflower and artichoke were not enlisted as flowers. The researcher also found that, for a general perception, edible flowers were some special varieties of flowers, and the commonly consumed flowers are cauliflower, broccoli, pumpkin flower are considered as vegetables; Star anise and Javitri as spice and sun flower oil and rose water is considered for its extract. The edible parts of flower may vary from flower to flower. In most of the cases petals are edible, but in some

flower, its pollen, nectar and other parts are used for consumption. Edible flowers exhibited nutritional, antioxidant, antimicrobial properties and enhances the human health and also recommend that proper legal legislation has to be done for the marketing the edible flowers (Pensamiento-Niño *et al*., 2024).

2.5.1 Drying

The use of edible flowers has been on rise for its colour stability, phytochemicals and nutritive value. Different preservation and processing methods applied to enhance its shelf life and retain the colour, nutrient content and phytochemicals to ensure its functional properties and application in food products (Barani *et al*., 2022).

Drying is a common method of preservation since ages and drying of edible flowers has been showcased to be most efficient method for preservation through inhibition of spoilage caused by microbes and enzymes. Traditional drying methods such as sun drying, solar drying, and shade drying have been tested for drying of edible flowers. However, with progression and evolving modern method in drying, hot/dehumidified air drying, freeze drying, vacuum drying, microwave drying and hybrid drying (combination of two or more types of drying) were the widely tested drying methods for fruits and vegetables and hybrid drying method could be promising for preservation of edible flowers (Zhao *et al*., 2019). Solar drying, shade drying and vacuum drying of *T. erecta* flower is trailed by found that the nutritional content is increased due to drying but the anti-oxidant activity and total phenol content decreased. However, among all these methods, vacuum drying is adjudged to be superior due to higher retention of β-carotene. *T. erecta* exhibited maximum retention of carotenoids and phenolic compounds after infrared drying (Purohit *et al*., 2021).

Processing of flowers after harvesting could retain the aroma, nutritional content and its volatile compounds. Various drying methods were applied to process the edible flowers including shade dried for a week, sun dried and oven dried for 72 hours, microwave dried for 5 minutes showed that shade dried flowers exhibited better colour retention, appearance and chemical compounds (Chetia *et al*., 2025; Abbas *et al*., 2021). Different drying methods such as sun, shade and oven drying showed an effect on phenolic content, flavonoid content, and its volatile and bioactive compounds (Salamatullah *et al*., 2024).

2.5.2 Toxicological effect of Edible Flowers

The safety concern towards the consumption of edible flowers should be focused as few flowers may poses food allergies and all the flowers are not consumable. Therefore, the need to identify the suitability of edible flower is gaining attention. Few researchers have found that the flowers purchased from gardens, florists or nurseries are not recommended to consume or garnish due to the pesticide or other harmful toxins sprayed to prolong its shelf life. Some edible flowers may also be collected from wild forests for its medicinal properties which should be checked for its originality or authenticity. It may cause asthma, hay fever, or allergies while consuming the unauthorized edible flowers (Guine *et al*., 2021). It may also exhibit contaminants or other harmful compounds when harvested from poorly maintained farms including hazardous bacteria and chemical compounds from the fertilizers or pesticides used (Matyjaszczyk & Smiechowska, 2019).

Edible flowers also exhibited a minimal quantity of antinutritional factors including trypsin inhibitors, hemagglutinating activity. Few flowers also exhibited toxic substances including alkaloids, cyanogenic glucosides, oxalic acid, terpenes and erucic acid that interfere the metabolism and absorption of nutrients. Many flowers may have the similar colour and other physical properties and identifying edible and toxic flowers was crucial. The edible flowers should not be considered as medicinal plant in treating a disease even though it possesses many health benefits and potential functional properties without proper guidance (Jadhav *et al*., 2023).

Edible flowers consumption has increased due to its many health beneficial applications. But there is an increasing cause for the flowers being contaminated and affected. Researchers also found that storing the fresh edible flower at refrigerator condition (4ºC) increased the shelf life upto seven days as the cold temperature inhibit the and due to its anti-microbial property. Different processing techniques including ozone dryer has improved the antimicrobial property. Proper hygienic practices during harvesting and packaging should be ensured to avoid further microbial load. Researchers also found that organic edible flowers showed high microbial count as compared to its conventional flowers which might be due to the usage of organic manure during cultivation. The researcher also studied the belief and awareness of consuming edible flowers among adults and found that many people had confusion in differentiating edible and non-edible flowers and also suggested that proper labelling could avoid such confusion. Labelling should also contain the details of herbicides, fertilizers, or pesticides used and also

recommend that the flowers should be fresh, organic and free of pesticides or preservatives (Carboni *et al*., 2025).

2.5.3 Selected Edible Flowers – A Functional Enhancer

2.5.3.1 Moringa (*Moringa Oleifera* Lam.)

Moringa (Mo*ringa oleifera* Lam.) is the magic tree found indigenous to northern parts of India but also located in other tropical and subtropical places. Traditional medicine has found the use of Moringa leaves, flowers, seeds, and roots for centuries. It is native to the sub-Himalayan region in the north of India, Pakistan, Africa, Asia Minor, and Arabia and has been introduced in other parts of the world. Moringaceae, which includes 13 species distributed throughout the world and moringa is the only genus present in the monotypic family. It is found native to the range from Angola to Namibia and Egypt to Kenya, Madagascar, the Indian subcontinent, and Arabian Peninsula. In the Indian subcontinent, it is found in the range from Pakistan to India. Due to its economic and medicinal properties, it has been introduced to most parts of the world for cultivation purposes. Most of the species of *Moringa* were restricted in distribution and with very little information. They were represented by herbaceous plants to the huge tree as a life form. Only three species that were widely cultivated were *Moringa oleifera*, *M. Stenopetala*, and *M. peregrina.*

Flowers were present in large terminal or axillary panicles. Calyx consists of five gamosepalous, cup-shaped, unequal five five-lobed segments, petaloid, linear-lanceolate, 10.12 mm long, reflexed. It also consists of five petals, spatulate, unequal, 10–15 mm long, creamy white, with five stamens. Moringa flowers, along with fruits, leaves, and seeds, contain bioactive pigments such as chlorophyll, anthocyanins, carotenoids, and lycopene, which are derivatives of fats and flavonoids. These compounds, including alkaloids, flavonoids, flavanols, phenols, polyphenols, and anthocyanins, exhibit potent antioxidant properties that help reduce the risk of chronic diseases such as cancer. The rich phytochemical composition of moringa flowers and other plant materials offers significant health benefits, capturing the interest of botanists, pharmacists, and food industrialists for their potential in promoting human health and wellness (Patil *et al*., 2022). It is one of the various medicinal plants that can be used both as a functional food and as a natural food additive. Moringa has been used for centuries, with reference to its use in more than 80 countries, and researches about its nutritional values have been carried out since 1970. In 1998, the World Health Organization (WHO) promoted this plant as an alternative

supplement to treat malnutrition. Countless benefits were assigned to this plant, such as antioxidant activity, hepatoprotective, anti-inflammatory and antihypertensive properties. It is also associated with hyperglycemia decreasing, showing an antidiabetic effect. Hence, the plant is called "Miraculous Tree" and "Tree of Life" and is also recognized for the beneficial effects on water sanitation (Hodas *et al*., 2021).

Moringa is used to treat various diseases, like skin infections, swelling, anaemia, asthma, bronchitis, diarrhoea, headache, joint pain, rheumatism, gout, diarrhoea, heart problems, fevers, digestive disorders, wounds, diabetes, conjunctivitis, haemorrhoids, goitre, earache, measles and smallpox in the indigenous system of medicine. Immature pods and flowers exhibited higher content of total monounsaturated fatty acids (MUFA, 16–30%) and were low in PUFA (34–47%), when compared to leaves. In other edible parts of moringa, more than 102 bioactive compounds have been identified in the root, while 74 essential oils have been identified in the flowers. Glucosinolates are also predominant in stems, flowers and pods of moringa. It contains antioxidants called flavonoids, polyphenols and ascorbic acid in the leaves, flowers and seeds. It plays an important role in protecting the liver from damage, oxidation and toxicity due to the high concentrations of polyphenols, especially quercetin, in its leaves and flowers (Milla *et al*., 2021).

2.5.3 Agathi (*Sesbania grandiflora* (L.) Poir.)

Agathi **(***Sesbania grandiflora* (L.) Poir.) is a popular Myanmar medicinal plant which belongs to the family Leguminosae. It is a small, erect, fast-growing and sparsely branched tree that reaches 15 m in height. Agathi species have pinnately compound leaves, where each leaf is divided into multiple leaflets. The leaves can be up to 30 cm long with 5-15 paired leaflets that are oblong to elliptic in shape and about 3 cm in length. Two varieties of agathi flowers were recognized, namely, red flower variety and white flower variety and were large and 7-9 cm long.

The bioactive chemical constituents were leucocyanidin and cyanidin present in agathi seeds, whereas Oleanolic acid and its methyl ester and kaempferol-3-rutinoside were present in flowers. The bark contains tannins and gum and saponin and sesbanimide were observed in seeds. All parts of agathi were used for medicine and as a vegetable in Southern Asia and India. In Folk Medicine, it is reported to be aperient, diuretic, emetic, emmenagogue, febrifuge, laxative, and tonic. It is also used for the treatment of bruises, catarrh, dysentery, fevers, headaches, smallpox, sores, sore throat, and stomatitis. It also possesses anxiolytic, anticonvulsive and hepatoprotective properties (Baessa *et al.,* 2019;

Tun *et al*., 2021). Phenolic acids (syringic, salicylic, and chlorogenic acids), present in agathi flowers, inhibit AChE and BuChE enzymes, thereby supporting nerve health by preventing acetylcholine degradation and aids in reducing oedema and inflammation. The presence of bioactive compounds (oleanolic acid, its methyl ester, and kaempferol-3-rutinoside) poses high medicinal properties (Prabawati *et al*., 2021; Tun *et al*., 2021).

2.5.4 Hibiscus (*Hibiscus rosa-sinensis* L.)

Hibiscus (*Hibiscus rosa-sinensis* L.), known for its vibrant color and tangy flavor, provides therapeutic benefits, including antioxidant, antibacterial, lipid-modulating, and insulin resistance-reducing effects. It contains phenolic acids, flavonoids, organic acids, lutein, tannins, and various anthocyanins. These compounds enhance their antioxidant, anti-inflammatory, anti-cancer, anti-aging, antimicrobial, hepatoprotective, and neurogenic properties (Dos Santos Silva *et al.,* 2023; Vasic *et al.,* 2023; Shelke *et al.,* 2021). Red five-petal hibiscus flowers (*Hibiscus rosa-sinensis*) were harvested at peak bloom. It has five petals, each 6–8 cm long and 4–6 cm wide, varying by type. The calyx is green, cup-like, and has lobes, with an additional outer layer of 5–10 narrow bracts (epicalyx). The stamens were joined together to form a long column with yellow tips. The flowers were trumpet-shaped, brightly colored, and have a prominent central style.

2.5.5 Rose (*Rosa damascena* Herrm.)

Rose (*Rosa damascena* Herrm.), is widely recognized in traditional and modern medicine for its essential oils, which offer antioxidant, antibacterial, antimicrobial, and anti-inflammatory benefits, aiding in conditions like menstrual bleeding, inflammatory bowel disease (IBD), and gastroesophageal reflux. Rose contains flavonoids (quercetin, kaempferol, apigenin), flavan-3-ols (catechin), anthocyanins, proanthocyanidins (procyanidin), phenolic acids (gallic and ellagic acid), and stilbenes like resveratrol (Trendafilova *et al.,* 2023; Hegde *et al.,* 2022; Akram *et al.,* 2020). Pink damask rose petals (*Rosa damascena*) were harvested at full bloom for its optimal nutritional and aromatic properties. The petals of damask rose were broad and oval or reverse-oval in shape, typically 3–5 cm long and 2–4 cm wide. The flower has five green, lance-shaped sepals that curve backward, forming a persistent calyx. The stamens were numerous and arranged in a circle, with yellow or reddish tips. The petals were soft, thin, and fragrant, commonly used in cooking and traditional medicines.

2.6 MILLET AND EDIBLE FLOWER-BASED PRODUCTS

The demand for healthy foods with functional compounds has increased over the past few years and resulted in many product innovations where fruits, vegetables, and edible flowers have been included in the developed food products. Flowers were part of the traditional cooking practices for the past thousand years. The medicinal values and its impacts on health is mentioned in Vedas and traditional knowledge and in recent years, modern science is also taking significant interest to explore the potential of edible flowers. Due to its superior nutritional and bioactive compounds along with enhancing the flavour and aroma, edible flowers could be an ideal choice in various products.

Edible flowers were used in traditional dishes globally for its health benefits and also to enhance the flavour of the food products. In ancient Rome, roses were used in the preparation of puree and omelette whereas in Mexico, hibiscus is utilized in preparing drinks **(**Chetia *et al*., 2025). Edible flowers were mostly used as culinary ingredients in food because of their powerful and unique flavours, soft textures and bright colours. Edible flowers were also used as salads, and to make beverages such as tisanes and wines. In addition, flower extracts were also introduced as aroma or flavour enhancer (Purohit *et al*., 2021). The edible flowers and its extracts were utilized in the production of spreads such as butter or fruit preserves, vinegar, marinades, and dressings. It is not only used in the culinary preparation but also possess immense potential to be a source of value-added products. Similarly, comparison of bioactive compounds and sensory evaluation of edible flower infused tea is done by Hussin *et al*. (2019) where the three common edible flowers namely, France rose buds, jasmine flower and osmanthus flower from Malaysian market were taken and found that the osmanthus flower exhibited high caffeine and polyphenolic content when compared with other two flowers. In a survey conducted by Matyjaszczyk & Smiechowska (2019) which focused on advantages and risk pertaining to edible flower and its consumption, showed a positive attitude among consumers associated with food products containing flowers with “health benefits”; whereas, yoghurt with flowers is considered as an innovative product. Several products that were incorporated with edible flower such as jam, jellies, sauce, vinegars, liquors, honey were also reported as an innovative formulations. It is also used for making tea, ice cubes, salads, candies and several beverages (Purohit *et al*., 2021).

Edible flowers with modern processing interventions have the potential for value added product development as its shelf life has increased. Commercialization of value-

added edible flower products was far away due to lack of scientific reports. Among the tested preservation methods, novel drying methods and innovative packaging methods could be the game-changer in promoting edible flowers for commercial practices. Moreover, there is a need to bring in strategic regulation to ensure safe use of edible flowers. There is a huge potential of using flowers in food. It will not only help the present but also be a potential food for future generations (Purohit *et al*., 2021).

In cookies and biscuits production, antioxidants and anti-browning additives were normally used as the preservatives for shelf life of products and intake of artificial additives could possibly be toxic effects (Dey & Nagababu, 2022). Therefore, the natural antioxidant compounds such as total phenolic and total anthocyanin compounds were gaining attention in the food industry due to its health benefits, including anti-inflammatory activity, antioxidant activity on human low-density lipoproteins, eye function, and protection from cancer and cardiovascular diseases (Bharathy & Thanikachalam, 2024).

Edible flowers were high sources of natural antioxidant compounds, including total phenolics and total anthocyanins. Furthermore, edible flowers were nontoxic flowers and offer positive health effects, when consumed as human diet. Compared with common fruits and vegetables, edible flowers had very high antioxidant properties due to their high phenolics and anthocyanins compounds. Among edible flowers, the rose is one of the popular edible flowers, which has been used as a food additive in many food products such as tea, jam, jelly, wine, juice, and snacks because of their positive health effects, such as antidepressant and anti-inflammatory activities and so on. It seems that cookies with rose flower powder (RFP) can fill a demand for now health-conscious consumers who were looking for healthier foods (Zhang *et al*., 2023).

Among millets, sorghum and pearl millet were superior grain as compared to several cereals including rice and wheat. Sorghum and pearl millet exhibit higher levels of protein, dietary fibre, vitamins and minerals like iron, zinc and phytochemicals. The health benefits of millets aids in formulating beverages, bakery items and diet foods. Sewak *et al*. (2023) found that, germinated pearl millet is suitable for porridge and salad preparation whereas, puffed sorghum were suitable in bread preparation. Pearl millet and sorghum exhibited slowly digestible and resistant starch and high gelatinization temperature. Food products developed from raw sorghum and pearl millet can reduce the acceptability due to its flavour and conventional processing techniques like roasting, puffing, soaking and

germination should be applied to increase the consumer acceptability and nutritional value.

Selladurai *et al*. (2023) found that, the market demand of gluten-free products is increasing and millets have become the major constituent and remains as the staple food. Gluten-free ready-to-eat products can be done through processing of millets and it also helps in shelf-life extension. Processing of millets aids in producing different varieties of products that expand the market to non-traditional millet consumers. Utilization of millets in making flat bread, roti, beverages, ice creams, fermented foods (dosa, idli, injera, masa which is popular in India, Africa and China), porridges were the conventional food products. Non-conventional millet products were also increasing including, flakes, baked products (cakes, khatai, muffins and rusk), extruded products (macaroni, spaghetti). The market demand for millet showed a increasing trend due to the awareness, and its high nutritional profile.

Meena *et al*. (2024), stated that the demand for millet-based products has increased and the major millet production were utilized by fast-moving consumer goods companies and utilized in the production of baked products, extruded snacks, flakes, puffs, confectionery, snacks and ready-to-cook foods. Traditional and modern processing enhances its shelf life and the properties of millets including water and oil absorption properties enhances the palatability, retain flavour with stabilising and emulsifying capacity in bakery products, puddings and confectioneries.

Millet like pearl millet and sorghum has been consumed as a staple food in different forms. Processing techniques has increased the consumption rate and the shelf life of the products. The present study focused on utilizing pearl millet and sorghum in formulating and standardising millet edible tableware is the novel idea and a sustainable solution to replace single-use plastic cutleries in food service sector. The nutritional and function properties of the pearl millet and sorghum tableware are further enhanced by convention processing and by adding shade dried edible flower powder. Due to the biodegradable property, it eliminates the waste disposal system and paves way to achieve Sustainable Development Goals.