DEVELOPMENT AND EVALUATION OF ANTIOXIDANT ENRICHED EDIBLE CUTLERY

A THESIS SUBMITTED IN PARTIAL FULFILMENT OF THE

DEGREE OF MASTER OF PHILOSOPHY (M.Phil)

IN

FOOD SCIENCE AND NUTRITION

by

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July 2019

CERTIFICATE

I certify that the dissertation entitled "**Development and Evaluation of Antioxidant Enriched Edible Cutlery**" submitted for the **Degree of Master of Philosophy (M.Phil)** by AT. Agilandeswari is the record of research work carried out by her during the period from 2018-2019 under my guidance and supervision and that this work has not formed the basis for the award of any Degree, Diploma, Associateship, Fellowship or other Title in this University or any other University or Institution of Higher Learning.

31/7/19

Signature of Head of the Department

31/7/19

Assistant Professor

Signature of Supervisor

with Designation

DECLARATION

I declare that the dissertation entitled "**Development and Evaluation of Antioxidant Enriched Edible Cutlery**" submitted by me for the **Degree of Master of Philosophy (M.Phil)** is the record of research work carried out by me during the period from 2018-2019 under the guidance of **Dr. R. Balasasirekha**, Assistant Professor, Department of Food Science and Nutrition, Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore and not formed the basis for the award of any Degree, Diploma, Associateship, Fellowship or other Title in this University or any other University or other similar institution of Higher Learning.

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Signature of the Candidate

ACKNOWLEDGEMENT

The investigator places her deep thanks and gratitude to **GOD ALMIGHTY** for showering his blessings her as she could carry out the research work successfully.

The investigator records her sincere thanks to her sincere thanks to **Dr. (Thiru). P.R. Krishnakumar**, Chancellor, Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore, for providing the infrastructural facilities to conduct the study.

The investigator wishes to express her profound gratitude to **Dr. (Mrs). Premavathy Vijayan**, Vice Chancellor, Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore, for being a constant source of guidance during the course of the study.

The investigator extends her sincere thanks to **Dr.(Mrs).S. Kowsalya**, Registrar, Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore, for extending all possible help for the smooth conduct of the study.

The investigator gratefully acknowledges her heartfelt thanks to **Dr. (Mrs). N. Vasugi**, Dean, Faculty of Home Science, Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore, for her concern and guidance rendered during the course of the study.

The investigator expresses her special thanks and sincere gratitude to **Dr. (Mrs.) A.Thirumani Devi,** Professor and Head, Department of Food Science and Nutrition, Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore for the valuable help, concern and encouragement which helped to complete the study.

The investigator is deeply indebted and gives her immense pleasure and proudness to offer gratitude to her guide **Dr. (Mrs). R. Balasasirekha**, Assistant Professor, Department of Food Science and Nutrition, Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore for her concern and encouragement which helped to complete the study and stimulating support, constructive suggestions,

inspiring guidance and encouragement throughout the research period and for documenting the thesis.

The researcher owes her sincere thanks to all the **Faculty Members** of the Department of Food Science and Nutrition, Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore for being supportive and understanding.

Finally, the investigator owes her profound gratefulness to her father **Mr. AR. Athinamilaki** and her mother **Mrs. AT. Swarnambigai** and brother **Master. AT. Arunachalam** for providing unfailing support and continuous encouragement throughout the period of study and through the process of researching and writing this thesis. The accomplishment of the study is not possible without them.

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1. INTRODUCTION

Food packaging is the material that acts as a shield to protect the food materials from external factors and barriers that harm them. Besides, they also possess the capacity to prevent unfavorable factors such as chemical contaminants, spoilage microorganisms, moisture, oxygen, light, external force, etc harming them. It acts as a barrier against permeation of water vapour, oxygen, carbon dioxide and other volatile compounds (Mohanty and Swain, 2017). They additionally possess traceability, suitableness, and tamper indication along with mechanical, thermal, and optical properties. The goal of food packaging is to comprise food in a very efficient approach that satisfies business necessities and client wishes, maintain food safety and minimize environmental impact (Robertson, 2005).

Usage of packages like polythene and different plastic packaging material do not seem to be properly disposed and it ends up in warming, affecting the fertility of the soil and marine life. It leads to ecological imbalance and affects the food quality *i.e.* packaging of hot food merchandise in plastic packages, act with the food and ends up in malignant neoplastic diseases (Siracusa *et al.,* 2008). These additionally leads to health problems like cancer and affects the gut microbiota. Thus, perishable packaging materials existing in current trend act as a substitute of non- perishable packages. So, to tackle and notice resolution for these problems, food engineering emphases on formulating the alternatives to disposable plastic utensils (Marsh and Bugusu, 2007).

Edible packaging has taken a rebirth within the past twenty years with the utilization of coatings and films in food applications. Interest in edible packaging for food applications has been growing in recent years; thanks to customers insisting for higher-quality and safe foods with extended shelf lives and additionally their aspiration for natural and perishable materials as a replacement for artificial and non-biodegradable materials. The utilization of edible, perishable, expandable and renewable materials to interchange (partially or totally) plastic packaging materials has increased the interest of the world market place for edible packaging solutions (Miller and Krochta, 1997).

Edible packaging is only one part of the global bio-based packaging substantial option; it is predicted that the global bioplastic packaging demand may reach to 884,000 tons by 2020, the compounds' annual growth rate being 24.9% from 2010 to 2015 and 18.3% from 2015 to 2020. In 2010, the group of water-soluble polymers and starch- and cellulose based bioplastics represented 44.3% of the market. According to Pira (2013), the bioplastics change from biodegradable and compostable polymers to bio-based packaging from renewable and sustainable materials.

Global Edible Packaging Market was valued at $697 million in 2016, and is projected to achieve $1,097 million by 2023, growing at a Compound Annual Growth rate (CAGR) of 6.81% from 2017 to 2023. The Economic times, 2018 has estimated that Indian packaging industry has registered a vigorous growth of 15 % CAGR in the last five years and is estimated to achieve $32 billion annual turnover by 2025. Edible packaging has witnessed exaggerated adoption due to factors like high consumption of processed food product, rise in hygiene issues among individuals, and increase in packaging waste by the usage of artificial polymers thereby touching the setting, that boost the edible packaging market growth (Kritika,2017).

Edible coatings and films are a good attempt to increase the storability of foods, controlling gas exchange, moisture, solute migration, and oxidative reaction. In addition to these gains, edible coating/films can be used as carriers of bioactive compounds to improve the quality and enhance the nutritional value of food products, such as antimicrobials, antioxidants, flavors, probiotics, and other components, such as nutraceuticals and basic nutrients. Therefore, these approaches, in addition to being used to prolong shelf life, also provide functionality to food products (Malathi *et al.,* 2014).

Functional compounds are incorporated into the edible coating/film to perform their functions so they become benefit for food as well as for consumers. Advances in this area imply that diet and/or its components should contribute to reduce the risk of diseases, thus improving well-being and quality of life. These new concepts have led to the introduction of a new category of health-promoting foods or functional foods.

Despite the great number of research works and products already available in the market, the use of edible packaging to guarantee the quality and safety of food products is still under development and investment is still needed. Edible cutlery without any doubt is one of the emergent technologies that meets consumer demands for sustainability, use of biodegradable materials, and replacement of synthetic additives by natural compounds. The use of new materials, their modification to enhance their properties, evaluation of their combination with other processing and conservation techniques, as well as their use as biodegradable packaging also as supplementations are some of the trends of edible packaging that are expected to increase their possible applications and, consequently, commercial interest in the near future (Stollman *et al.,* 1994).

New approaches to enhance transport, mechanical, and thermal properties, as well as to address the control of moisture in edible packaging are needed, despite the great number of studies regarding these topics, success cases are limited. Chemical structure modification (e.g., creation of hydrophobic groups) and the interaction between molecules of different materials (e.g., protein–polysaccharide blends, nanocomposite incorporation, and cross-linking) are some of the methodologies used to obtain edible packaging materials with enhanced properties ; nevertheless, in these cases, the edibility of the corresponding packaging materials has not always been guaranteed (Yam and Lee, 2012) .

Today a great number of methods are used in the processing and preservation of food products. As like packaging, plastic plays a major role in usage among the common people which are non-biodegradable and usage of plastics leads to many diseases such as cancer, etc. so as to prevent or minimize the usage of plastic utensils an alternate way of production of cutlery are adopted in the recent years. Biodegradable and edible cutlery which were formulated with either biodegradable materials or edible materials can be consumed as such after consuming the food. This reduces the plastic usage and also supports agriculture on the production of millets and cereals (Narayan, 2015).

These cutlery are cost effective and also are formulated with different flavours and further on. These cutlery also act as a carrier of numerous nutrients in the most acceptable way. These products can be formulated with nutritional benefits and this product also will bring a revolution in the agricultural and modern medical field as various nutrients and functional components can be incorporated into these cutlery and also can be used as an attractive supplement.

However, the still underperforming properties (when compared with petroleum-based synthetic materials), the adaptation of processing devices, and the cost of the materials used are some of the problems faced in the development of biodegradable and edible cutlery. One of the potential applications of edible cutlery is their use as vehicles for bioactive and functional compounds (active and smart packaging), and the release of such compounds can be controlled by the materials used in the production. Besides the diffusion control of bioactive compounds into the matrix the incorporation of antifungals, vitamins and antioxidants, respectively, will increase the potential applications of formulation active and smart edible cutlery.

The future of edible cutlery materials is promising, and their use for very specific applications is already viewed as an innovative solution close to commercial and consumer market. Still open is their use to replace synthetic non-biodegradable materials, enhancement of their nutritional benefits where great effort is needed regarding the investment in research, customized machineries which can turn the global use of anti-oxidants enriched edible cutlery into a reality during the next decade.

Nowadays, innovations constantly appear in food packaging, which lead to a demand for new foods, always aiming at creating a more efficient quality preservation and ecofriendly system. The bioactive compounds play a major in promotion of health and it is very important for the normal functioning of the body. Anti-oxidants have numerous functional properties and also consist of specific health benefits beyond the normal nutritional content. They are used in formulation of nutraceuticals and drugs to treat several medical conditions. These cutlery can also be used as replacement for nutraceuticals and the rate of acceptability will be more as it acts as a new solution to treat/ prevent the cause of medical condition in an attractive way.

Reactive Oxygen Species (ROS) are made by living organisms as a result of traditional cellular metabolism. At low to moderate concentration, they perform in physiological cell processes, however at higher concentrations, they turn out adverse modification to cell part like lipids, proteins and DNA polymer. The shift in balance between oxidants / antioxidants in favour of oxidants is termed as oxidative (aerophilic) stress. It ends up in several severe physiological conditions which is able to scale back the generation of conditions like cancer, neurological disorders, coronary artery disease, cardiovascular disease, ischemia / insertion, diabetes, acute respiratory disorder syndrome, idiopathic pulmonary fibrosis, chronic obstructive pulmonary disease, asthma, etc. Antioxidants, bioactive compounds, phytochemicals and phenolic components facilitate to scale back the aerophilic stress to keep up healthy body (Hegde *et al.,* 2005).

Being a primary binding agent, millets and cereals makes best pair on forming a structure and promotes strong outlook for a product. They have less penetration which will improve the stability and rigidity of the product and also provides extended shelf life. As they are non-perishable product the rate of microbial growth will be very less and the nutritional value remains the same for a long period of time. It adds the texture, aroma and acceptability for the consumer with more functional benefits. It also has ability to hold the nutrients and trap the properties and enhance the quality of the product. So, incorporating anti-oxidants in the products made out of millets and cereals may be trapped and help promote maximum utilization in the body and to overcome the medical conditions (Yam and Lee, 2012).

Millets are the tiny seeded crops which can be used as a replacement of cereals. They are more nourishing and contributes with various micronutrient content. Pearl millet (*Pennisetum glaucum*), finger millet (*Eleusine coracana*), foxtail millet (*Setaria italica*), little millet (Panicum sumatrence), barnyard millet (*Echinochloa esculenta*) and sorghum (*Sorghum bicolor*) are in use for ages (Devi et al., 2014). They are gluten-free, loaded with macromolecule and fiber, rich in vitamins, calcium, iron, magnesium, and zinc. With more health advantages like decreased risk of polygenic disorder and cardiovascular diseases, it is an exclusive food for polygenic disorder. It also promotes

heart health as it consists various elements like magnesium and potassium, thus reducing the risk of cardiovascular to an outsized extent (Rao *et al.,* 2006).

Millets helps in reducing steroid alcohol levels, improves the health of gut microbiota, reduces the danger of cancer by reducing the oxidative stress, helps in detoxication and improves the immune functions of the body. Reduces the danger of polygenic disorder in non-diabetic individuals and helps regulate the blood glucose levels due to its low glycemic index. Millets contains large quantities of phenolics and other compounds of use in human foods to prevent deterioration of health. It additionally reduces the endocrine resistance within the body and assist in reaching the target post nutrition glucose level (Saleh *et al.*, 2013).

In plants, several phytochemical constituents with different and specific modes of action, have antioxidants like saponins which aids in immunosuppression and helps to reduce the oxidative stress. Several studies reveal that the involvement of free radicals in the pathogenesis and complications of oxidative stress as radicals are able to damage cell proteins, lipids and DNA which alter the cell function. Millets promotes anti-inflammatory effect and anti-oxidant activity by inhibiting the enzymes which are involved in eicosanoid production as they are rich in polyphenols (Rahmat *et al.,* 2006).

Processing of millet - based products potentially represents a rich source of phenolic compounds and dietary fibre, which has numerous potential nutraceutical resources. They are available in the cheaper cost and easily accessible. The utilization of the bioactive components in millets and plants may aid in improvement of yield and demand for traditional products. It will be efficient, inexpensive and environment friendly platform for the production of novel nutraceuticals or for the improvement of older ones in the new means of techniques (Hegde *et al.*, 2005)

Fruits do possess the oxidative stress reducing properties and play a vital role in fortification and improving the quality of the food product. Some of the cheap nutrient rich fruits are ultimate source of trace nutrients with high bio-availability. These include fruits like guava, pear, oranges, strawberry, goji berry, blueberry, mangoes, raspberry and banana, which has ample antioxidants, phytochemicals, phenolic components with numerous health benefits.

Guava (*Psydium gujava*) contain four times the vitamin C content present in oranges which helps in improving the immunity, keeps the body healthy and protects it from pathogens that cause infections. Magnesium present in guava helps in relaxing the nerves and muscles. It also contains vitamin B3 (niacin), vitamin B6 (pyridoxine) and helps in improving blood circulation to the brain and relaxing the nerves. It is rich in vitamin C, A and antioxidants like lycopene and carotene that protects the skin from wrinkles and fine lines by reducing the oxidative stress (Mondal *et al.*, 2009).

Banana (*Musa paradisiaca*) is the superior fruit that is commonly consumed by all people. They are rich in dietary fibre, calcium, magnesium, folate, iron, potassium, manganese, vitamins B6, riboflavin, polyphenols, etc.100 g of raw banana constitutes 0.3 g of total fat, 1 mg of sodium, about 360 mg of potassium, 2.6 g of dietary fibre, 12 g of sugars and 1.1 g of proteins (Jones, 2019). It aids in reducing oxidative stress by lipid peroxidation, enhances the resistance to oxidative modification of LDL as it is important in atherogenesis. It also protects neuron cells against oxidative stress-induced neurotoxicity and is beneficial to ameliorate chemo preventive effects which plays an important role in reducing the risk of neurodegenerative disorders such as Alzheimer's disease (Heo *et al.*, 2008). Antioxidants and pro anthocyanidin in banana could minimize the postprandial increase of lipid hydroperoxides in plasma and then in LDL by protecting against the buildup of new peroxides in the digestive tract and/or by contributing to the plasma antioxidant capacity. The consumption of banana reduces the plasma oxidative stress and enhances the resistance to oxidative modification of LDL (Yin *et al.,* 2008).

To overcome oxidative stress, new and novel merchandising edible cutlery enriched with antioxidant rich fruit powder is formulated with millets and cereals as the primary ingredients. Antioxidant rich edible cutlery are multipurpose and act as a most acceptable supplement for all age groups particularly for old age. They help to reduce the free radicals in the body and the risk of oxidative stress in the individuals.

Hence these components can be used in the formulation of edible cutlery. Millets suits for the formulation of edible cutlery as it provides more nutritional benefit, enhanced quality, physical properties, sensory characteristics and degree of

acceptability, suitable for all age groups and for consumption of all types of food. Millets along with fruits provide bioactive components, improves the antioxidant capacity, maintains the reactive oxygen species level and reduces oxidative stress. It acts as an active supplement to the individuals as well as is multipurpose.

With the above gridlock the present study on "**Development and Evaluation of Antioxidant Enriched Edible Cutlery**" was undertaken by the investigator with the following objectives:

- Formulation and standardization of edible cutlery rich in antioxidants
- Carry out sensory evaluation of the developed antioxidant rich edible cutlery and identification of the most acceptable variable
- Analyze the physicochemical properties for the most accepted variation of edible cutlery
- Assessment of total antioxidant capacity and ferric reducing antioxidant power of the most accepted variation of edible cutlery
- Analyze the nutrients and phytochemicals present in the most accepted edible cutlery
- Carry out shelf life studies of the product

2. REVIEW OF LITERATURE

The Review of Literature pertaining to the study "**Development and Evaluation of Antioxidant Enriched Edible Cutlery**" is discussed under the following topics:

2.1 Edible packaging

2.1.1 Social, commercial and scientific interest of edible packaging

2.1.2 Designer / Edible packaging- Edible coating and spraying- A key to promote product quality.

2.1.3 Protein as a base for edible packaging and technique- bio fortification

2.2 Edible cutlery- A vehicle for bio active functional components

2.2.1 Millets- The base in edible cutlery formulation

2.2.2 Millets -The power house of micronutrients and bioactive components

2.3 Oxidative stress- A threat for future generation

2.3.1 Antioxidant potential of fruits

2.3.2 Recent progress for the utilization of antioxidants against oxidative stress

2.4 Guava and Banana- The key to reduce oxidative stress

2.1 Edible packaging

Edible packaging has taken a rebirth in the past 20 years with the use of coatings and films in food applications. The growing interest in this technology is enlightened and aspects such as consumers and environmental needs, commercial interest, and new scientific findings are presented as the promoters of the recent development of edible packaging (Robertson, 2005). Packaging has been defined as a socio scientific discipline that operates in society to ensure the delivery of goods to the consumer in the best condition intended for their use. In particular case of foods, a package can be used for a great number of applications where the main goals are to serve as a container for the protection and preservation of a perishable product and as a way of communication with the consumer (Bigliardi and Galati, 2013).

According to Zepf (2009) a package is defined as "a metal can, glass bottle, plastic bag, or pouch which serves the functions of containing and protecting the product, as well as providing convenience and communicating to the consumer." Edible

packaging can be included in the presented packaging definition; however, in this case, all the materials used should be edible according to the legislation, both in the initial (packaging ingredients) and in the final (packaging) forms. Two types of edible packaging are usually described: coatings and films. It is considered a coating, when the film-forming solution is applied directly on the food product (by immersion, spray, brushing, or other) and is left to dry on the food surface to form a thin film, which will perform the desired function. A film is the dried film-forming solution that is used and applied as a self-standing material on the food product. For the past several years, public attention has gone on natural fibers as a resource due to the fast growth.

Nowadays, natural fibres are widely used as reinforcements both in partially and totally biodegradable natural fiber composites. Natural fibers are an alternative resource to synthetic fibres as reinforcement for polymeric materials for the manufacture of cheap, renewable and environmentally friendly composites. Waste plastic has caused unbearable stress to environment in recent years. Environmental awareness, new rules and legislations are forcing industries to seek new materials which are more environmentally friendly. Plant fibers from agricultural crops are renewable materials which have potential for creating green products and replacing synthetic materials which are currently being used such as glass fiber, carbon fiber and plastic fibers. The combinations of bio-fiber and bio-polymer could be the products of fully biodegradable composites (Cerqueira and Miquel*,* 2009).

The banana and guava lectins recognize internal α 1,3 - linked glucosyl residues, which occur in the linear polysaccharides elsinan and nigeran (Coutino *et al.,* 2001). Concanavalin A and lectins from pea and lentil, also mannose/glucose binding lectins, did not precipitate with any of these linear α- glucans. The authors believe, the first report of the recognition of internal α 1,3-glucosidic bonds by a plant lectin. It is possible that these lectins are present in the pulp of their respective fruit, complexed with starch (Mo *et al.,* 2001).

As fruits and millets possess binding properties they can be used in the formulation of edible cutlery. These materials possess stability to retain the rigid

structure of the product with more nutritional benefits. They also lock the nutritional content and they cannot be exploited easily by external barriers. As they are biodegradable, if they are consumed, they act as add on to promote nutritional profile of the individual otherwise if they are disposed, they can be decomposed and nourishes the soil fertility. Thus, they act as great alternative/ replacement for the other materials of cutlery.

2.1.1 Social, commercial and scientific interest of edible packaging

One of the evidences regarding the use of edible packaging is the number of registered inventions related to this topic, where edible coatings and films are distinguished based on their possible innovative applications.

Today, most of the inventions submitted regarding edible coatings are related to their application in fresh-cut fruits. Fruit symbiose Inc. submitted an invention for the preservation of at least one organoleptic property of fruits and vegetables, in which the coating composition comprises a polysaccharide solution (Girard, 2013).

Inventions regarding edible films for food applications appeared much later when compared with edible coatings, the first one being from 1990s. This invention used polysaccharides and proteins as main materials, with the possibility of using plasticizers and lipids during the production. In the last 5 years, several inventions appeared dealing with new film. From these inventions and other research studies, several companies actually present edible coatings in their products. It is clear that the eco-friendly label of this kind of packaging and potential applications for several food products leads to a growing interest by the industry for the development of new solutions (Zepf, 2009).

From scientific point of view, the use of bio-based materials for the production of edible coatings and films integrates the knowledge and contributions of a significant number of scientific areas (e.g., polymer, chemistry, food science, and biology) (Girard, 2013). Besides the potential application in food and pharmaceutical industries (proved by a great number of publications and patents), the great interest of these systems regarding more in-depth scientific works is due to the following aspects:

- Different materials used such as polysaccharides, proteins, lipids, and waxes, and the interaction between these and other materials used in their production (e.g., plasticizers and surfactants).
- Processing techniques and different techniques of application.
- Transport, thermal and mechanical properties, influenced by the materials used and processing techniques, and also by the external factors (e.g., relative humidity, temperature, gases, moisture, and light).
- Possible use as a vehicle for bioactive and functional compounds.
- Use of nanotechnology for the formation of coatings and multilayers at the nanoscale and the incorporation of nanostructures in films, potentially bringing new and interesting findings.

2.1.2 Designer / Edible packaging- Edible coating and spraying- A key to promote product quality

Designer packaging is normal food packaging fortified with health promoting ingredients and engineered based on the quality and nature of food product. These packaging are similar in appearance to normal forms of packages and are also used regularly as a part of packaging. The benefits of available designer packages are edible packaging and bio-based packaging etc. Packages developed using hurdle technology were enriched with micro and macro nutrients and designer proteins. Designer packages are produced by the process of fortification or nutrification and also based on properties of the product packed. With the advances in the biotechnology, bio fortification of foods using technologies such as recombinant DNA technology and fermentation procedures are gaining advantage in the industry. These technologies play a major role in upcoming packaging industry (Ribeiro , 2016).

The new packaging technology, composed of Food and Drug Administration (FDA) approved edible polymers that have an undetectable taste and smell, is ideal for items we dissolve in water anyway, and there are plenty of these materials in the form of gum polysaccharides. With the versatility and established safety of most gum polymers, novel applications for gum films seem almost limitless. The concept of drug,

vitamin, and mineral delivery films will likely expand and while there are more and more of these novelty film products appearing in stores, other creative concepts are likely to evolve, including cheese, ketchup, or sour cream films, or various spice films that food scientists, product formulators, or chefs could create. The convenience and microbial stability of dried forms of food films are the biggest selling point for developing these products (Bigliardi and Galati, 2013).

Active ingredients, flavors, and colors can be incorporated directly into these recipes before the film is cast. These active ingredients, which can comprise up to 30% of the film by weight, become locked into the film matrix, and must remain stable until product consumption. Examples of actives used in film strips include ingredients for oral hygiene such as mint, alertness such as caffeine, as well as nutrients and botanicals (Sood and Deepshika, 2018).

2.1.3 Protein as a base for edible packaging and techniques- bio fortification

Biofortification is a feasible and cost-effective means of delivering micronutrients to populations that may have limited access to diverse diets and other micronutrient interventions. Fortification refers to "the practice of deliberately increasing the content of an essential micronutrient in food irrespective of whether the nutrients were originally in the food before processing or not, so as to improve the nutritional quality of the food. It can be purely a commercial choice to provide extra nutrients in a food, or sometimes it is a public health policy which aims to reduce number of people with dietary deficiencies in a population. When foods are labeled “fortified” with something that means that an extra amount has been added beyond the amount that was present before it was processed. Purpose of food fortification is to improve nutritional quality of food, reduce nutritional disorders, fortification for body building and medical treatment (Zepf, 2009).

2.2 Edible cutlery- a vehicle for functional components

Food packaging attains transition in each era and it has advanced in all aspects and progressed in the field of food and engineering. They were customized based on

each food products and this leads to demand for new foods, always aiming at creating a more efficient quality enhanced ecofriendly system. Edible coatings and films are a good attempt to increase the storability of foods, control gas exchange, moisture, solutes migration, and oxidative reaction rates. In addition to these gains, edible coatings/ films/ cutlery can be used as carriers of bioactive compounds to improve the quality and enhance the nutritional value of food product, such as antimicrobials, antioxidants, flavors, probiotics, and other components, such as nutraceuticals or basic nutrients. Therefore, these approaches, in addition to being used to prolong shelf life, also provide functionality to food products. When the functional compounds are incorporated into the edible coating/film/cutlery to perform their functions, they became a benefit for food as well as for consumers (Joana and Manuela, 2015).

The baking method plays a vital role in formulation of edible cutlery as it reduces the moisture content of the product and provides rigid structure to the product with extended shelf life (Yam *et al.,* 2012). The edible cutlery can be formulated by fortifying or adding the functional components along with the basic ingredients a sit traps the nutrients and provides bioavailability of the nutrient to the body and also acts as a key to impart nutrients to our body and promotes health (Srivastava *et al.,* 2018)

Furthermore, the functional compounds are protected from the external factors and controlled release is allowed. Bioactive edible coating and film is defined as a protective coating, film applied to the surface of a food and furthermore may possess other benefits, for example, adding high value to food products through the addition of functional compounds such as antioxidants, colors, flavors, nutraceuticals, nutrients, probiotics, prebiotics, and antimicrobials that increase the functionality of the coating and add extra functions to food products (Salmieri and Lacroix, 2006).

Phytochemicals are chemicals of non-nutritious plants that contain protective compounds (antioxidants and antimicrobials) that prevent microbial growth and certain diseases. They are mainly associated with the prevention and/or control of certain chronic diseases, such as cancer, diabetes, cardiovascular disease, and hypertension (Traka and Mithen, 2011). These compounds help to prevent cell damage, replication of malignant cells, and reduce cholesterol. In addition, several of these compounds are

phenolics with antioxidant capacity for direct activity in elimination of free radicals and an indirect effect due to chelation of ions of pro-oxidant metals (Flora, 2009). These compounds can be found in plants/seeds, but during certain processing steps, they are removed or lose their activity, failing in promoting health, or preventing disease (Mattila and Kumpulainen, 2002).

As edible cutlery, are consumed with product, incorporation of these should not adversely affect consumer acceptance (Rashid, 2019). Hence, the flavors are usually incorporated with the main aim of increasing customer satisfaction and promote consumption and consumer acceptance.

2.2.1 Millets- The base in edible cutlery formulation

Sorghum with a pigmented pericarp provide a unique opportunity to produce special food products with a natural, attractive dark color, high levels of dietary fiber, and antioxidants with a variety of phenols (Hedge *et al.,* 2005). Black and tannin sorghum brans have been added into yeast-leavened bread formulas for production of food products with potential health benefits. For example, good-quality breads containing tannin sorghum bran have high phenols, antioxidant activity, and dietary fiber levels with a natural dark-brown color and excellent flavor (Gordon, 2001).

Millets contains large quantities of phenolics and other compounds of use in human foods to prevent deterioration of health. Different phenols with varying properties exist, but relatively little effort to demonstrate the potential of these compounds in human health has been made. Of all the cereals, sorghum has the potential to be bred specifically to produce high levels of different phenols that can be easily concentrated by simple processes (Saleh *et al.*, 2013).

Being a primary binding agents millets and cereals makes best pair on forming a structure and promotes strong outlook for a product. They have less penetration which will improve the stability and rigidity of the product and also provides extended shelf life. It adds the texture, aroma and acceptability of the consumer with more functional benefits. It also has ability to hold the nutrients and trap the properties and enhance the

quality of the product. Thus, it suits to formulate an edible product that can be used multipurpose as well (Devi *et al.,* 2014).

2.2.2 Millets -The power house of micronutrients and bioactive components

Sorghum is a good source of phenolic compounds with a variety of genetically dependent types and levels including phenolic acids, flavonoids, and condensed tannins. Most sorghums do not contain condensed tannins, but all contain phenolic acids. Pigmented sorghums contain unique anthocyanins that could be potential food colorants. Some sorghums have a prominent pigmented testa that contains condensed tannins composed of flavan-3-ols with variable length. Flavan-3-ols of up to 8–10 units have been separated and quantitatively analyzed. These tannin sorghums are excellent antioxidants, which slow hydrolysis in foods, produce naturally dark-colored products and increase the dietary fiber levels of food products. Sorghums have high concentration of 3-deoxyanthocyanins (*i.e*. luteolinidin and apigenidin) that give stable pigments at high pH. Pigmented and tannin sorghum varieties have high antioxidant levels that are comparable to fruits and vegetables. Finger millet has tannins in some varieties that contain a red testa. (Dykes and Rooney, 2006).

Sorghum and millet have anti-carcinogenic properties. For example, Van Rensburg (1981) reported that populations consuming sorghum and millet had lower incidences of esophageal cancer compared to those consuming wheat or maize. However, Morton (1970, 1972) reported that there was an association between high tannin sorghum consumption and human esophageal cancer, but these studies were criticized due to inadequate experimental design (Awika *et al*., 2003) showed that polymeric tannins from sorghum had higher anti-mutagenic activity than the lower molecular weight tannins. Gomez *et al., (*2001) showed that sorghum tannins increased melanogenic activity without increasing total melanin and reduced the formation of human melanoma colony cells.

The millets are considered as the important crops because of its ability to be stored for a long term as a food, as a seed with an extended germination ability. From

the nutritional aspect, barnyard millets are highly nutritious, rich in protein, lipid, vitamins B1 and B2, and nicotinic acid compared with other cereals, such as rice and wheat grains (Watanabe, 1999).

The amino acid composition of millet protein is good, and oleic and linoleic acids are abundant with respect to the fatty acid composition (Taira, 1984). Millets has been used as food materials, in place of rice and wheat grains, for those patients with allergic disease including atopic dermatitis. Polyphenolic compounds such as flavonoids, phenolic acids, and proanthocyanidins, which are of great interest for their radical-scavenging activity, are expected to be effective in the prevention of many diseases and morbid states. Among the cereals, catechins and proanthocyanidins from barley, isovitexin from rice (Ramarathnam *et al*., 1989), and phytic acid from various kinds of seeds are known as antioxidants which is also found in barnyard millet.

2.3 Oxidative stress- a threat for future generation

Reactive Oxygen Species (ROS) are produced by living organisms as a result of normal cellular metabolism. At low to moderate concentration, they function in physiological cell processes, but at higher concentrations, they produce adverse modification to cell component such as lipids, proteins and DNA. The shift in balance between oxidants / antioxidants in favour of oxidants is termed as oxidative stress (Bhattacharjee, 2019). Reactive Oxygen and Nitrogen Species (RONS) are produced by several endogenous and exogenous processes, and their negative effects are neutralized by antioxidant defenses. Oxidative stress occurs from the imbalance between RONS production and these antioxidant defenses. It leads to many severe physiological conditions which will reduce our life span (Birben *et al.,* 2012).

Ageing is a process characterized by the progressive loss of tissue and organ function. The oxidative stress theory of ageing is based on the hypothesis that age-associated functional losses are due to the accumulation of RONS-induced damages. At the same time, oxidative stress is involved in several age-related conditions (*i.e*, cardiovascular diseases, chronic obstructive pulmonary disease, chronic kidney disease, neurodegenerative diseases, and cancer), including sarcopenia and frailty.

Different types of oxidative stress biomarkers have been identified and may provide important information about the efficacy of the treatment, guiding the selection of the most effective drugs/dose regimens for patients (Huffman *et al.,* 2011).

The major types of free radicals found in biological systems are reactive oxygen species (ROS) and reactive nitrogen species (RNS) (Irshad and Chaudhuri, 2002). Free radicals are produced mainly by cellular and environmental sources. They are generated by absorption of radiant energy, endogenous oxidative reactions, enzymatic metabolism of exogenous chemicals, and generation of free radicals in pathogenic conditions (Ajitha and Rajnarayana, 2001).

Oxidative stress relates to inflammation and endothelial dysfunction, interacting with conditions such as adiposity, glycemia and smoking. Such oxidative stress, even in young adulthood, may contribute to long term disease risk long before clinical disease (Monaghan *et al.,* 2009). Cancer of posterior one-third of tongue is seen in 0.43% of total world population. Worldwide, cancer of tongue constitutes 5% of the total cancer incidence. Squamous cell cancer of head and neck is the most common cancer encountered in India. Oxidative stress is potentially harmful to cells and ROS are involved in multistage carcinogenesis, in initiation and promotion. Moreover, the extent of ROS-induced oxidative damage can be exacerbated by decreased efficiency of antioxidant defense mechanisms. Increased levels of oxidative stress markers and decreased levels of antioxidants in carcinoma of posterior one-third of tongue suggest that oxidative stress markers play a significant role in the pathophysiology of tongue cancer (Sharma *et al.*, 2009)

Antioxidants, bioactive compounds, phytochemicals and phenolic components help to reduces the oxidative stress to maintain healthy body. Incorporation of antioxidant rich fruit powder aids to prevent the free radical formation and reduce the risk of oxidative stress in the body of the individuals. Anti-oxidant defense involves several strategies, both enzymatic and non-enzymatic. In the lipid phase, tocopherols and carotenes as well as oxy-carotenoids are of interest, (as are vitamin A and ubiquinols. In the aqueous phase, there aI-C ascorbate, glutathione and other com-pounds. In addition to the cytosol, the nuclear and mitochondrial matrices and

extracellular fluids are protected. Overall, these low molecular mass antioxidant molecules add significantly to the defense provided by the enzyme's superoxide dismuta.se, catalcase and glutathione peroxidases (Sies, 1997).

A combination of antioxidant-deficiency and malnutrition may render individuals more vulnerable to oxidative stress, thereby increasing the risk of cancer occurrence. In addition, antioxidant defense can be overwhelmed during sustained inflammation such as in chronic obstructive pulmonary diseases, inflammatory bowel disease, and neurodegenerative disorders, cardiovascular diseases, and ageing. Certain antioxidant vitamins, such as vitamin C, vitamin A, vitamin D are essential in regulating biochemical pathways that lead to the proper functioning of the organs (Ischiropoulos and Beckman, 2003). Antioxidant supplementation has been shown to attenuate endogenous antioxidant depletion thus alleviating associated oxidative damage in some clinical research. However, some results indicate that antioxidants exert no favorable effects on disease control (Ray and Husain, 2002).

Anti- oxidants are the ultimate source that promotes sound health and reduces oxidative stress. It consists of numerous health benefits but they are present in trace amounts and present in varieties of foods which may not be able to consume all time. An edible cutlery is a new innovative means to constitute the numerous benefits together in a product and acts as a means to transport the required nutrients as like supplements and are multipurpose. The anti-oxidants acts as a key to reduce oxidative stress in our body. When they are incorporated in the edible cutlery will help to impart the nutrients for consumption and it helps to reduce the free radical formation and reduces or prevents the incidence of oxidative stress. The FRAP, DPPH, TAC, ABTS, ORAC are the tests which helps to find out the antioxidant potential of the food and this helps to find out the profile and the rate of antioxidant content when increased will help to reduce the oxidative stress (Thaipong *et al.,* 2006).

2.3.1 Antioxidant potential of fruits

Considerable epidemiological evidence suggests an association between consumption of fruit and vegetables and a decreased risk of cardiovascular disease and

certain forms of cancer. It is not known what dietary constituents are responsible for this association, but it is often assumed that antioxidants contribute to the protection. Paixao *et al*., (2007). have found that, in general, more than 80% of the total antioxidant capacity in fruits and vegetables comes from ingredients other than vitamin C, indicating the presence of other potentially important antioxidants in these foods. Flavonoids and other phenolic compounds appear to be antioxidants that contribute to the high antioxidant capacity observed in certain fruits and vegetables. Table I gives the role of nutritional antioxidants on human diseases / ageing.

TABLE I

ROLE OF NUTRITIONAL ANTIOXIDANTS IN HUMAN DISEASES AND AGEING

Nutritional antioxidant	**Common dietary sources**	**Supplemental effects on human diseases or aging**
Lipoic acid	Muscle meats, kidney, liver, and heart; low content in fruits and vegetables (Shay *et al.,* 2009).	* Protect neurons against OS-induced mitochondrial dysfunction (Moreira *et al.,* 2010)
Lycopene	Tomatoes, watermelon, papaya, apricot, and pink grapefruit (Sesso *et al.,* 2005; Wood *et al.,* 2012).	* Improved clinical asthma outcomes by suppressing airway inflammation (Wood *et al.,* 2012). * Reduced LDL oxidation in blood (Ignarro *et al.,* 2007). * Intake of lycopene was inversely correlated with cardio vascular disease incidence (Kohlmeier and Hastings, 1995).
Melatonin	Banana, white mustard (seed), black mustard (seed), almond (seed), celery, walnuts, sweet corn, rice.	* Attenuated OS-related lung deterioration in lung diseases (Gumral *et al.,* 2009).
Phytochemicals	Fruits (Mazo *et al.,* 2017)	* Potentially prevent or delay the development of Parkinsons disease (Mazo *et al.,* 2017).

Polyphenols	Fruits like banana, guava, berries, vegetables, coffee, tea, and cereals (Ignarro *et al.,* 2007).	*Anti-cancer activity against lung, breast, tongue, gastric, larynx, colon, and prostate cancers. Extended life span in animal models (Peng *et al.,* 2014). * Higher polyphenol intake was linked with reduced risk of CVD (Vita, 2005).
Resveratrol	Purple wine and peanuts (Anekonda, 2006).	* Protect neurons from Aβ and oxidative stress induced toxicity
Anthocyanin	Strawberries, black rice (Winter *et al.,* 2017).	* Alleviated astrogliosis and preserved neuromuscular junctions and muscle function in amyotrophic lateral sclerosis (Winter *et al.,* 2017). *Extended lifespan in animal models (Peng *et al.,* 2014).
Selenium	Tuna, oyster, salmon, eggs, green peas, pepper, onion, pork, beef.	* A combination of selenium and vitamin E protected against oxidative damage in the colon of rats with ulcerative colitis (Bitiren *et al.,* 2010).
Vitamin A	Eggs, dairy products, orange-colored fruits, green leafy and yellow - colored vegetables (Tang, 2010).	* Intake of vitamins A and C was inversely associated with the incidence of asthma (Tang, 2010).
Vitamin C	Strawberry, grapefruit, broccoli, guava and orange (Bitiren *et al.,* 2010).	* Reduced airway inflammation and exercise-induced bronchoconstriction in asthma (Tecklenburg *et al.,* 2007).
Vitamin E	Wheat germ oil, sunflower oil, hazelnut, and almonds (Vita, 2005).	* Reduced the incidence of cardio vascular disease death and non-fatal myocardial infarction (Stephens *et al*., 1996). *Attenuated functional decline associated with Alzheimer's disease (Sano *et al.,* 1997). *A combination of vitamin E and coenzyme Q10 improved energy generation in some cases of Friedreich ataxia (Lodi *et al.,* 2001). *A combination of selenium and vitamin E protected against oxidative damage in the colon of rats with ulcerative colitis (Bitiren *et al.,* 2010).

2.3.2 Recent progress for the utilization of anti-oxidants against oxidative stress

Traditionally, Reactive Oxygen Intermediates (ROIs) were considered to be toxic by-products of aerobic metabolism, which were disposed of using antioxidants. However, in recent years, it has become apparent that plants actively produce ROIs as signaling molecules to control processes such as programmed cell death, abiotic stress responses, pathogen defense and systemic signaling. Recent advances including microarray studies and the development of mutants with altered ROI-scavenging mechanisms provide new insights into how the steady-state level of ROIs are controlled in cells. In addition, key steps of the signal transduction pathway that senses ROIs in plants have been identified. These raise several intriguing questions about the relationships between ROI signaling, ROI stress and the production and scavenging of ROIs in the different cellular compartments. (Mittler, 2002) (Plate 1).

Despite the great number of research works and products already available in the market, the use of edible packaging to guarantee the quality and safety of food products is still under development, and investment is still needed. Edible cutlery are without any doubt one of the emergent technologies that meets consumers' demands for sustainability, use of biodegradable materials, and replacement of synthetic additives by natural compounds. The use of new materials, their modification to enhance their properties, the evaluation of their combination with other processing and conservation techniques, as well as their use as biodegradable packaging are some of the trends of edible packaging that are expected to increase their possible applications and, consequently, commercial interest in the near future (Rhim *et al.,* 2013).

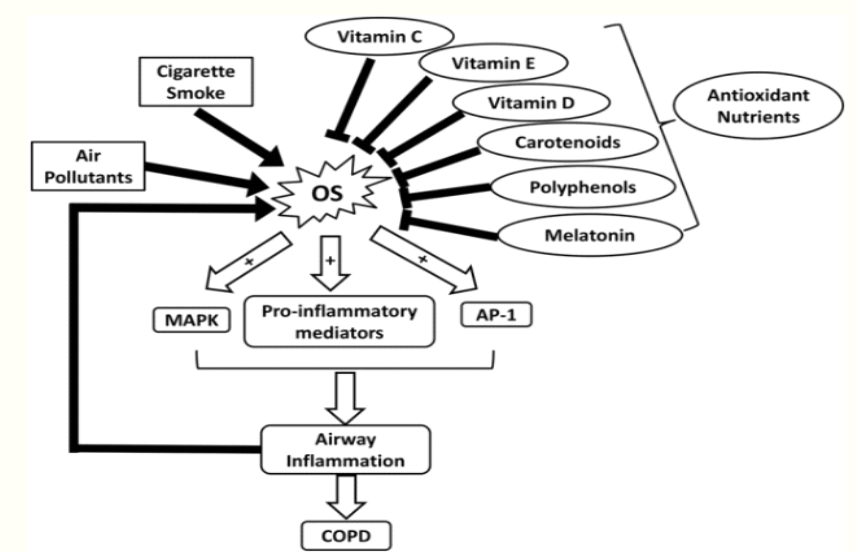


Plate 1 - Bio-nanocomposites for food packaging applications (Rhim *et al*., 2013)

2.4 Guava and Banana- The key to reduce oxidative stress

Natural antioxidants, particularly in fruits and vegetables have gained increasing interest among consumers and the scientific community because epidemiological studies have indicated that frequent consumption of natural antioxidants is associated with a lower risk of cardiovascular disease and cancer (Renaud *et al.,* 1998). The defensive effects of natural antioxidants in fruits and vegetables are related to three major groups: vitamins, phenolics, and carotenoids (Mondal *et al.,* 2009). Ascorbic acid and phenolics are known as hydrophilic antioxidants, while carotenoids are known as lipophilic antioxidants (Halliwell, 1996).

As a consequence, antioxidant compounds that are capable of neutralizing free radicals, may play a major role in the prevention of certain diseases, such as cancer, cataracts, cerebral pathologies and rheumatoid arthritis (Clifford, 1995). Fruits and vegetables contain different antioxidant compounds, such as vitamin C, vitamin E and carotenoids, whose activities have been established in recent years. However, these compounds are not the only ones contributing to the antioxidant activity of fruit and vegetables (Garcia *et al.,*2004).

Some recent studies show that the presence of polyphenol compounds, such as flavonoids (in fruits and vegetables) also contribute to beneficial effects of this group of foods. Apart from their biological properties, flavonoids are also of interest in the food, cosmetic, and pharmaceutical industries, as they can be used as substitutes for synthetic antioxidants (Moure *et al.,* 2001). Flavonoids are a family of compounds with a C6-C3- C6 skeleton structure. Flavanols, flavonols and anthocyanins are included in this group. All of them are found ubiquitously in the plant kingdom and have been shown to possess antioxidant activity, which depends mainly on the number and position of hydroxyl groups within their structure (Rice *et al.,* 1996). Between flavanols, the most common in fruits are of the catechin and gallocatechin and exist in the monomer form or can polymerise, giving rise to condensed tannins or pro anthocyanidins (Garcia *et al.,* 2004).

Guava (*Psidium guajava L)* fruit is considered a highly nutritious fruit because it contains a high level of ascorbic acid (50–300 mg/100 g fresh weight), which is three to six times higher than oranges. Red-fleshed Brazilian guava has several carotenoids such as phytofluene, β- carotene, β-cryptoxanthin, ϒ- carotene, lycopene, rubixanthin, crypto-flavin, lutein, and neochrome (Finkel and Holbrook, 2000). Setiawan *et al*., (2001) reported that guava is an excellent source of provitamin A carotenoids. Phenolic compounds such as myricetin and apigenin (Monaghan *et al.,* 2009), ellagic acid, and anthocyanins are also at high levels in guava fruits. Therefore, producing guava specially bred for higher levels of antioxidant compounds, is a realistic approach to increase dietary antioxidant intake.

Banana is an excellent tropical fruit with the highest consumption in the world. The banana has an agreeable flavor and a high nutritional value. The content of sugars, fiber, vitamins, and minerals of bananas is high, while the content of fat is low. Moreira *et al.,* (2010) examined the antioxidative potency in several fruits and fruit juices and reported that banana had a medium antioxidative potency among these fruits. Yin *et al.,* (2008) had also examined the antioxidative potency of several fruits and found that tropical fruits had strong activity. They found that banana extract suppressed the autoxidation of linoleic acid after incubation in an emulsion system, as determined from

the peroxide value and thio barbituric acid reactivity, and identified dopamine in bananas as a strong water-soluble antioxidant (Heo *et al.,* 2008).

The lipid peroxidation of plasma and lipoproteins, and the susceptibility to oxidative modification of LDL of healthy individuals were significantly decreased following the consumption of banana meal (Yin *et al*., 2008). Phenolic compounds, including catecholamines, phenolic acids and flavonoids (anthocyanins; flavan-3-ols monomers and polymers, the latter also known as tannins) have been found in banana (Aurore *et al*., 2009). Banana also contains antioxidant compounds including polyphenols, catecholamines and carotenoids (Gumral *et al*., 2009).

Today a great number of methods are used in the processing and preservation of food products. From ultraviolet or gamma radiation sterilization to refrigeration and high-pressure processing, there are several techniques that need to be used in combination with the packaging materials. This implies the evaluating behavior during the application of these processing and preservation techniques, including the possibility of materials modification and their interaction with food products (Siracusa *et al.,* 2008). This calls for more studies to understand how edible packaging could be used in combination with these techniques and thus guarantee the quality and safety of the products (Apel and Hirt, 2004). When edible packaging is presented as biodegradable packaging and focused as one of the solutions for the replacement of synthetic packaging, the market and food applications increase. However, the still underperforming properties (when compared with petroleum-based synthetic materials), the adaptation of processing devices, and the cost of the materials used are some of the problems faced in the development of biodegradable packaging (Jimenez *et al.,* 2001).

One of the further potential applications of edible packaging is their use as vehicles for bioactive and functional compounds (active and smart packaging), where the release of such compounds can be controlled by the materials used in the packaging production (Rahmat *et al.,* 2006). Besides the diffusion control of bioactive compounds into the matrix (depending on the materials used and on the interaction between materials), the encapsulation of these bioactive compounds followed by their entrapment in the packaging matrix can also be of great interest, once it is possible to

control their release rates under different external environments. The use of nanostructures such as nanohydrogels, nano emulsions, and nanoparticles for the incorporation of antifungals, vitamins, and antioxidants, respectively, should increase the potential applications of active and smart edible packaging (Cerqueira *et al.,* 2014).

The future of edible cutlery materials is promising, and their use for very specific applications is already viewed as an innovative solution close to market. Still open is their use to replace synthetic non-biodegradable materials, add on as a supplement, where great efforts are needed regarding the investment in research (both public and private), which can turn the global use of anti-oxidants rich edible cutlery into a reality during the next decade (Woranuch and Yoksan, 2013).

3. METHODOLOGY

The methodology pertaining to the study on "**Development and Evaluation of Antioxidant Enriched Edible Cutlery**" is discussed under the following segments :

3.1. Selection and procurement of ingredients

3.2. Formulation and standardisation of antioxidant enriched edible cultery

3.3. Conducting organoleptic evaluation of the developed edible cultery

3.4. Analysis of parmeters for the most accepted variation of edible cutlery

3.4.1 Analysis of physicochemical properties

3.4.2 Determination of total antioxidant capacity

3.4.3 Estimation of nutrient content

3.4.4 Evaluation of phytochemical properties

3.4.5 Microbial analysis of the formulated cutlery

3.5. Collection of feedback from the consumers

3.6. Interpretation and analysis of data using appropriate statistical tools

3.7. Ethical clearance

3.1. Selection and procurement of ingredients

The study was carried out to develop antioxidant rich edible cutlery which reduces oxidative stress. It is formulated with nutritious ingredients such as cereals, millets and locally available foods that are rich in antioxidants.The foods incorporated in formulation were selected based on certain edible characteristics such as presence of bioactive components and antioxidants, nutritious, food that reduces the oxidative stress in the body, blending with other food ingredients thoroughly, cheap, easily available, non toxic and more acceptable by the consumer. The ingredients required for the standardization of the edible cutlery was procured from the local departmental stores. This ensures quality of the ingredient without any impurities.

3.2. Formulation and standardization of antioxidant enriched edible cultery

Antioxidants, bioactive compounds, phytochemicals and phenolic components facilitate to reduce the oxidative stress and helps to keep up healthy body. Incorporation of antioxidant rich fruit powder aids to delay / stop the radical formation and scale back

the chance of oxidative stress. Enthralling of these into account, a standard formulation was done to provide replacement version of edible cutlery possessing antioxidant property (Liguori *et al*., 2018).

3.2.1. Formulation and standardization of edible cutlery

The ingredients used in the formulation of the standard edible cutlery are wheat flour (*Triticum*), barnyard millet flour (*Echinochloa esculenta*), sorghum flour (*Sorghum bicolor*) and corn flour (*Zea mays L*). They were incorporated in the ratio of 4:2:2:1. Measured quantity of flour with the specific ratio was taken and sieved thrice. This ensures uniform mixing of all the flour together, removes impurities and incorporates aeration. To this, 50 ml of water was taken and kneaded to make a smooth and soft dough. The dough was sheeted to 5 mm of uniform thickness. It was then molded into required shapes of spoons, cups and plates and baked in a preheated oven at 160^{o} C for 20 minutes. The combination of flour with different millets was tired out and with different percentages; the amount of water used was standardized and the temperature and time taken for baking was standardized after repeated trials. To this antioxidant rich fruit powder was incorporated (Plate 2).

The method of application of hydraulic pressure was also tried along with baking method. In this method, the cutlery were tried out with same proportion of ingredients and procedure followed to make the dough similar to that of baking method in oven, In this method, dough was sheeted to an uniform thickness of 7mm and was placed in the semi-automatic hydraulic machine, which has different molds for spoons and plates. With the application of 1.5 ton of weight to the mold and by passing 5 KW of electricity, uniform heat at 70^{0}C was applied for 5-6 minutes. The dough was molded into a plate. The plates were molded in two different sizes of 8 -inch and 12-inch (diameter). The spoons were made with the hydraulic machine at a temperature of 220^{0}C with the application of 1.5 ton of weight and 5 KW of electricity for 7 minutes. The dough was converted into a spoon. The plate/spoon was made in the same machine but with the use of different molds. When the pressure was applied the excess dough was removed by the machine. Plate/ poon of uniform thickness was obtained (Plate 3).

The research design of the study is presented in Figure 1 and the method employed for developing cutlery is presented in Figure 2.

3.2.2. Formulation of antioxidant enriched edible cutlery

After standardization of the edible cutlery, antioxidants in the form of dehydrated fruit powder was incorporated into the standardized edible cutlery. The dehydrated fruit powder was incorporated into the standardized formula by partially replacing the cereal flour. After a thorough survey of literature, antioxidant rich fruits that help to combat the stress namely guava and banana was selected. Dehydrated fruit powders was prepared. The guava was cut into 2.5 mm piece cubes and allowed to dry in a cabinet drier. The temperature was set at 80^0 C and dried until the moisture content reduced to less than 5%. It was dried for approximately 20 hours. Simultaneously banana was cut into 5 mm thickness. Spread in a tray and allowed to dry in a cabinet dried at 80^0 C until the moisture content decreased to less than 10%. It was dried for approximately 35 hours. The dried fruits were then powdered using a pulverizer and sieved in a sieve to ensure no residues and lumps. The powder was then stored in air tight containers for incorporation into the standardized cutlery (Figure 3).

The guava and banana fruit powders were incorporated into the standard formulation with the replacement of wheat flour with guava powder in one variation and banana powder in another variation. The fruit powders were incorporated by replacing the quantity of wheat flour in three different proportions as 10, 20 and 30 percentage. Each fruit powder was tried with three variations with the following proportions (Table II).

TABLE II

COMPOSITION OF FORMULATED ANTIOXIDANT ENRICHED EDIBLE CUTLERY

Ingredients	Standard	Variation I (%)	Variation II (%)	Variation III (%)
Corn flour	10	10	10	10
Barnyard millet flour	20	20	20	20
Sorghum flour	20	20	20	20
Wheat flour	50	40	30	20
Dehydrated Banana/ Guava powder	-	10	20	30

Weighing the ingredients

Adding and sifting the ingredients

Mixing the ingredients

Sheeting into dough

Cutting and molding the sheeted dough to cutlery shape

Baking in oven for 20 minutes at 160^0 C

Edible cutlery

Plate 2- Formulation of Edible cutlery (oven baking method)

Sheeting the dough

Filling the sheeted dough inside the mold

Hydraulic press was applied with the application of 1.5 ton of weight

Removal of the prepared cutlery from the machine

Edible cutlery

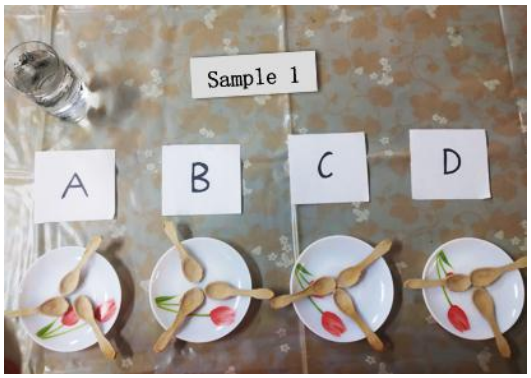
Plate 3- Formulation of Edible cutlery (Hydraulic Pressure Method)

3.3. Conducting organoleptic evaluation of the developed edible cutlery

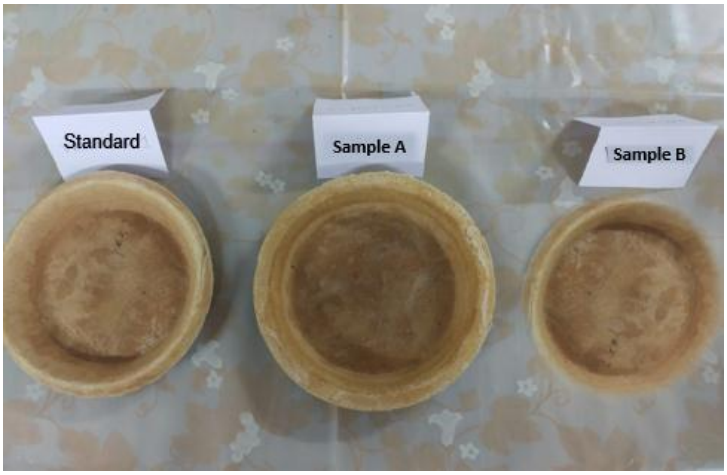
Sensory qualities is the key for food acceptance because the customers request the merchandise with specific sensory characteristics. The acceptance of the food depends on the sensory characteristics that are normally accepted by the patron.The measuring of sensory properties and determination of specific properties play a significant accomplishment in sensory analysis.The standard attributes was scaled using hedonic rating scale of a food product (Meilgaard *et al*., 2007)

Sensory evaluation of the developed edible cutlery was done in Foods Laboratory of the Food Science and Nutrition Department of Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore. Thirty semi trained panel members who were doing postgraduation and research scholars of the department of Food Science and Nutrition and Food Service Management and Dietetics were the panel members. Coded samples namely standard, variation I, II, III of the cutlery made out of guava powder and banana powder was served to the panelist at around 10.30 am in the morning along with water. They were made to sit comfortably and the score card was given for evaluation. The score card given to the panel members for the evaluation of the edible cutlery has been enclosed in the Appendix I and Plates 4 and 5.

Plate 5- Sensory evaluation by the semi-trained panel members



Edible cutlery made using Baking method



Edible cutlery made using Hydraulic pressure method

Plate 4 – Variation of edible cutlery

3.3.1 Quality attributes of developed edible cutlery

Quality attributes has been defined as scientific description used to evoke chief analysis core relationship to those characteristic foods and materials as they are professed by a sense of sight, smell, taste, touch and hearing. These are based on hedonic scale. The products are formed only once or twice and the segment of the target population that will accept the product is determined (FSSAI, 2015). The sensory attributes used in the scale are flavour, colour, texture, taste, apperanance, and overall acceptability.

3.3.2 Hedonic Test

The hedonic scale may be used to determine the degree of acceptability of one or more products. This scale is a category-type scale with an odd number (five to nine) categories ranging from “dislike extremely” to “like extremely.” A neutral midpoint (neither like nor dislike) is included. Semi trained panel members rate the product on the scale based on their response (FSSAI, 2015). In the present study the hedonic scale is rated with score ranging from 5 to 1 corresponding to different credentials for each characteristic of the edible cutlery.

3.3.2.1 Flavour

Flavour factor include both sensation perceived by the tongue, which comprise sweet, salty, sour and bitter tastes and aroma perceived by the tongue and nose respectively. Flavour is a blend of both palate and aroma and is chiefly subjected and thus hard to measure (FSSAI, 2015).The developed cutlery is ranked from 5 through 1 representing the corresponding criteria with highly acceptable, partially acceptable, acceptable, unacceptable and off flavour respectively.

3.3.2.2 Colour

Colour is perceived when the light is reflected by the product surface and falls upon the eyes of the retina. It depends on light and intensity of light. Chemical and physical characteristics of the product is the person’s ability to differentiate various chemical and physical characteristics of the product. Colour is used as an index for the

quality of number of foods (FSSAI, 2015). In the present study, the colour was ranked based on the criteria creamish brown, creamish white, brownish white, dark brown and blackish brown with the corresponding scores of 5 to 1 respectively.

3.3.2.3 Texture

Texture is also an important factor in determining the quality of the food product. Degree of softness or crispness is often used as an instrument for objective measurement of firmness. Subjective firmness can be used to check and characterize the quality of the product. The product must be unbreakable and wont attain soggy texture soon as it leads to poor acceptability (FSSAI, 2015).The criterias used in the hedonic scale for evaluation are strong and crunchy, crispy, brittle, hard and too hard with scores corresponding to 5 to 1 respectively.

3.3.2.4 Taste

Taste is the important factor that helps to differntiate the food and it holds the most acceptable position on rating a food. While coming to the edible cutlery its taste should not affect the taste of the food they consume. At the same time it should hold its unique taste which will be acceptable by the people consuming that (FSSAI, 2015). Taste was ranked with criteria excellent, very good, good, fair and poor based on their acceptability with scores corresponding to 5 to 1 respectively.

3.3.2.5 Appearance

Appearance plays a major role on evaluating a product as it is the primary factor which can be assessed initially before we taste it. It also helps to catagorize the food based on its characteristic appearance (FSSAI, 2015). In the present study, the edible cutlery were assessed based on the following criteria like most attractive, attractive, normal, sobber and dull with scores corresponding to 5 to 1 respectively.

3.3.2.6 Overall acceptability

The overall acceptability indicates the acceptance of the product with all its characteristic and their overall opinion on the product. It is consolidated based on all the sensory characters of the product. In this study, the product is assessed based on the

following criterias like excellent, very good, good, fair, poor with scores corresponding to 5 to 1 respectively.

The scores as scored by the panelist are consolidated and tabulated for further interpretation of the results.

3.4 Analysis of parameters for the most accepted variation of edible cutlery

3.4.1 Analysis of physicochemical properties

The physicochemical properties of the most accepted edible cutlery namely volume, weight, density, thickness, diameter, spread ratio, water holding period and water absorption capacity were analysed using standard procedures (Plate 6).

3.4.1.1 Determination of moisture content

The moisture content was determined using an electronic Moisture Analyzer Shimadzu (MOC-12OH). One gram of the sample was placed on the sample pan. The mode was selected and the temperture was set at 120^{o} C. The final result displayed on the display board gives the percentage of the moisture content present in the sample and recorded (AOAC, 2009).

3.4.1.2 Volume

To measure the volume of the developed cutlery, 100 ml of water is taken in a container having measuring scale. Into this the sample to be measured is immersed. The rise in level of the water is noted. The difference between the initial and final value measures the volume of the sample. The reading was noted in ml and they were converted to cm. *i.e.* 20 cubic cm as 1 ml= 1 cm^3 (AOAC, 2009).

Volume = Final value – Initial value

The experiment was repeated thrice to get concordant values for both standard and for the most accepted variation.

3.4.1.3 Density

To measure the density of the developed cutlery, the weight of the cutlery is noted by weighing it in the weighing balance and volume of the cutlery was noted by

taking 100 ml of water in a container, then the cutlery to be measured is now immersed into the container containing water. The increase in volume is noted by observing the rise in level of the water. The difference between initial and final volume gives the volume of the cutlery. The density is determined by dividing the weight of the sample by volume of the sample (Ayo *et al*., 2008). The density of the edible cutlery was determined using the formula given below:

$$\text{Density} = \frac{\text{weight}}{\text{Volume}}$$

3.4.1.4 Spread ratio

The spread ratio was determined using standardised method as given by Ayo *et al* ., (2008). Five pieces of the developed cutlery was placed one above the other. The thickness was measured using a measuring scale. The diameter of the sample was measured using a measuring scale. Spread ratio was calculated using the formula

$$\text{Spread ratio} = \frac{\text{Diameter}}{\text{Thickness}}$$

The experiment was repeated thrice to get concordant values for both standard and the most accepted variation.

3.4.1.5 Water holding period

100 ml of water was taken in a bowl. The developed cutlery was immersed into the bowl. The initial time was noted. The time taken for the cutlery to start absorbing the water was recorded as final time. The difference between the initial and final time gives the water holding period of the cutlery.

3.4.1.6 Water absorption capacity

Ground cutlery sample was suspended in 30 ml of water at 30^0 C in 50 ml preweighed centrifuge tube and centrifuged at 3000 rpm for 10 minutes. The supernatant was poured into dish. The remaining gel was weighed and the water absorption capacity was recorded (Nawabueze,2006).

Water absorption capacity (WAC) = . Gel weight (g) .

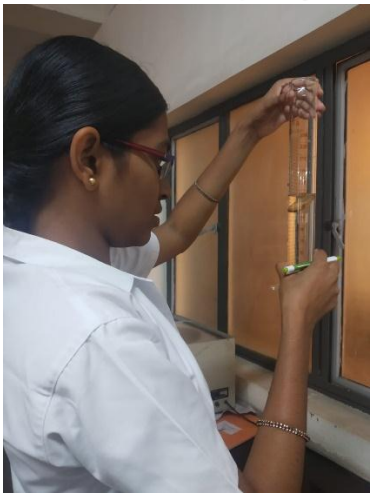
Dry sample weight (g)

3.4.1.6 Determination of texture analysis

Texture analysis of the formulated edible cutlery was done by Texture analyzer. Texture analysis was done by two methods (TA and TPA test). TA test was done for measuring cutting force of edible cutlery and TPA for firmness, cohessiveness and springiness (Zheng and Lu, 2012). The test was performed under the following states: Test speed: 5mm/ s; stain: 50% and trigger force : 5 g. A piece of edible cutlery was compressed twice to obtain five primary texture parameters namely hardness, breakability, springiness, cohesiveness and resilience. Chewiness, the only secondary texture parameter, was calculated as the product of hardness, cohesiveness, springiness (Szczesniak *et al*., 2003). Instrumental analysis of edible cutlery texutral properties was performed to record the hardness, breakability, springiness, cohesiveness, resilience and chewiness. The speed stain was noted for the edible cutlery prepared by both baking and hydraulic pressure method. These were compared and examined for their textural properties (Plate 6).

Determination of Water absorption capacity

Determination of textural properties of the edible cutlery



Determination of volume

Determination of Ash content

Moisture analysis

Plate 6 – Analysis of nutrients and physicochemical properties of the edible cutlery

3.4.2 Determination of total antioxidant capacity

Antioxidants have long been recognized as having protective functions against cellular damage and reduce the risk of chronic diseases.

3.4.2.1 Determination of the Ferric Reducing Antioxidant Power (FRAP)

FRAP reagent was prepared by mixing in 25 ml acetate buffer (30 mm; pH 3.6), 2.5 mL TPTZ solution (10 mm) and 2.5 ml ferric chloride solution (20 mm). The mixture

was incubated for 15 minutes at 37°C before use. Ascorbic acid (vitamin C) was employed as a standard in this assay, and its calibration curve was obtained by using its concentrations ranging from 50 mg/l to 500 mg/l in water. To 2.85 ml FRAP reagent in a test tube, 150 µl sample (0.1 mg/mL, in methanol) or standard was added (Benzie and Strain, 1996). The mixture was incubated for 30 minutes in the dark, and its absorbance was measured at 593 nm. The blank contained an equal volume of methanol instead of the plant sample (AOAC international, 2006). The results were reported as µg of ascorbic acid equivalents (AAE) per ml.

$$\text{FRAP Value (µm)} = \frac{\text{Abs sample x Frap value of Std (µm)}}{\text{Abs Std}}$$

3.4.2.2. Determination of Total Antioxidant Capacity

The total antioxidant capacity of the methanol extract of the sample was evaluated by the phosphomolybdenum method according to the procedure described by (Prieto *et al*.,2003). A 0.3 ml of extract was combined with 3 mL of reagent solution (0.6 M sulfuric acid, 28 mM sodium phosphate and 4 mM ammonium molybdate). The tubes containing the reaction solution were incubated at 950^{o}C for 90 min. Then, the absorbance of the solution was measured at 695nm using a UV-VIS spectrophotometer against blank after cooling to room temperature. Methanol (0.3 ml) in the place of extract was used as the blank. The total antioxidant activity is expressed as the number of gram equivalent of ascorbic acid. The calibration curve was prepared by mixing ascorbic (1000, 500, 250, 125, 62.5 and 31.25 µg/ml) with methanol (AOAC International, 2006).

$$\text{Total antioxidant capacity} = \frac{\text{Absorption – intercept}}{\text{Slope}}$$

3.4.3 Estimation of nutrient content

A food substance provides energy and is necessary for growth and repair. Nutrients are the beneficial chemicals in foods and beverages. Nutrients analysis refers to the process of determining the nutritional content in foods and food products. The

process can be performed through a variety of methods like laboratory analysis, nutrient analysis software, online nutrition analysis, turnkey nutrition analysis services.

The different nutrients analyzed for the edible cutlery are namely ash, moisture, dietary fibre, carbohydrate, protein, fat, iron, calcium, vitamin C and β carotene (Plate 6).

3.4.3.1 Ash content

By continuous heating, dry powder of sample gets charred which can be used for the determination of minerals present. 2g of the dry powder were separately weighed accurately into different platinum or porcelain crucible. The crucible was then placed on a clay pipe triangle and heated over a low flame till all the material was completely charred, followed by heating in a muffle furnace for about 2 hours, at 600°c. The crucible was then cooled in a desiccator and weighed. To ensure completeness of ash formation in the crucible, it was again heated in a muffle furnace for half an hour, cooled and weighed. This was repeated till two consecutive weights were the same and the ash was almost white or greyish white in colour (AOAC International, 2006).

3.4.3.2 Dietary fibre content

The dietary fibre content present in the edible cutlery is analyzed and estimated using Enzymatic gravimetric method (AOAC International, 2009). The sample is homogenized and dried (freeze-dry is recommended). Defat with petroleum ether if >10% fat content, otherwise false high results. Weigh duplicate test portions (difference in weight should not >20 mg). After defatting, the food sample is treated with enzymes that impersonate the digestive process in the human small intestine. Digestible carbohydrates are broken down into simple sugars and removed from the sample by precipitation and filtration. The non-digestible precipitate contains the dietary fiber but also contains protein and inorganic material. These should not be included in dietary fiber so protein and inorganic material must be measured separately and subtracted from the weight.

This method measures all components of dietary fibre. Most resistant starch and all non-digestible oligosaccharides are not included which results in an underestimation

of dietary fiber. Collect the residues (soluble fibre + insoluble fibre) in pre-weight crucibles (AOAC International, 2009).

$$\text{Total dietary fibre} = \frac{[\text{weight residue} - \text{protein} - \text{ash} - \text{blank}]}{\text{weight test portion}}$$

Weight residue = average of duplicate, Weight test portion = average of duplicate

3.4.3.3 Carbohydrate

The total carbohydrate present in the given sample was estimated by anthrone reagent method. Homogenize 0.1 to 0.5 g of sample in hot 5 ml of 80% ethanol till the centrifuge and retain the residue. The residue is washed repeatedly with 80% ethanol till the washing do not give colour with anthrone reagent. The residue was dried well over a water bath. To the residue, added 5 ml of water and 6.5 ml of 52% perchloric acid. Extracted at 0^0 for 20 minutes, centrifuge and save the supernatant and make up to 100 ml. pipetted out 0.1 ml to 0.5 ml of the supernatant and made up to 1 ml with water, prepare the standard by taking 0.2, 0.4, 0.6, 0.8 and 1.0 ml working standard and made up to 1 ml with distilled water. Add 4 ml of anthrone reagent to each tube. Heat for 8 minutes in a boiling water bath, cool rapidly and read the intensity of green to the dark at 630 nm (FSSAI, 2015). standard graph by plotting concentration of the standard on the X-axis versus absorbance on the Y-axis. From the graph, calculated the amount of carbohydrate present in the sample tube (Nayaka and Londonkar, 2019).

$$\text{Concentration of the Carbohydrate (\%)} = \frac{\text{OD (test)} \times \text{Conc (std)} \times 100}{\text{OD (std)} \times \text{Aliquot (test)}}$$

3.4.3.4 Protein

Total Protein present in the given sample was estimated by Lowry's Method. Extraction of Protein from sample: Extraction is usually carried out with buffers used for the enzyme assay. Weighed 500 mg of the sample and grinded well with a pestle and mortar in 5-10 ml of the buffer. Centrifuged and used the supernatant for protein estimation. Pipetted 0.2, 0.4, 0.6, 0.8 and 1 ml of the working standard into a series of test tubes. Pipetted 0.1 ml and 0.2 ml of the sample extract in two other test tubes. Made up the volume to 1 ml in all the test tubes. A tube with 1 ml of water served as the

blank. Added 5 ml of reagent C to each tube including the blank. Mixed well and allow standing for 10 minutes. Then added 0.5 ml of reagent D, mixed well and incubated at room temperature in the dark for 30 minutes. Blue colour was developed. Taken the readings at 660 nm. Drawn a standard graph and calculate the amount of protein in the sample and expressed the amount of protein in mg/g or 100 g sample (FSSAI, 2015).

$$\text{Concentration of the Protein (\%)} = \frac{\text{OD (test) x Conc (std) x100}}{\text{OD (std) x Aliquot (test)}}$$

3.4.3.5 Fat

The fats present in the given sample was estimated using Soxhlet method. Weighed, accurately 5-10 g (W1) of dry sample into a thimble and cotton plug was kept on top of it. Placed the thimble in a Soxhlet apparatus and added ½ volumes of ether into a pre-weighed flat- bottom flask (W2) and distilled for 16 hours. Cooled the apparatus and filtered the solvent into a pre- weighed conical flask (W2). Rinsed the flask of the apparatus with small quantities of ether and then added washings to the above flask. Removed ether by evaporation and dried the flask with fat at 80-100^{o}C, cooled in a desicator and weighed (W3) (AOAC International, 2006).

$$\text{Fat content (g/ 100\%)} = \frac{(W3 - W2)}{W1} \times 100 = X$$

3.4.3.6 Energy

In more recent calorimeter designs, the whole bomb, pressurized with excess pure oxygen (typically at 30atm) and containing a weighed mass of a sample (typically 1–1.5 g) and a small fixed amount of water is submerged under a known volume of water (ca. 2000 ml) before the charge is electrically ignited. The bomb, with the known mass of the sample and oxygen, form a closed system and no gases escape during the reaction. The weighed reactant put inside the steel container is then ignited. Energy is released by the combustion and heat flow from this cross the stainless-steel wall, thus raising the temperature of the steel bomb, its contents, and the surrounding water jacket. The temperature change in the water is then accurately measured with a thermometer. This reading, along with a bomb factor is used to calculate the energy given out by the sample burn. A small correction is made to account for the electrical energy input, the burning

fuse, and acid production (by titration of the residual liquid). After the temperature rise has been measured, the excess pressure in the bomb is released (AOAC International, 2006).

The energy of a product can also be calculated using the standard calorific values of carbohydrates, proteins and fats. The calorific value of carbohydrate is 4 k.cal / g, protein is 4 k.cal / g and fat is 9 k.cal / g (FSSAI, 2005).

3.4.3.7 Iron

The iron present in the given sample was estimated using Atomic absorption spectrophotometry method. Took 100 ml standard flask. Prepared iron standards (Nist traceable) to 0.05, 0.1, 0.125, 0.15, 0.20 and 0.25 mg/l in nitric acid (1:499) from 1000 ppm solution. Prepared a blank solution in 100ml distilled water. Pipetted out 100 ml of sample in a beaker and digested with 0.5 ml. of conc. Nitric acid and added 25 ml CaCl2 till the volume reduced to three fourth. Made up to 100 ml. with distilled water. Processed the blank also in the above manner. Set the AAS as per the specific work instruction. Aspirated the blank, standards and digested food sample solutions. Measured the absorbance of the iron at 248.3nm. The value is calculated by drawing the standard calibration graph by plotting the absorbance Vs standard concentration for each standard (AOAC International, 2006).

3.4.3.8 Calcium

The sample was dried in an air oven at 105°C for 3 hours. The dried sample was then charred. The charred sample was ashed in a muffle furnace at 550°C until the whitish or greyish ash was obtained. The ash was treated with concentrated hydrochloric acid, transferred to a volumetric flask and made up to 100 ml (AOAC International, 2006). Took above 100ml in conical flask. Added 2-3 drops of sodium hydroxide 1N solution (4.1) and to raise the pH 12 -13. Added a pinch of Patton and Reeder (4.3) indicator and stir well. Titrated against the solution with 0.01M EDTA (4.4). The end point is appearance of blue colour.

$$\text{Calcium (mg/100g)} = \frac{\text{Volume of EDTA x Eq.wt of Ca x100}}{\text{Weight of sample}}$$

3.4.3.9 Vitamin C

The vitamin C present in the given sample was estimated using titration method. Pipetted a 20 ml aliquot of the sample solution into a 250 ml conical flask and added about 150 ml of distilled water and 1 mL of starch indicator solution. Titrated the sample with 0.005 mol l−1 iodine solution. The endpoint of the titration is identified as the first permanent trace of a dark blue-black colour due to the starch-iodine complex. Repeated the titration with further aliquots of sample solution until you obtain concordant results are obtained (titres agreeing within 0.1 ml) (AOAC International, 2006).

3.4.3.10 β-carotene:

The given sample was pulverized with 95% ethanol. The suspension was refluxed for about half an hour in the boiling water bath. The clear supernatant was filtered, diluted with 20 ml of 85% ethanol. Extracted the solution repeatedly with petroleum ether using 20 ml portions every time and the extraction were done for 3 or four times. Carotene was extracted in the petroleum ether, pooled the ether extract and made up to 100 ml with ether. Took different volume of standard carotene solution 2 to 8 ml corresponding to 40 to 160 γ . The volume of all solution is made up to 8 ml with petroleum ether. The extract was considered to be unknown. 8 ml of the made-up extract was taken for the experiment. The colour developed was read at 540 nm in a colorimeter.

All the tests were done for the standard and most accepted variation of antioxidant rich edible cutlery thrice to get concordant value and the values were used for interpretation.

3.4.4 Evaluation of the phytochemical properties

3.4.4.1 Qualitative analysis

Phytochemical analysis, was done using various aqueous extract of the sample screening for alkaloids, flavonoid, tannins, terpenoids, steroid, saponins, phenolic compounds.

Samples were extracted in aqueous medium of different polarity viz water. Powdered material (10 g) was extracted in 150ml methanol using Soxhlet apparatus by

continuous hot percolation method at 60°C temperature for 24 hours. The resultant content was filtered with Whatman filter paper no.1 and kept for evaporation of solvent to get the dry concentrated extract. The dried crude concentrated extract was weighed to calculate the extractive yield and then transferred to glass vials (6 ×2 cm) and stored in a refrigerator (4°C), till used for analysis (AOAC International, 2006).

Test for Tannins

10 ml of bromine water was added to the 0.5 g aqueous extract. Discoloration of bromine water showed the presence of tannins (AOAC International, 2006)**.**

Test for Saponins

5.0 ml of distilled water was mixed with aqueous extract in a test tube and it was mixed vigorously. The frothing was mixed with few drops of olive oil and mixed vigorously and the foam appearance showed the presence of saponins (AOAC International, 2006).

Test for Flavonoids

Alkaline Reagent Test. 2 ml of 2.0% NaOH mixture was mixed with aqueous extract; concentrated yellow color was produced, which became colorless when we added 2 drops of diluted acid to mixture. This result showed the presence of flavonoids (AOAC International, 2006).

Test for Terpenoids

2.0 ml of chloroform was added with the 5 ml aqueous extract and evaporated on the water path and then boiled with 3 ml of H_2SO_4 concentrated. A grey color formed which showed the entity of terpenoids (AOAC International, 2006).

Test for Steroids

2 ml of chloroform and concentrated H_2SO_4 were added with the 5 ml aqueous extract. In the lower chloroform layer red color appeared that indicated the presence of steroids (AOAC International, 2006).

Test for Alkaloids

Sample is dissolved in dilute Hydrochloric acid and filtered. **Mayer's Test -** Filtrates were treated with Mayer's reagent (Potassium Mercuric Iodide). Formation of a yellow coloured precipitate indicates the presence of alkaloids (AOAC International, 2006).

Test for phenols (ferric chloride test)

Extracts were treated with 3-4 drops of ferric chloride solution. Formation of bluish black colour indicates the presence of phenols (AOAC International, 2006).

3.4.4.2 Test for quantitative analysis of phytochemicals

Determination of Alkaloids

The plant extract (1mg) was dissolved in dimethyl sulphoxide (DMSO), added 1ml of 2 N HCl and filtered. The solution was transferred to a separating funnel, 5 ml of bromocresol green solution and 5 ml of phosphate buffer were added. The mixture was shaken with 1, 2, 3 and 4ml chloroform by vigorous shaking and collected in a 10-ml volumetric flask and diluted to the volume with chloroform. A set of reference standard solutions of atropine (20, 40, 60, 80 and 100 µg/ml) were prepared in the same manner as described earlier. The absorbance for test and standard solutions were determined against the reagent blank at 470 nm with an UV/Visible spectrophotometer. The total alkaloid content was expressed as mg of AE/g of extract (AOAC International, 2006).

Determination of Total flavonoid content

Total flavonoid content was measured by the aluminium chloride colorimetric assay. The reaction mixture consists of 1 ml of extract and 4 ml of distilled water was taken in a 10 ml volumetric flask. To the flask, 0.30 ml of 5 % sodium nitrite was treated and after 5 minutes, 0.3 ml of 10 % aluminium chloride was mixed. After 5 minutes, 2 ml of 1M Sodium hydroxide was treated and diluted to 10 ml with distilled water. A set of reference standard solutions of quercetin (20, 40, 60, 80 and 100 µg/ml) were prepared in the same manner as described earlier. The absorbance for test and standard solutions were determined against the reagent blank at 510 nm with an UV/Visible

spectrophotometer. The total flavonoid content was expressed as mg of QE/g of extract (AOAC International, 2006).

Determination of total phenolic content

The concentration of phenolics in sample extracts was determined using spectrophotometric method. Folin-Ciocalteu assay method was used for the determination of the total phenol content. The reaction mixture consists of 1 ml of extract and 9 ml of distilled water was taken in a volumetric flask (25 ml). One milli litre of Folin-Ciocalteu phenol reagent was treated to the mixture and shaken well. After 5 minutes, 10 ml of 7 % Sodium carbonate (Na_2CO_3) solution was treated to the mixture. The volume was made up to 25 ml. A set of standard solutions of gallic acid (20, 40, 40, 60, 80 and 100 µg/ml) were prepared in the same manner as described earlier. Incubated for 90 min at room temperature and the absorbance for test and standard solutions were determined against the reagent blank at 550 nm with an Ultraviolet (UV) /Visible spectrophotometer. Total phenol content was expressed as mg of GAE/gm of extract (AOAC International, 2006).

Determination of tannin Content

The tannins were determined by Folin - Ciocalteu method. About 0.1 ml of the sample extract was added to a volumetric flask (10 ml) containing 7.5 ml of distilled water and 0.5 ml of Folin- Ciocalteuphenol reagent, 1 ml of 35 % Na_2CO_3 solution and dilute to 10 ml with distilled water. The mixture was shaken well and kept at room temperature for 30 min. A set of reference standard solutions of gallic acid (20, 40, 60, 80 and 100 µg/ml) were prepared in the same manner as described earlier. Absorbance for test and standard solutions were measured against the blank at 725 nm with an UV/Visible spectrophotometer. The tannin content was expressed in terms of mg of GAE /g of extract (AOAC International, 2006).

3.4.5 Microbial analysis of the formulated cutlery

Microbiology is a study of micro-organisms, either unicellular (single cell), multicellular (cell colony) or a cellular (lacking cells). Microbial analysis was carried out

to find out the shelf life of the edible cutlery prepared which were highly accepted in the sensory evaluation (Stollman *et al.,*1994). The product was stored in ambient room temperature in an air tight container. By standard plate count method, the proportion of the sample we serially diluted in appropriate temperature for a given time, after which all visible colonies are counted (Jay, 1996). The number of microbes is tested by SPC (Standard Plate Count) method. The incubation period for the nutrient agar plate is 24 hours (AOAC International, 2006). The microbial analysis procedure was appended in the appendix II.

3.4.5.1 Total bacterial count

This method gives general guideline for the detection of total microbial count organism present in food sample.

Blended the sample in a sterile blender jar for 2 minutes or macerated with sterile mortar, using 10 ml of diluting fluid per gram of sample (in pour plate technique diluting fluid, with a 1g inoculum of a 1/10 Suspension). The diluting fluid for preparing the homogenate should be 0.1 percent peptone (AOAC International, 2006)

Took two sterile petri dishes, using a sterile pipette, transferred to each dish 1 ml of the test sample. Took two other sterile petri dishes, using a fresh sterile pipette, transferred to each dish 1 ml of the First decimal dilution (10 -2) of the test sample and repeated the procedure described with the further dilutions, using a fresh sterile pipetted for each decimal dilution. Aseptically pipetted 1 ml each of the sample and 1 ml each of suitable dilutions into the duplicate petri plates and pour 10-15 ml of agar medium (cooled to 45º - 50º c) and rotated the petri dishes clockwise and anti-clockwise for uniform distribution of the inoculums and allow to solidify. Poured the media and diluents control plates. (The elapsing time between the dilution and media. Plating is not to exceed 15 minutes). Carefully mixed the inoculum and allowed to solidify, after solidified inverted and incubated the plates for 72 hours at 30ºC. After the specified the period of incubation colony was counted using colony counting equipment.

For the result to be valid, it is generally considered necessary to count the colonies on at least one dish containing at least 10 colonies [total colonies, typical

colonies or colonies complying with identification criteria, calculate the number N of microorganisms present in the test sample as a weighted mean from two successive dilutions using Equation (1):

$$N = \sum C / V \times 1.1 \times d$$

Where,

$\sum C$ = Sum of the colonies counted on the two dishes retained from two successive dilutions, at least one of which contains a minimum of 10 colonies; V = The volume of inoculum placed in each dish, in milliliters; d = The dilution corresponding to the first dilution retained [d 1 when the undiluted liquid product (test sample) is retained].

3.5. Collection of feedback form from the consumers

A survey was conducted to collect the feedback from the consumers on the edible cutlery that was formulated (Arndt, 1967).The survey was conducted among the residental people of 3 different parts of Coimbatore district. The product ws assessed with a closed ended questionaire which consisted a set of 15 questions related with the product quality and feed back on the edible cutlery. The questionnaire was assessed among 100 respondents belonging to the age group of 20-50 years. These questionnaires was evaluated based on the probability of the response of the respondents and were considered to assess the product acceptabilty among the community. The questionnaire includes questions related with the product quality, acceptability and opinion related with promotion of the product. The questionaries used in collection of feedback is enclosed in Appendix II.

Plate 7 – Collection of feedback form from the consumers

3.6. Interpretation and analysis of data using appropriate statistical tools

Process of analysis and interpretation of data was carried out in a systemic manner. After the data has been collected, the investigator started analysing the gathered data. The collected data was properly recorded, consolidated, tabulated and analyzed to conclude the study with appropriate conclusions without any error.The statistical tools used in the interpretation of data were response surface methodology for interpreting the resultsof sensory evaluation of the antioxidant rich edible cutlery, SPSS software was used for analysis of t-test, standard deviation and mean for interpretation of data.

3.6.1 Statistical Package for Social Science (SPSS)

The SPSS software is used to determine the statistical data such as F-Value, t - test, standard deviation and mean for analysing the sensory evaluation, feedback of the study, nutritional interpretation and other parameters.The MS Word Excel is used to feed the data collected in the study and were used for further interpretation of the study.

By using the above methods standard and the variations of the edible cutlery was analyzed to determine the value and the values were discussed in the Chapter IV.

3.7 Ethical clearance

The research design and the etiquettes used in the study was submitted for scrutinisation and approval to the Institutional Human Ethics Committee and ethical clearance approval was obtained.The Ref.No. is AUW/IHEC-18-19/FSN/FHP-05. The ethical clearance approval letter was enclosed in AppendiX III.

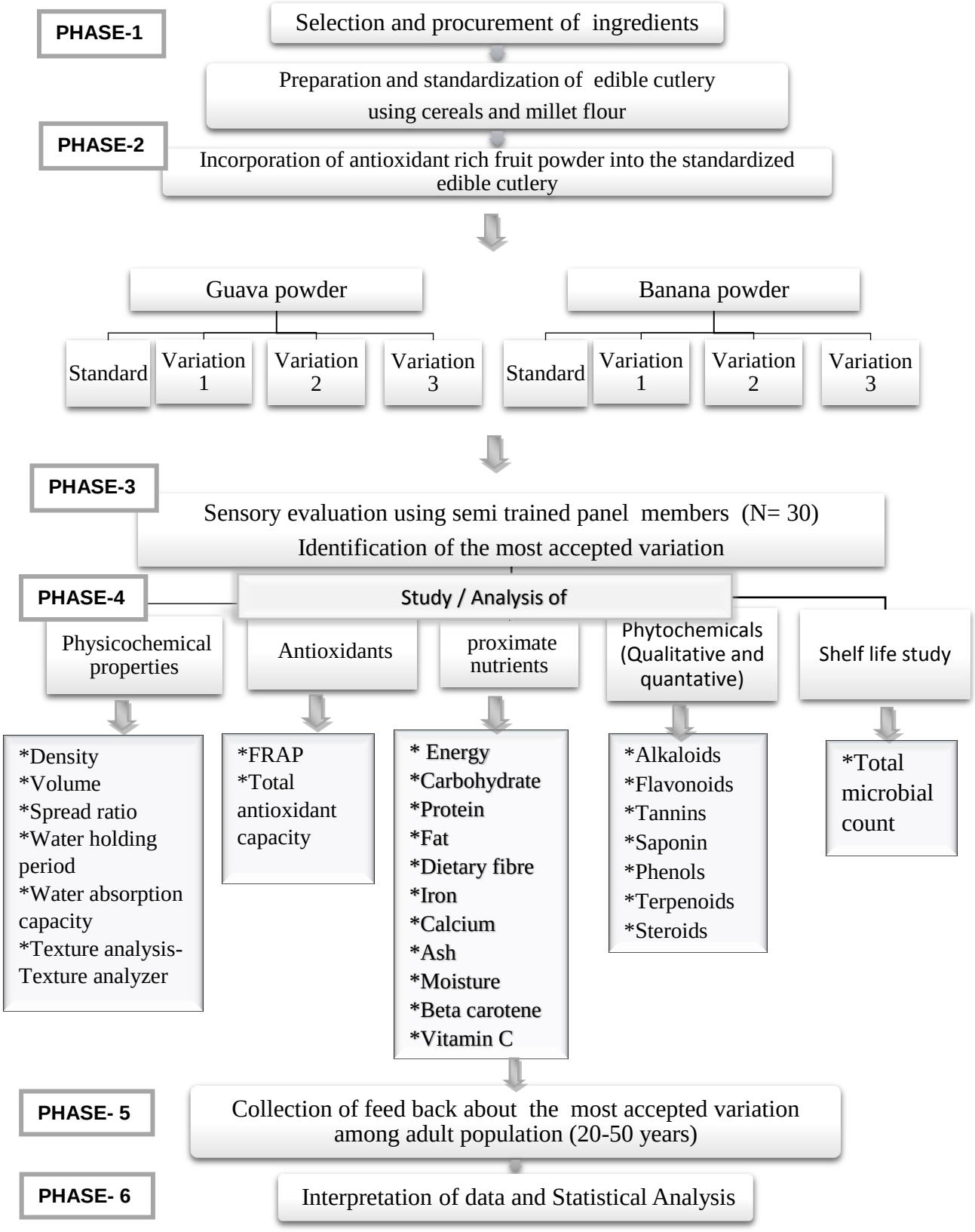


Figure 1

Research design

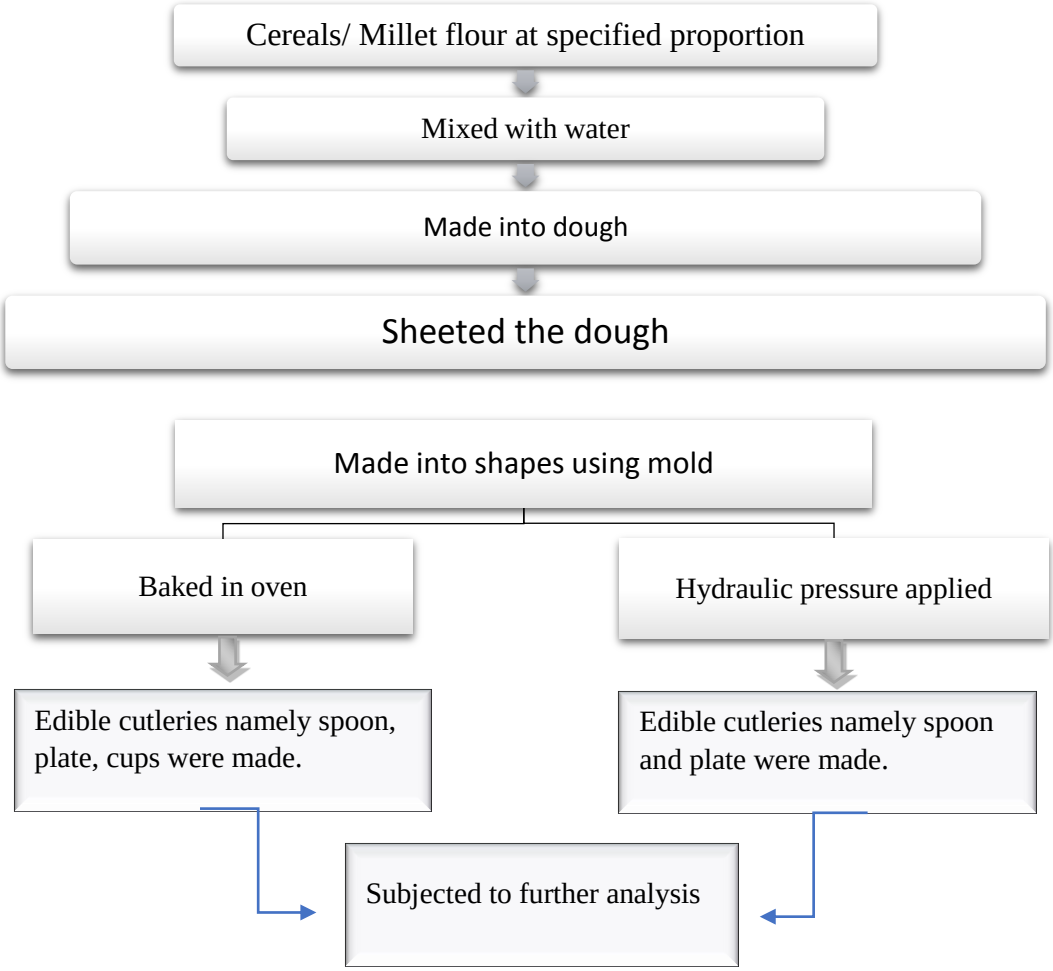


Figure 2

Preparation of antioxidant enriched edible cutlery

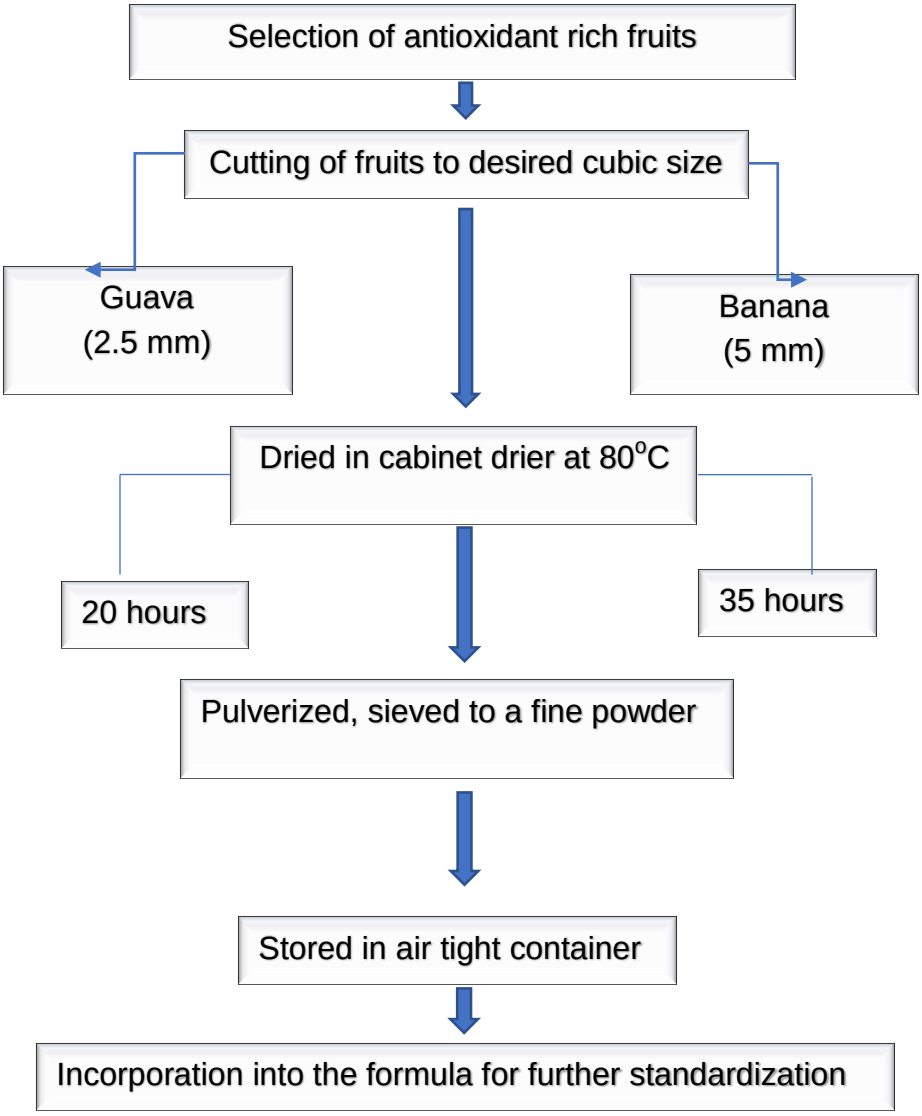


Figure 3

Preparation of Dehydrated Antioxidant Rich Fruit powder

4. RESULTS AND DISCUSSION

The Results and Discussion pertaining to the study on "**Development and Evaluation of Antioxidant Enriched Edible Cutlery**" was analyzed, consolidated discussed and systematically presented under the following segments :

4.1 Formulation and standardisation of antioxidant enriched edible cultery

4.2 Organoleptic Evaluation of the antioxidant enriched edible cultery

4.3 Analysis of the most accepted variation of antioxidant enriched edible cutlery

- 4.3.1 Physicochemical properties
- 4.3.2 Textural properties
- 4.3.3 Total antioxidant capacity
- 4.3.4 Nutrient content
- 4.3.5 Phytochemical properties
- 4.3.6 Microbial analysis

4.4 Cost scrutiny of the antioxidant enriched edible cultery

4.5 Feedback of the community about the antioxidant enriched edible cultery

4.1 Formulation and standardisation of antioxidant enriched edible cultery

The millets like sorghum flour (*Sorghum bicolour*), barnyard millet flour (*Echinochola esculenta*), wheat flour (*Triticum*), corn flour (*Zea mays L*) were used as the basic ingredients for the formulation of the edible cutlery. These were enriched with antioxidants and acts as a key to prevent the cause of oxidative stress. The fruits were used in the form of dried powder as the key ingredient to include into the cutlery enhancing the antioxidant property.

Reviewing the literature for antioxidant rich fruits, it was decided to use guava (*Psydium guajava*) and banana (*Musa paradisiaca*) for the study. These fruits were dehydrated using cabinet drying method to a residual moisture content of less than 10 per cent. They were dried, powdered and incorporated into the standardized formula of edible cutlery.

Table III given below depicts the composition of variations of standarized edible cutlery incorporated with dehydrated fruit powder.

TABLE III

COMPOSITION OF STANDARDISED EDIBLE CUTLERY INCORPORATED WITH DEHYDRATED FRUIT POWDER

Ingredients	Standard	Variation I (%)	Variation II (%)	Variation III (%)
Corn flour	10	10	10	10
Barnyard millet flour	20	20	20	20
Sorghum flour	20	20	20	20
Wheat flour	50	40	30	20
Dried guava / banana powder	-	10	20	30

The temperature, time and moisture content were the most important aspects that affects the physicochemical, nutritional and microbial characteristics of the product. Hence, the temperature and time taken for dehydration using cabinet drier and weight (both initial and final) of the guava and banana fruit was recorded.

Table IV given below depicts the temperature, time, moisture content and weight (initial and final) of the cabinet dried fruit.

TABLE IV

TEMPERATURE, TIME, MOISTURE CONTENT AND WEIGHT OF THE CABINET DRIED FRUIT POWDER

Fruit	Temperature C^0	Time for drying (hours)	Weight (g)		Moisture %	
			Fresh	After drying	Fresh	After drying
Guava	80	20	1000	185	129.6	5.4
Banana	80	35	1000	155	116.8	7.6

One kilogram of guava with the moisture content of 129.6 per cent was taken and was dehydrated for 20 hours. After dehydration using cabinet drier, the moisture content was found to be 5.4 per cent with a final weight of 185 g. So 1000 g of fresh guava

yielded 185 g of dried product after drying with 5.4 per cent moisture. One kilogram of banana with the moisture content of 116.8 per cent was taken and were dehydrated for 35 hours.The weight after dehydration reduced to 155 g with a moisture content of 7.6 per cent. It was observed that banana took 35 hours than guava with 20 hours for dehydration. The temperature used for dehydrating the sample was 80^0C for both guava and banana fruits.

4.2 Organoleptic Evaluation of the formulated culteries

Sensory evaluation of the developed edible cutlery was done in Foods Laboratory of the Food Science and Nutrition Department of Avinashilingam Institute for Home Science and Higher Education for Women , Coimbatore. The score card was given to the panel members for evaluation of the edible cutlery incorporated with fruit powder at different concentrations (Appendix I). The sensory evaluation was done for two samples of dehydrated powders of guava and banana enriched edible cutlery with three variations along with the standard. The mean scores of evaluation of the dehydrated guava powder incorporated edible cutlery along with the variations is given in Table V and Figure 4.

TABLE V

SENSORY CHARACTERISTICS OF THE DEHYDRATED GUAVA POWDER INCORPORATED EDIBLE CUTLERY

Criteria	Standard	Variations		
		I	II	III
Flavour	5.00±0.00 ^{c}	4.56±0.77^b	4.63±0.66^b	*4.73±0.58^c
Colour	5.00±0.00 ^{c}	4.46±0.97^b	4.50±0.90^b	4.80±0.55^c
Appearance	5.00±0.00 ^{c}	4.60±0.67^b	4.46±0.86^b	4.76±0.57^c
Texture	4.97±0.18^c	4.16±1.20 ^{b}	4.13±1.22^b	4.93±0.37^c
Taste	4.90±0.31^c	4.36±1.03^b	4.33±0.92^b	*4.50±0.77 ^{c}
Overall acceptability	4.97±0.18^c	4.46±0.89^b	4.53±0.86^b	4.70±0.59 ^{c}

b- Not significant within groups, c- significant for both between and within groups.

***** $p<0.05$; Significant at 5 per cent level

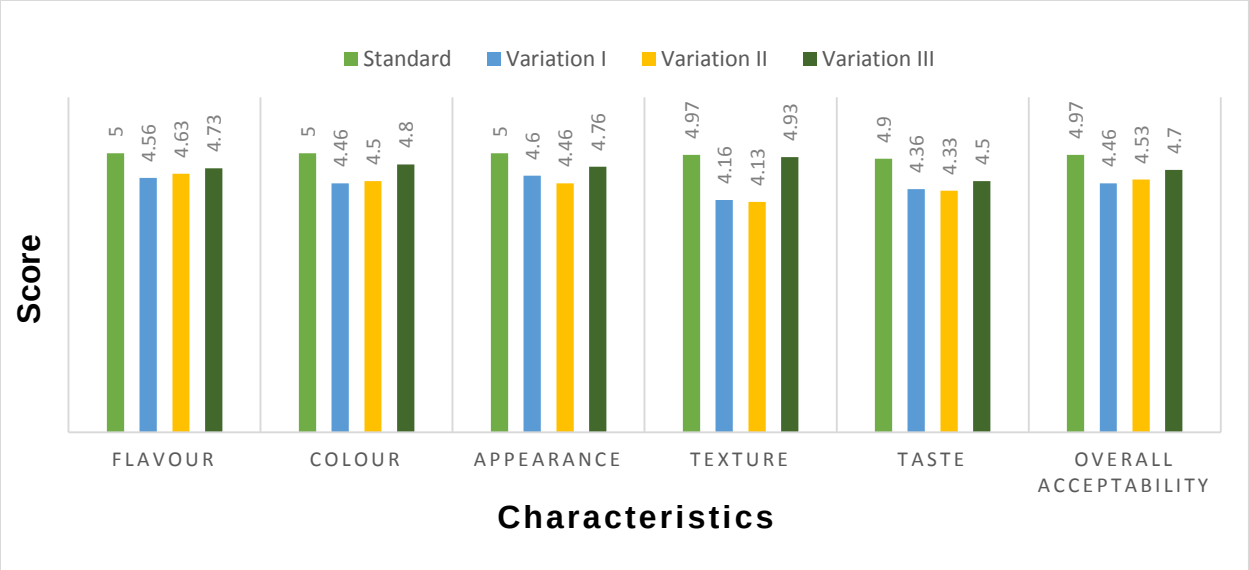


Figure 4

Sensory characteristics of the dehydrated guava powder incorporated edible cutlery

Sensory evaluation of dehydrated guava powder incorporated edible cutlery revealed that the flavour for standard is 5, variation III is 4.73, variation II is 4.63 and the variation I is 4.56 and is found to be statistically significant at 5 per cent. The mean value obtained for colour was 5 for standard, followed by 4.8 for variation III, 4.5 for variation II and 4.4 for varation I. The mean score for appearance of standard is 5 , followed by 4.76 for variation III, 4.6 for variation I is and the least is 4.4 for variation II. The mean score for texture of standard is 4.97 , followed by 4.93 for variation III, 4.16 for variation I and the least is 4.14 for variation II . The mean scores for taste of standard is 4.9 , followed by 4.5 for variation III, 4.36 for variation I and the least is 4.33 for variation II.

The overall acceptability of dehydrated guava powder incorporated edible cutlery revealed that variation III had a maximum mean score of 4.7 and was comparable with the standard with 4.9. Overall the variation I and II were not significant within groups but standard and variation III was significant at 5 per cent level for both within and between the groups.

The mean scores of the sensory evaluation of the dehydrated banana powder incorporated edible cutlery along with the variation is presented in the Table VI and Figure 5.

TABLE VI

SENSORY CHARACTERISTICS OF THE DEHYDRATED BANANA POWDER INCORPORATED EDIBLE CUTLERY

Criteria	Standard	Variations		
		I	II	III
Flavour	5.00±0.00 ^{c}	*3.67±0.8^{ab}	3.66±0.75^{ab}	3.50±0.77^{ab}
Colour	5.00±0.00 ^{c}	*3.70± 0.84 ^{ab}	3.63±0.71^{ab}	3.53±0.77^{ab}
Appearance	5.00±0.00 ^{c}	*3.60 ± 0.72 ^{ab}	3.53±0.73^{ab}	3.50 ± 0.77 ^{ab}
Texture	4.97±0.18^{c}	2.97±0.61^{ab}	3.20±0.61 ^{ab}	3.13±0.62^{ab}
Taste	4.90±0.31^{c}	*3.63±0.80^{ab}	3.43±0.72^{ab}	3.46±0.73^{ab}
Overall acceptability	4.97±0.18^{c}	*3.50 ± 0.73 ^{ab}	3.46±0.68^{ab}	3.46±0.73^{ab}

a-Not significant between groups , b- Not significant within groups, c- significant for both between and within groups. * p<0.05; Significant at 5 per cent level

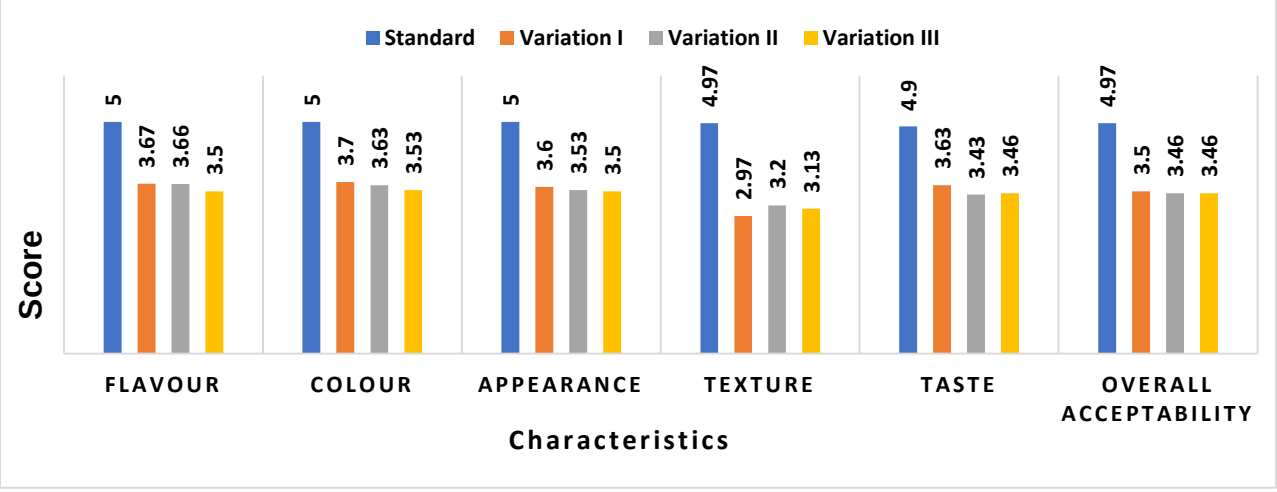


Figure 5

Sensory characteristics of the dehydrated banana powder incorporated edible cutlery

Sensory evaluation of dehydrated banana powder incorporated edible cutlery revealed that the mean score for flavour for standard is 5.00, variation I is 3.67, variation II is 3.60 and the variation III is 3.50 The mean value obtained for colour was 5.00 for standard, followed by 3.70 for variation I, 3.60 for variation II and 3.5 for varation III. The mean value for appearance for standard is 5.00 , followed by 3.60 for variation I, 3.53 for variation II and 3.50 for variation III. The mean scores of texture for standard is 4.97 , followed by 3.20 for variation II, 3.13 for variation III and the least is 2.90 for variation I. The mean values of taste for standard scored 4.90 , followed by 3.46 for variation III, 3.63 for variation I is and the least is 3.43 for variation II.

The overall acceptability of dehydrated banana powder incorporated edible cutlery revealed that variation I had a maximum mean score of 3.50 and was comparable with the standard of 4.90. When compared with variation II and III seems to be the same *i.e* 3.46. Overall the variation I, II and III were not significant within groups and also between the groups. Standard was significant at 5 per cent level for both within and between the groups.

4.4 Analysis of the most accepted variation of antioxidant enriched edible cutlery

4.3.1 Physicochemical properties

Table VII explains the physicochemical properties of antioxidant enriched edible cutlery.

TABLE VII

PHYSICOCHEMICAL PROPERTIES OF THE DEHYDRATED GUAVA POWDER INCORPORATED EDIBLE CUTLERY

Criteria	Baking method				Hydralic pressure method			
	Spoon		Plate		Spoon		Plate	
	Standard	Variation (III)	Standard	Variation (III)	Standard	Variation (III)	Standard	Variation (III)
Volume (cm^3)	4	4	7	7	6	6	12	11

Weight (g)	15	15	70	70	18	18	110	110
Density g/cm^3	3.75	3.75	10	10	3	3	9.2	9.2
Thickness (mm)	3	3	4	4	2	2	6	6
Diameter (mm)	110	110	150	150	148	148	160	160
Spread ratio (cm)	3.7	3.7	3.8	3.8	7.4	7.4	2.6	2.6
Water holding period (minutes)	45	42	60	55	65	62	125	115
Water absorption capacity (%)	50	45	50	45	45	42	45	42

Two different methods were opted for prepartion of edible cutlery namely baking method and hydraulic pressure method. The physicochemical properties namely volume, weight, density , thickness, diameter, spread ratio, water holding capacity and water absorption capacity of the cutlery were assessed for edible cutlery - spoon and plate using baking and hydraulic pressure method.The physical properties were assessed for the most accepted variation of dehydrated guava powder incorporated edible cutlery at 30 per cent level .

The dehydrated guava powder incorporated spoon by baking method at 30 per cent concentration had same mean volume of 4 cm^3 as that of the standard. The mean weight of standard spoon and variation III spoon was 15 g. The density of standard spoon was 3.75 g/cm^3 which was the same as that of variation III. The mean thickness of both standard and variation III was 3 mm. The mean diameter was found to be 110 mm for standard spoon and 30 per cent dehydrated guava powder incorporated spoon *i.e* variation III. The mean spread ratio was found to be 3.7 cm for standard spoon and variation III. It was observed that mean water holding capacity was 45 minutes for standard spoon whereas it was 42 minutes for variation III. The mean water absorption capacity was 50 per cent for standard spoon and 45 per cent for variation III *i.e.* dehydrated guava powder incorporation at 30 per cent level.

The dehydrated guava powder incorporated plate by baking method at 30 per cent concentration had same mean volume of 7 cm^3 as that of the standard. The mean weight of standard plate and variation III plate was 70 g. The density of standard plate was 10 g/cm^3 which was the same as that of variation III. The mean thickness of both standard and variation III plate was 4 mm. The mean diameter was found to be 150 mm for standard plate and 30 per cent dehydrated guava powder incorporated spoon *i.e* variation III. The mean spread ratio was found to be 3.8 cm for standard plate and variation III. It was observed that mean water holding capacity was 60 minutes for standard plate whereas it was 55 minutes for variation III. The mean water absorption capacity was 50 per cent for standard plate and 45 per cent for variation III *i.e.* dehydrated guava powder incorporation at 30 per cent level.

The dehydrated guava powder incorporated spoon by hydraulic pressure method at 30 per cent concentration had same mean volume of 6 cm^3 as that of the standard. The mean weight of standard spoon and variation III was 18 g. The density of standard spoon was 3 g/cm^3 which was the same as that of variation III. The mean thickness of both standard and variation III spoon was 2 mm. The mean diameter was found to be 148 mm for standard spoon and 30 per cent dehydrated guava powder incorporated spoon *i.e* variation III. The mean spread ratio was found to be 7.4 cm for standard spoon and variation III. It was observed that mean water holding capacity was 65 minutes for standard spoon whereas it was 62 minutes for variation III. The mean water absorption capacity was 45 per cent for standard spoon and 42 per cent for variation III *i.e.* dehydrated guava powder incorporation at 30 per cent level.

The dehydrated guava powder incorporated plate by hydraulic pressure method at 30 per cent concentration had mean volume of 12 cm^3 for standard and 11 cm^3 for variation III. The mean weight of standard plate and variation III was 110 g. The density of standard plate was 9.2 g/cm^3 which was the same as that of variation III. The mean thickness of both standard and variation III plate was 6 mm. The mean diameter was found to be 160 mm for standard plate and 30 per cent dehydrated guava powder incorporated plate *i.e* variation III. The mean spread ratio was found to be 2.6 cm for standard plate and variation III. It was observed that mean water holding capacity was

125 minutes for standard plate whereas it was 115 minutes for variation III. The mean water absorption capacity was 45 per cent for standard plate and 42 per cent for variation III *i.e.* dehydrated guava powder incorporation at 30 per cent level.

The mean scores obtained for volume, weight , density , thickness, diameter, water holding capacity was observed to be very high for cutlery made with hydraulic pressure method for both spoon and plate for standard and for variation III. Spread ratio and water absorption capacity is lesser than the baked method. These properties suits for commericialization of the cutlery but not for consumption as they are too thick and hard. The spoons was edible and can be consumed due to their lesser thickness and density. There is a need in customization of the machineries for formulation of edible cutlery with less molding thickness, temperature, preparation time, etc as like waffle makers. Spoons and plates prepared using baking method were not too tough and were easily chewable. Hence the acceptablity was reported high for baked cutlery for both spoon and plate prepared using dehydrated guava powder.

TABLE VIII

PHYSICOCHEMICAL PROPERTIES OF THE DEHYDRATED BANANA POWDER INCORPORATED EDIBLE CUTLERY

Criteria	Baking method			
	Spoon		Plate	
	Standard	Variation (I)	Standard	Variation (I)
Volume (cm^3)	4	6	7	9
Weight (g)	15	15	70	74
Density (g/cm^3)	3.75	2.5	10	8.2
Thickness (mm)	3	5	4	6
Diameter (mm)	110	110	150	150
Spread ratio (cm)	3.6	2.2	3.7	2.5
Water holding period (minutes)	45	16	60	27
Water absorption capacity (%)	50	55	50	58

Two different methods were opted for prepartion of edible cutlery namely baking method and hydraulic pressure method. The physicochemical properties was assessed only for baking method as hydraulic pressure method did not come out well, as the dough did not lend for hydraulic pressure method.The dough squeezed out before applying the hydraulic pressure. Hence the physicochemical characteristics was assessed for spoons and plates prepared by baking method only.

The dehydrated banana powder incorporated spoon by baking method at 10 per cent concentration had the mean volume of 4 cm^3 for standard and 6 cm^3 for variation I. The mean weight of standard spoon and variation I was 15 g. The density of standard spoon was 3.75 g/cm^3 and 2.5 g/cm^3 for variation I. The mean thickness of the standard was 3 mm and variation I was 5mm. The mean diameter was found to be 110 mm for standard spoon and 10 per cent dehydrated banana powder incorporated spoon *i.e* variation I. The mean spread ratio was found to be 3.6 cm for standard spoon and 2.2 cm for variation I. It was observed that mean water holding capacity was 45 minutes for standard spoon whereas it was 16 minutes for variation I. The mean water absorption capacity was 50 per cent for standard spoon and 55 per cent for variation I *i.e.* dehydrated banana powder incorporation at 10 per cent level.

The dehydrated banana powder incorporated plate by baking method at 10 per cent concentration had the mean volume of 7 cm^3 for standard and 9 cm^3 for variation I. The mean weight of plate standard was 70 g and variation I was 74 g. The density of standard plate was 10 g/cm^3 and 8.2 g/cm^3 for variation I. The mean thickness of the standard was 4 mm and variation I was 6 mm. The mean diameter was found to be 150 mm for standard plate and 10 per cent dehydrated banana powder incorporated plate *i.e* variation I. The mean spread ratio was found to be 3.7 cm for standard plate and 2.5 cm for variation I. It was observed that mean water holding capacity was 60 minutes for standard plate whereas it was 27 minutes for variation I. The mean water absorption capacity was 50 per cent for standard plate and 58 per cent for variation I *i.e.* dehydrated banana powder incorporation at 10 per cent level.

It was found that the 10 per cent dehydrated banana powder incorporated edible cutlery (variation I) was not strong as they had low water holding period and high water absorption capacity.

Thus the 30 per cent dehydrated guava powder incorporated edible cutlery is found to be better in its physicochemical properties than the 10 per cent dehydrated banana powder incorporated edible cutlery.

4.3.2 Texture profile analysis

The texture profile namely speed stain, hardness and adhesive force of the edible cutlery , *i.e.* spoon and plate incorporated with dehydrated guava powder for both standard and variation III by both methods of baking and hydraulic pressure method is given in the Table IX and the Figure 6.

TABLE IX

TEXTURE PROFILE OF THE
DEHYDRATED GUAVA POWDER INCORPORATED EDIBLE CUTLERY

Criteria	Baking method (Guava)				Hydralic pressure method			
	Spoon		Plate		Spoon		Plate	
	Standard	Variation III	Standard	Variation III	Standard	Variation III	Standard	Variation III
Speed stain (mm/sec)	5	5	5	5	5	5	15	15
Hardness(N)	45.0714	45.001	157.221	153.011	47.023	46.0041	441.321	438.011
Adhesive force (N)	0.05587	0.05585	0.85340	0.08782	0.2027	0.2063	0.38987	0.38754

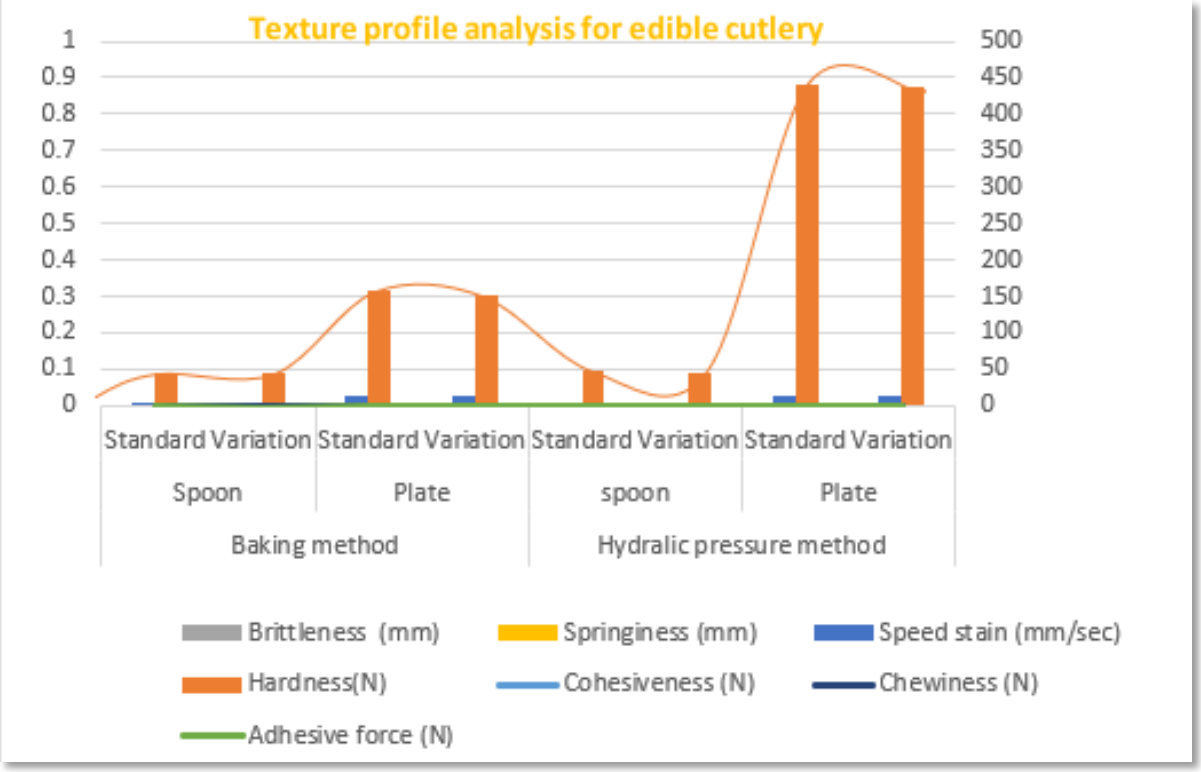


Figure 6

Textural properties of the dehydrated guava powder incorporated edible cutlery

The hardness of the edible plates made using hydraulic pressure method is too hard *i.e* 441.3 and 438.01 N for standard and variation III respectively. with the application of speed stain of 15 Newtons and has the adhesiveness of 0.38 N respectively. They are considered to be too hard for consumption. But the edible spoons made using hydraulic pressure method has the hardness of 47 and 46 N for standard and variation III respectively with the application of speed stain of 5 Newtons and the adhesiveness of 0.2027 for standard and 0.2063 for vatiation III which was hard but not brittle and they are acceptable for consumption.

Hardness of the edible plates and spoons made using baking method were also analyzed which showed hardness of 157 N and 153 N for standard and variation III plates respectively. The spoons had 45 N hardness with the application of 5 Newtons of force and 0.05 N of adhesive force for both standard and hydraulic pressure method.

It shows that the textural properties of the plates made by baking method is more suitable for consumption than the plates prepared by hydraulic pressure method. No much difference were observed with the textural properties of edible spoons prepared using both the methods for both standard and variation III. The brittleness, stroke, springiness, cohesiveness, chewiness of the edible cutlery were also tested and the result showed that there existed no such properties for the formulated edible cutlery.

The texture analysis as analyzed using texture analyzer for dehydrated banana powder incorporated edible cutlery is given in Table X.

TABLE X

TEXTURE PROFILE OF THE
DEHYDRATED BANANA POWDER INCORPORATED EDIBLE CUTLERY

Criteria	Baking method (Banana)			
	Spoon		Plate	
	Standard	Variation	Standard	Variation
Speed stain (mm/sec)	5	5	5	5
Hardness(N)	45.0714	7.60396	157.221	62.031
Adhesive force (N)	0.05587	0.01550	0.85340	0.04331

Hardness of the edible plates and spoons made using baking method were analyzed which showed hardness of 157 N and 62 N for standard and variation I plates respectively. The spoons has 45 N and 7.60396 N hardness with the application of 5 Newtons of force and 0.05 N and 0.015 N of adhesive force for both standard and Variation I. It shows that the textural properties of the plates made by baking method is more suitable for consumption. The brittleness stroke, springiness, cohesiveness, chewiness of the edible cutlery were also tested and the result showed that there existed no such properties for the formulated edible cutlery.

4.3.3 Total antioxidant capacity

Antioxidants have long been recognized as having protective functions against cellular damage and reduce the risk of chronic diseases. The total anti-oxidant capacity of the product is discussed in the following Table XI.

TABLE XI

ANTIOXIDANT STATUS OF THE ANTIOXIDANT ENRICHED EDIBLE CUTLERY

Antioxidant Test	Dehydrated fruit powder incorporated edible cutlery	
	Guava	Banana
Ferric Reducing Antioxidant Power (FRAP)	98 µg/g	56.61 µg/g
Total Antioxidant Capacity (TAC)	170 µg/g	108 µg/g

The antioxidant status of the formulated edible cutlery were done for the dehydrated guava powder incorporated edible cutlery at 30 per cent and dehydrated guava powder incorporated edible cutlery at 10 per cent. The ferric reducing antioxidant power was 98 µg/g for dehydrated guava powder incorporated edible cutlery and 56.61 µg/g for dehydrated banana powder incorporated edible cutlery. FRAP test done reveals the capacity of antioxidants enriched edible cutlery reduced the oxidative stress in the body. The 30 per cent dehydrated guava powder incorporated edible cutlery showed higher content of FRAP than the 10 per cent dehydrated banana incorporated edible cutlery. The total antioxidant capacity of the edible cutlery was recorded as 170 µg/g for 30 per cent dehydrated guava powder incorporated edible cutlery and 108 µg/g for 10 per cent dehydrated banana powder incorporated edible cutlery. Thus, the results showed that the 30 per cent dehydrated guava powder incorporated edible cutlery are rich in antioxidants than the dehydrated banana powder incorporated edible cutlery at 10 per cent.

4.3.4 Nutrient content

The nutrient content of the most accepted edible cutlery- dehydrated guava powder incorporated edible cutlery and dehydrated banana powder incorporated edible cutlery is given in Table XII.

TABLE XII

NUTRIENT CONTENT OF THE ANTIOXIDANT ENRICHED EDIBLE CUTLERY

Name of the Nutrient	Dehydrated fruit powder incorporated edible cutlery Content / 100 g	
	Guava	**Banana**
Energy (KCal)	346.5	311.74
Carbohydrates (g)	73.5	64.12
Protein (g)	10.2	9.18
Fats (g)	1.3	2.06
Dietary fibre (g)	8.8	10.8
Iron (mg)	4.6	3.3
Calcium (mg)	28.0	22.0
Vitamin C (mg)	2.5	0.8
β carotene (µg)	54.0	13.4
Ash content (g)	5.0	6.3
Moisture content (%)	5.6	7.4

Table XII revealed that the 30 per cent dehydrated guava powder incorporated edible cutlery had energy with 346.5 KCal which includes carbohydrates (73.5 g), protein (10.2g), fats (1.3 g) and dietary fibre (8.8 g). The minerals like iron and calcium estimated by preparing ash solution was 4.6 mg and 28 mg respectively. The micro nutrient content present in 100 g of sample was recorded as 54 µg of β carotene and 2.5 mg of vitamin C. The ash content present in 100 g of the sample was recorded as 5 g and its moisture content is 5.6 per cent. From this reading, it is observed that the product formulated is rich in energy, dietary fibre, iron, calcium, vitamin C and β carotene.

The edible cutlery *i.e* dehydrated banana powder incorporated edible cutlery at 10 per cent level had energy with 311.74 Kcal which includes carbohydrates (64.12 g),

protein (9.18g), fats (2.06 g) and dietary fibre (10.8 g). The minerals like iron and calcium estimated by preparing ash solution and 3.3 mg and 22 mg respectively. The micronutrient content present in 100 g of sample was recorded as 13.4 µg of β carotene and 0.8 mg of vitamin C. The ash content present in 100 g of the sample is recorded as 6.3 g and the moisture content was 7.4 per cent. From this reading, it is observed that the product formulated is rich in energy, dietary fibre, iron, calcium, ash and moisture content.

On comparison, it was observed that energy, carbohydrates, fats, iron, calcium, vitamin C and β carotene is more in dehydrated guava powder incorporated edible cutlery (variation III) than the dehydrated banana powder incorporated edible cutlery (variation I). However, the fat, ash and the moisture content were more in dehydrated banana powder incorporated edible cutlery (variation I) than dehydrated guava powder incorporated edible cutlery (variation III).

4.3.5 Phytochemical properties

Phytochemical constituents present in the formulated edible cutlery incorporated with dehydrated guava powder at 30 per cent and dehydrated banana powder at 10 per cent was estimated both qualitatively and quantitatively and is presented below in Table XIII.

TABLE XIII

PHYTOCHEMICALS OF THE ANTIOXIDANT ENRICHED EDIBLE CUTLERY

Phytochemical	Dehydrated fruit powder incorporated edible cutlery			
	Qualitative		Quantitative (%)	
	Guava Variation III	Banana Variation I	Guava Variation III	Banana Variation I
Alkaloids	+	+	1.8	2.6
Flavonoids	+	+	0.5	0.8
Tannins	+	+	1.2	0.03
Saponin	-	+	-	0.6
Phenol	+	+	2.2	0.5

From the above Table XIII, it was revealed that the dehydrated guava powder incorporated edible cutlery with 30 per cent incorporation is analyzed for the presence of phytochemicals. Alkaloids, flavonoids, tannins, phenol showed positive result *i.e* the presence of alkaloids, flavonoids, tannins, phenol and gave negative result for saponin, terpenoids and steroids *i.e* absence of saponin, terpenoids and steroids. The quantitative analysis depicts the quantity of phytochemicals present in the given sample (variation III). The dehydrated guava powder incorporated edible cutlery consists of 1.8 per cent of alkaloids, 0.5 per cent of flavonoids, 1.2 per cent of tannins and 2.2 per cent of phenols respectively. Thus, the formulated edible cutlery was rich in phytochemicals especially phenols and alkaloids.

The dehydrated banana powder incorporated edible cutlery with 10 per cent incorporation is analyzed for the presence of phytochemicals. Alkaloids, flavonoids, tannins, saponin, phenol showed positive result *i.e* the presence of alkaloids, flavonoids, tannins, saponin, phenol and gave negative result for terpenoids and steroids *i.e*

absence of terpenoids and steroids. The quantitative analysis depicts the quantity of phytochemicals present in the given sample (variation I). The dehydrated banana powder incorporated edible cutlery consists of 2.6 per cent of alkaloids, 0.8 per cent of flavonoids, 0.03 per cent of tannins, 0.6 per cent of saponin and 0.5 per cent of phenols respectively. Thus, the formulated edible cutlery was rich in phytochemicals especially phenols and alkaloids.

4.3.6 Microbial analysis

The shelf life study was done using the total microbial count method to find out the microbial content of the most accepted edible cutlery – dehydrated guava powder incorporated edible cutlery (variation III) and dehydrated banana powder incorporated edible cutlery were assessed for day 1 and day 7 and after 2 months is depicted in Table XIV.

TABLE XIV

TOTAL BACTERIAL COUNT OF THE ANTIOXIDANT ENRICHED EDIBLE CUTLERY

Period of analysis	**Total microbial count of the dehydrated fruit powder incorporated edible cutlery**	
	Guava	**Banana**
1st day	22 x 10^1 cfu/g	26 x 10^1 cfu/g
7th day	51 x 10^1 cfu/g	53 x 10^1 cfu/g
60th day	79 x 10^1 cfu/g	83 x 10^1 cfu/g

Cfu – Colony forming Unit

A food is reported to be toxic when it reaches > 103 X 10^1 cfu/g. (FSSAI, 2018) In the formulated edible cutlery, the total microbial count for dehydrated guava powder incorporated edible cutlery for the day 1 is reported to be 22 x 10^1 cfu/g and for day 7 as 51 x 10^1 cfu/g. It clearly shows that the rate of growth of microorganism is very slow. After a storage period of more than 2 months it had 79 x 10^1 cfu/g, it was noted that there is no characteristic physical or textural change observed in the product. The total

microbial count for dehydrated banana powder incorporated edible cutlery for the day 1 is reported to be 22 x 10^1 cfu/g and for day 7 as 53 x 10^1 cfu /g. It clearly shows that the rate of growth of microorganism is slow but quite differs from the microbial count of dehydrated guava powder incorporated edible cutlery. After a storage period of more than 2 months it had 83 x 10^1 cfu/g. As the study period is less, the shelf life study could not be conducted for a longer period. But within this period of shelf life study, it was found that no characteristic change was observed in the edible cutlery. Hence the result proves that the product has good keeping quality, extended shelf life and the rate of spoilage is very less. This may be due to the baking method where the moisture content was reduced to 5.6 per cent and 7.4 per cent.

4.4 Cost scrutiny of the antioxidant enriched edible cutlery

The cost of the product valuates the value of the product. Cost calculation is the mandatory source and is an initiative for promoting a product in the market. In this study the cost incurred for the edible cutlery formulated namely spoons and plates by two different methods such as baking and hydraulic pressure method by incorporating dehydrated guava powder at 30 per cent and banana powder at 10 per cent is calculated and is presented in Table XV.

TABLE X

COST SCRUTINY OF THE ANTIOXIDANT ENRICHED EDIBLE CUTLERY

Variations	Product		Cost (Rs per piece)
Dehydrated guava powder incorporated edible cutlery	Spoon	Baked	7.00
		Hydraulic pressure	12.00
	Plate	Baked	20.00
		Hydraulic pressure	30.00
Dehydrated banana powder incorporated edible cutlery	Spoon	Baked	10.00
	Plate	Baked	22.00

The cost of dehydrated guava powder incorporated edible cutlery prepared by baking method was Rs. 7.00 per piece of spoon and Rs 20.00 per piece of plate. The cost of spoon prepared by hydraulic pressure method was Rs.12.00 per piece and plate is Rs. 30.00 per piece. The cost of dehydrated banana powder incorporated edible cutlery prepared by baking method was Rs. 10.00 per piece of spoon and Rs 22.00 per piece of plate.

By this discussion, we can observe that the cost of dehydrated guava powder incorporated edible cutlery are cheaper than the dehydrated banana powder incorporated edible cutlery. And also the baked cutlery are cost effective than the hydraulic pressure method developed cutlery.

4.5 Feedback of the community on the edible cutlery

After testing the product for its physical properties, nutrients, phytochemicals, microbial content and shelf life, the product is found to be acceptable for consumption. Thus, as a final stage of evaluating the product a survey was conducted using random sampling method with 100 participants belonging to the age group of 20 – 50 years (adult population) to find out the acceptability of the common people.

The response of the study participants was assessed using a close ended questionnaire and is depicted on the Table XVI given below:

TABLE XVI

FEEDBACK FROM THE COMMUNITY ON THE EDIBLE CUTLERY

N=100

Criteria	Yes	No
Useful to the community	100	-
Reduce the environmental pollution	100	-
Replace the plastic usage	100	-
Cost effective	89	11
Affordable and accessible for daily use	80	20
The product reduces oxidative stress	92	8
Improve the eating habit of the children	93	7
Improve the nutritional status of the children	96	4
Can be promoted for marketing	99	1
Help to regulate the body functions	98	2
Taste and the quality – acceptable	98	2
Cutlery will attract the children	94	6
Combination of the cutlery and the food suits	99	1
Find any change in the taste and flavour of the food	13	87
Characteristic change in the cutlery	11	89

The above Table XVI discusses the feedback by the community for the edible cutlery formulated and it shows that 100 per cent of the participants accepted that the product replaces the usage of plastic, reduces the environmental pollution and will be useful to the community. 99 per cent of adults accepted that the edible cutlery formulated can be promoted in the market and accepted that the combination of the cutlery suits for the consumption of food, 89 per cent accepted that they are cost effective and 80 per cent accepted that they are affordable and accessible for daily usage.

With the sensory characteristics 98 per cent accepted that the quality and taste of the product quality was good, 89 per cent accepted that the cutlery had no characteristic change and 87 per cent accepted that there is no change in taste and flavour of the food when consumed with the formulated edible cutlery and 94 per cent accepted that the cutlery will attract the children.

When coming to the health point of view 98 per cent accepted that it helps to regulate body functions, 96 per cent accepted that it improves the nutritional status of the individual, 93 per cent accepted that it improves the eating habit of the children and 92 per cent accepted that the product reduces oxidative stress.

Thus, with this survey it was concluded that the edible cutlery formulated were nutritious, health promoting, cost effective, easily accessible, attracts children, eco-friendly and consumer friendly product and also accepted by the community that it can be marketed and they will buy it as they liked the product and their specifications.

Hence the results proved that among variations dehydrated guava powder incorporated edible cutlery at 30 per cent and dehydrated banana powder incorporated edible cutlery at 10 per cent is more acceptable. The variations with banana did not come out well in hydraulic pressure method and also did not have strong and rigid physical properties and nutritional benefits when compared with variations with guava powder. The dehydrated guava powder incorporated edible cutlery at 30 per cent has positive results in all aspects such as method of preparation, sensory characteristics, physicochemical properties, antioxidant properties, nutritional properties, microbial count, cost effective and acceptable by the community to promote the product in the market. Thus, among all variations edible cutlery prepared with dehydrated guava powder incorporated at 30 per cent was the most accepted variation. They are antioxidant rich with high FRAP value and antioxidant capacity, which would help to overcome oxidative stress

5. SUMMARY AND CONCLUSION

Innovations are constantly appearing in food packaging, which leads to a demand for new foods, always aiming at creating a more efficient quality preservation and ecofriendly system. The bioactive compounds play a major in promotion of health and it is very important for the normal functioning of the body. Anti-oxidants have numerous functional properties and also consist of specific health benefits beyond the normal nutritional content. Being a primary binding agent, millets and cereals makes best pair on forming a structure and promotes strong outlook for a product. They have less penetration which will improve the stability and rigidity of the product and also provides extended shelf life. As they are non-perishable product the rate of microbial growth will be very less and the nutritional value remains the same for a long period of time. It adds the texture, aroma and acceptability for the consumer with more functional benefits. It also has the ability to hold the nutrients and trap the properties and enhance the quality of the product. So, incorporating anti-oxidants in the products made out of millets and cereals is trapped and help to promote maximum utilization in the body and to overcome the medical conditions.

Hence these components are used in the formulation of edible cutlery. Millets suits for the formulation of edible cutlery as it provides more nutritional benefit, enhanced quality, physical properties, sensory characteristics and degree of acceptability, suitable for all age groups and for consumption of all types of food. Millets along with fruits provide bioactive components, improves the antioxidant capacity, maintains the reactive oxygen species level and reduces oxidative stress. It acts as an active supplement to the individuals as well as it is multipurpose.

In the present study entitled "**Development and Evaluation of Antioxidant Enriched Edible Cutlery**" was aimed at formulating the antioxidant enriched edible cutlery by incorporating the antioxidant rich samples such as dehydrated guava powder and dehydrated banana powder in three different proportions such as 10, 20 and 30 per cent level by employing two different methods of preparation such as baking and hydraulic pressure method. The developed cutlery was subjected to sensory evaluation with 30 trained panel members and the most acceptable variation was selected for

further analysis of the study. Sensory evaluation of the antioxidant rich edible cutlery revealed that dehydrated guava powder incorporated edible cutlery at 30 per cent level *i.e* variation III and dehydrated banana powder incorporated edible cutlery at 10 per cent level *i.e* variation I was most accepted by the panel members. Hence these two variations prepared by both baking method and hydraulic pressure method were further analyzed for their physicochemical properties, textural properties, total antioxidant capacity, nutrient content, phytochemical properties, microbial analysis, cost scrutiny and feedback from the community of the formulated products were done with the study approval from Institutional Human Ethics Committee of Avinashilingam Institute for Home Science and Higher education for women, Coimbatore and the approval number was AUW/IHEC-18-19/FSN/FHP-05. The sensory scores and other parameters assessed in the study were statistically analyzed for mean, standard deviation, anova and t test to compare and find out the outcome of the study.

The salient findings of the study are summarized below:

- One kilogram of guava with the moisture content of 129.6 per cent was taken and was dehydrated for 20 hours. After dehydration using cabinet drier, the moisture content was found to be 5.4 per cent with a final weight of 185 g. So 1000 g of fresh guava yielded 185 g of dried product after drying with 5.4 per cent moisture. One kilogram of banana with the moisture content of 116.8 per cent was taken and were dehydrated for 35 hours.The weight after dehydration reduced to 155 g with a moisture content of 7.6 per cent. It was observed that banana took 35 hours than guava with 20 hours for dehydration. The temperature used for dehydrating the sample was 80^0C for both guava and banana fruits.
- Sensory evaluation of dehydrated guava powder incorporated edible cutlery revealed that the flavour for standard is 5, variation III is 4.73, variation II is 4.63 and the variation I is 4.56 and is found to be statistically significant at 5 per cent. The mean value obtained for colour was 5 for standard, followed by 4.8 for variation III, 4.5 for variation II and 4.4 for varation I. The mean score for appearance of standard is 5 , followed by 4.76 for variation III, 4.6 for variation I is and the least is 4.4 for variation II. The mean score for texture of standard is

4.97 , followed by 4.93 for variation III, 4.16 for variation I and the least is 4.14 for variation II . The mean scores for taste of standard is 4.9 , followed by 4.5 for variation III, 4.36 for variation I and the least is 4.33 for variation II with $p<0.05$ and significant at 5 per cent for vatiation III.

- The overall acceptability of dehydrated guava powder incorporated edible cutlery revealed that variation III had a maximum mean score of 4.7 and was comparable with the standard with 4.9. Overall the variation I and II were not significant within groups but standard and variation III was significant at 5 per cent level for both within and between the groups.
- The overall acceptability of dehydrated guava powder incorporated edible cutlery revealed that variation III had a maximum mean score of 4.7 and was comparable with the standard with 4.9. Overall the variation I and II were not significant within groups but standard and variation III was significant at 5 per cent level for both within and between the groups.
- Sensory evaluation of dehydrated banana powder incorporated edible cutlery revealed that the mean score for flavour for standard is 5.00, variation I is 3.67, variation II is 3.60 and the variation III is 3.50 The mean value obtained for colour was 5.00 for standard, followed by 3.70 for variation I, 3.60 for variation II and 3.5 for varation III. The mean value for appearance for standard is 5.00 , followed by 3.60 for variation I, 3.53 for variation II and 3.50 for variation III. The mean scores of texture for standard is 4.97 , followed by 3.20 for variation II, 3.13 for variation III and the least is 2.90 for variation I. The mean value of taste for standard scored 4.90 , followed by 3.46 for variation III, 3.63 for variation I is and the least is 3.43 for variation II with $p<0.05$ and significant at 5 per cent for vatiation I.
- The overall acceptability of dehydrated banana powder incorporated edible cutlery revealed that variation I had a maximum mean score of 3.50 and was comparable with the standard of 4.90. When compared with variation II and III seems to be the same *i.e* 3.46. Overall the variation I, II and III were not significant within groups and also between the groups. Standard was significant at 5 per cent level for both within and between the groups.

- Two different methods were opted for prepartion of edible cutlery namely baking method and hydraulic pressure method. The physicochemical properties namely volume, weight, density , thickness, diameter, spread ratio, water holding capacity and water absorption capacity of the cutlery were assessed for edible cutlery - spoon and plate using baking and hydraulic pressure method.The physical properties were assessed for the most accepted variation of dehydrated guava powder incorporated edible cutlery at 30 per cent level .
- The dehydrated guava powder incorporated spoon by baking method at 30 per cent concentration had same mean volume of 4 cm^3 as that of the standard. The mean weight of standard spoon and variation III spoon was 15 g. The density of standard spoon was 3.75 g/cm^3 which was the same as that of variation III. The mean thickness of both standard and variation III was 3 mm. The mean diameter was found to be 110 mm for standard spoon and 30 per cent dehydrated guava powder incorporated spoon *i.e* variation III. The mean spread ratio was found to be 3.7 cm for standard spoon and variation III. It was observed that mean water holding capacity was 45 minutes for standard spoon whereas it was 42 minutes for variation III. The mean water absorption capacity was 50 per cent for standard spoon and 45 per cent for variation III *i.e.* dehydrated guava powder incorporation at 30 per cent level.
- The dehydrated guava powder incorporated plate by baking method at 30 per cent concentration had same mean volume of 7 cm^3 as that of the standard. The mean weight of standard plate and variation III plate was 70 g. The density of standard plate was 10 g/cm^3 which was the same as that of variation III. The mean thickness of both standard and variation III plate was 4 mm. The mean diameter was found to be 150 mm for standard plate and 30 per cent dehydrated guava powder incorporated spoon *i.e* variation III. The mean spread ratio was found to be 3.8 cm for standard plate and variation III. It was observed that mean water holding capacity was 60 minutes for standard plate whereas it was 55 minutes for variation III. The mean water absorption capacity was 50 per cent for standard plate and 45 per cent for variation III *i.e.* dehydrated guava powder incorporation at 30 per cent level.

- The dehydrated guava powder incorporated spoon by hydraulic pressure method at 30 per cent concentration had same mean volume of 6 cm^3 as that of the standard. The mean weight of standard spoon and variation III was 18 g. The density of standard spoon was 3 g/cm^3 which was the same as that of variation III. The mean thickness of both standard and variation III spoon was 2 mm. The mean diameter was found to be 148 mm for standard spoon and 30 per cent dehydrated guava powder incorporated spoon *i.e* variation III. The mean spread ratio was found to be 7.4 cm for standard spoon and variation III. It was observed that mean water holding capacity was 65 minutes for standard spoon whereas it was 62 minutes for variation III. The mean water absorption capacity was 45 per cent for standard spoon and 42 per cent for variation III *i.e.* dehydrated guava powder incorporation at 30 per cent level.
- The dehydrated guava powder incorporated plate by hydraulic pressure method at 30 per cent concentration had mean volume of 12 cm^3 for standard and 11 cm^3 for variation III. The mean weight of plate standard and variation III was 110 g. The density of standard plate was 9.2 g/cm^3 which was the same as that of variation III. The mean thickness of both standard and variation III plate was 6 mm. The mean diameter was found to be 160 mm for standard plate and 30 per cent dehydrated guava powder incorporated plate *i.e* variation III. The mean spread ratio was found to be 2.6 cm for standard plate and variation III. It was observed that mean water holding capacity was 125 minutes for standard plate whereas it was 115 minutes for variation III. The mean water absorption capacity was 45 per cent for standard plate and 42 per cent for variation III *i.e.* dehydrated guava powder incorporation at 30 per cent level.
- The mean scores obtained for volume, weight , density , thickness, diameter, water holding capacity was observed to be very high for cutlery made with hydraulic pressure method for both spoon and plate for standard and for variation III. Spread ratio and water absorption capacity is lesser than the baked method. These properties suits for commericialization of the cutlery but not for consumption as they are too thick and hard. The spoons was edible and can be consumed due to their lesser thickness and density. There is a need in

customization of the machineries for formulation of edible cutlery with less molding thickness, temperature, preparation time, etc as like waffle makers. Spoons and plates prepared using baking method were not too tough and were easily chewable. Hence the acceptablity was reported high for baked cutlery for both spoon and plate prepared using dehydrated guava powder.

- The dehydrated guava powder incorporated spoon by baking method at 30 per cent concentration had same mean volume of 4 cm^3 as that of the standard. The mean weight of standard spoon and variation III spoon was 15 g. The density of standard spoon was 3.75 g/cm^3 which was the same as that of variation III. The mean thickness of both standard and variation III was 3 mm. The mean diameter was found to be 110 mm for standard spoon and 30 per cent dehydrated guava powder incorporated spoon *i.e* variation III. The mean spread ratio was found to be 3.7 cm for standard spoon and variation III. It was observed that mean water holding capacity was 45 minutes for standard spoon whereas it was 42 minutes for variation III. The mean water absorption capacity was 50 per cent for standard spoon and 45 per cent for variation III *i.e.* dehydrated guava powder incorporation at 30 per cent level.
- The dehydrated guava powder incorporated plate by baking method at 30 per cent concentration had same mean volume of 7 cm^3 as that of the standard. The mean weight of standard plate and variation III plate was 70 g. The density of standard plate was 10 g/cm^3 which was the same as that of variation III. The mean thickness of both standard and variation III plate was 4 mm. The mean diameter was found to be 150 mm for standard plate and 30 per cent dehydrated guava powder incorporated spoon *i.e* variation III. The mean spread ratio was found to be 3.8 cm for standard plate and variation III. It was observed that mean water holding capacity was 60 minutes for standard plate whereas it was 55 minutes for variation III. The mean water absorption capacity was 50 per cent for standard plate and 45 per cent for variation III *i.e.* dehydrated guava powder incorporation at 30 per cent level.
- The dehydrated guava powder incorporated spoon by hydraulic pressure method at 30 per cent concentration had same mean volume of 6 cm^3 as that of the

standard. The mean weight of standard spoon and variation III was 18 g. The density of standard spoon was 3 g/cm^3 which was the same as that of variation III. The mean thickness of both standard and variation III spoon was 2 mm. The mean diameter was found to be 148 mm for standard spoon and 30 per cent dehydrated guava powder incorporated spoon *i.e* variation III. The mean spread ratio was found to be 7.4 cm for standard spoon and variation III. It was observed that mean water holding capacity was 65 minutes for standard spoon whereas it was 62 minutes for variation III. The mean water absorption capacity was 45 per cent for standard spoon and 42 per cent for variation III *i.e.* dehydrated guava powder incorporation at 30 per cent level.

- The dehydrated guava powder incorporated plate by hydraulic pressure method at 30 per cent concentration had mean volume of 12 cm^3 for standard and 11 cm^3 for variation III. The mean weight of plate standard and variation III was 110 g. The density of standard plate was 9.2 g/cm^3 which was the same as that of variation III. The mean thickness of both standard and variation III plate was 6 mm. The mean diameter was found to be 160 mm for standard plate and 30 per cent dehydrated guava powder incorporated plate *i.e* variation III. The mean spread ratio was found to be 2.6 cm for standard plate and variation III. It was observed that mean water holding capacity was 125 minutes for standard plate whereas it was 115 minutes for variation III. The mean water absorption capacity was 45 per cent for standard plate and 42 per cent for variation III *i.e.* dehydrated guava powder incorporation at 30 per cent level.
- The mean scores obtained for volume, weight , density , thickness, diameter, water holding capacity was observed to be very high for cutlery made with hydraulic pressure method for both spoon and plate for standard and for variation III. Spread ratio and water absorption capacity is lesser than the baked method. These properties suits for commericialization of the cutlery but not for consumption as they are too thick and hard. The spoons was edible and can be consumed due to their lesser thickness and density. There is a need in customization of the machineries for formulation of edible cutlery with less molding thickness, temperature, preparation time, etc as like waffle makers.

Spoons and plates prepared using baking method were not too tough and were easily chewable. Hence the acceptablity was reported high for baked cutlery for both spoon and plate prepared using dehydrated guava powder.

- The dehydrated banana powder incorporated spoon by baking method at 10 per cent concentration had the mean volume of 4 cm^3 for standard and 6 cm^3 for variation I. The mean weight of standard spoon and variation I was 15 g. The density of standard spoon was 3.75 g/cm^3 and 2.5 g/cm^3 for variation I. The mean thickness of the standard was 3 mm and variation I was 5mm. The mean diameter was found to be 110 mm for standard spoon and 10 per cent dehydrated banana powder incorporated spoon *i.e* variation I. The mean spread ratio was found to be 3.6 cm for standard spoon and 2.2 cm for variation I. It was observed that mean water holding capacity was 45 minutes for standard spoon whereas it was 16 minutes for variation I. The mean water absorption capacity was 50 per cent for standard spoon and 55 per cent for variation I *i.e.* dehydrated banana powder incorporation at 10 per cent level.
- The dehydrated banana powder incorporated plate by baking method at 10 per cent concentration had the mean volume of 7 cm^3 for standard and 9 cm^3 for variation I. The mean weight of plate standard was 70 g and variation I was 74 g. The density of standard plate was 10 g/cm^3 and 8.2 g/cm^3 for variation I. The mean thickness of the standard was 4 mm and variation I was 6 mm. The mean diameter was found to be 150 mm for standard plate and 10 per cent dehydrated banana powder incorporated plate *i.e* variation I. The mean spread ratio was found to be 3.7 cm for standard plate and 2.5 cm for variation I. It was observed that mean water holding capacity was 60 minutes for standard plate whereas it was 27 minutes for variation I. The mean water absorption capacity was 50 per cent for standard plate and 58 per cent for variation I *i.e.* dehydrated banana powder incorporation at 10 per cent level.
- It was found that the 10 per cent dehydrated banana powder incorporated edible cutlery (variation 1) was not strong as they had low water holding period and high water absorption capacity.

- Thus the 30 per cent dehydrated guava powder incorporated edible cutlery is found to be better in its physicochemical properties than the 10 per cent dehydrated banana powder incorporated edible cutlery.
- The hardness of the edible plates made using hydraulic pressure method is too hard *i.e* 441.3 and 438.01 N for standard and variation III respectively. with the application of speed stain of 15 Newtons and has the adhesiveness of 0.38 N respectively. They are considered to be too hard for consumption. But the edible spoons made using hydraulic pressure method has the hardness of 47 and 46 N for standard and variation III respectively with the application of speed stain of 5 Newtons and the adhesiveness of 0.2027 for standard and 0.2063 for vatiation III which was hard but not brittle and they are acceptable for consumption.
- Hardness of the edible plates and spoons made using baking method were also analyzed which showed hardness of 157 N and 153 N for standard and variation III plates respectively. The spoons had 45 N hardness with the application of 5 Newtons of force and 0.05 N of adhesive force for both standard and hydraulic pressure method.
- It shows that the textural properties of the plates made by baking method is more suitable for consumption than the plates prepared by hydraulic pressure method. No much difference were observed with the textural properties of edible spoons prepared using both the methods for both standard and variation III. The brittleness, stroke, springiness, cohesiveness, chewiness of the edible cutlery were also tested and the result showed that there existed no such properties for the formulated edible cutlery.
- Hardness of the edible plates and spoons made using baking method were analyzed which showed hardness of 157 N and 62 N for standard and variation I plates respectively. The spoons has 45 N and 7.60396 N hardness with the application of 5 Newtons of force and 0.05 N and 0.015 N of adhesive force for both standard and Variation I. It shows that the textural properties of the plates made by baking method is more suitable for consumption. The brittleness stroke, springiness, cohesiveness, chewiness of the edible cutlery were also tested and

the result showed that there existed no such properties for the formulated edible cutlery.

- The antioxidant status of the formulated edible cutlery were done for the dehydrated guava powder incorporated edible cutlery at 30 per cent and dehydrated guava powder incorporated edible cutlery at 10 per cent. The ferric reducing antioxidant power was 98 µg/g for dehydrated guava powder incorporated edible cutlery and 56.61 µg/g for dehydrated banana powder incorporated edible cutlery. FRAP test done reveals the capacity of antioxidants enriched edible cutlery reduced the oxidative stress in the body. The 30 per cent dehydrated guava powder incorporated edible cutlery showed higher content of FRAP than the 10 per cent dehydrated banana incorporated edible cutlery. The total antioxidant capacity of the edible cutlery was recorded as 170 µg/g for 30 per cent dehydrated guava powder incorporated edible cutlery and 108 µg/g for 10 per cent dehydrated banana powder incorporated edible cutlery . Thus, the results showed that the 30 per cent dehydrated guava powder incorporated edible cutlery are rich in antioxidants than the dehydrated banana powder incorporated edible cutlery at 10 per cent.
- The 30 per cent dehydrated guava powder incorporated edible cutlery had energy with 346.5 KCal which includes carbohydrates (73.5 g), protein (10.2g), fats (1.3 g) and dietary fibre (8.8 g). The minerals like iron and calcium estimated by preparing ash solution was 4.6 mg and 28 mg respectively. The micro nutrient content present in 100 g of sample was recorded as 54 µg of β carotene and 2.5 mg of vitamin C. The ash content present in 100 g of the sample was recorded as 5 g and its moisture content is 5.6 per cent. From this reading, it is observed that the product formulated is rich in energy, dietary fibre, iron, calcium, vitamin C and β carotene.
- The edible cutlery *i.e* dehydrated banana powder incorporated edible cutlery at 10 per cent level had energy with 311.74 Kcal which includes carbohydrates (64.12 g), protein (9.18g), fats (2.06 g) and dietary fibre (10.8 g). The minerals like iron and calcium estimated by preparing ash solution and 3.3 mg and 22 mg respectively. The micronutrient content present in 100 g of sample was recorded

as 13.4 µg of β carotene and 0.8 mg of vitamin C. The ash content present in 100 g of the sample is recorded as 6.3 g and the moisture content was 7.4 per cent. From this reading, it is observed that the product formulated is rich in energy, dietary fibre, iron, calcium, ash and moisture content.

- On comparison, it was observed that energy, carbohydrates, fats, iron, calcium, vitamin C and β carotene is more in dehydrated guava powder incorporated edible cutlery (variation III) than the dehydrated banana powder incorporated edible cutlery (variation I). However, the fat, ash and the moisture content were more in dehydrated banana powder incorporated edible cutlery (variation I) than dehydrated guava powder incorporated edible cutlery (variation III).
- the dehydrated guava powder incorporated edible cutlery with 30 per cent incorporation is analyzed for the presence of phytochemicals. Alkaloids, flavonoids, tannins, phenol showed positive result *i.e* the presence of alkaloids, flavonoids, tannins, phenol and gave negative result for saponin, terpenoids and steroids *i.e* absence of saponin, terpenoids and steroids. The quantitative analysis depicts the quantity of phytochemicals present in the given sample (variation III). The dehydrated guava powder incorporated edible cutlery consists of 1.8 per cent of alkaloids, 0.5 per cent of flavonoids, 1.2 per cent of tannins and 2.2 per cent of phenols respectively. Thus, the formulated edible cutlery was rich in phytochemicals especially phenols and alkaloids.
- The dehydrated banana powder incorporated edible cutlery with 10 per cent incorporation is analyzed for the presence of phytochemicals. Alkaloids, flavonoids, tannins, saponin, phenol showed positive result *i.e* the presence of alkaloids, flavonoids, tannins, saponin, phenol and gave negative result for terpenoids and steroids *i.e* absence of terpenoids and steroids. The quantitative analysis depicts the quantity of phytochemicals present in the given sample (variation I). The dehydrated banana powder incorporated edible cutlery consists of 2.6 per cent of alkaloids, 0.8 per cent of flavonoids, 0.03 per cent of tannins, 0.6 per cent of saponin and 0.5 per cent of phenols respectively. Thus, the formulated edible cutlery was rich in phytochemicals especially phenols and alkaloids.

- In the formulated edible cutlery, the total microbial count for dehydrated guava powder incorporated edible cutlery for the day 1 is reported to be 22 x 10^1 cfu/g and for day 7 as 51 x 10^1 cfu/g. It clearly shows that the rate of growth of microorganism is very slow. After a storage period of more than 2 months it had 79 x 10^1 cfu/g, it was noted that there is no characteristic physical or textural change observed in the product. The total microbial count for dehydrated banana powder incorporated edible cutlery for the day 1 is reported to be 22 x 10^1 cfu/g and for day 7 as 53 x 10^1 cfu /g. It clearly shows that the rate of growth of microorganism is slow but quite differs from the microbial count of dehydrated guava powder incorporated edible cutlery. After a storage period of more than 2 months it had 83 x 10^1 cfu/g. As the study period is less, the shelf life study could not be conducted for a longer period. But within this period of shelf life study, it was found that no characteristic change was observed in the edible cutlery. Hence the result proves that the product has good keeping quality, extended shelf life and the rate of spoilage is very less. This may be due to the baking method where the moisture content was reduced to 5.6 per cent and 7.4 per cent.
- The cost of dehydrated guava powder incorporated edible cutlery prepared by baking method was Rs. 7.00 per piece of spoon and Rs 20.00 per piece of plate. The cost of spoon prepared by hydraulic pressure method was Rs.12.00 per piece and plate is Rs. 30.00 per piece.
- The cost of dehydrated banana powder incorporated edible cutlery prepared by baking method was Rs. 10.00 per piece of spoon and Rs 22.00 per piece of plate.
- By this discussion, we can observe that the cost of dehydrated guava powder incorporated edible cutlery are cheaper than the dehydrated banana powder incorporated edible cutlery. And also the baked cutlery are cost effective than the hydraulic pressure method developed cutlery.
- The feedback by the community for the edible cutlery formulated and it shows that 100 per cent of the participants accepted that the product replaces the usage of plastic, reduces the environmental pollution and will be useful to the

community. 99 per cent of adults accepted that the edible cutlery formulated can be promoted in the market and accepted that the combination of the cutlery suits for the consumption of food, 89 per cent accepted that they are cost effective and 80 per cent accepted that they are affordable and accessible for daily usage.

- With the sensory characteristics 98 per cent accepted that the quality and taste of the product quality was good, 89 per cent accepted that the cutlery has no characteristic change and 87 per cent accepted that there is no change in taste and flavour of the food when consumed with the formulated edible cutlery and 94 per cent accepted that the cutlery will attract the children.
- When coming to the health point of view 98 per cent accepted that it helps to regulate body functions, 96 per cent accepted that it improves the nutritional status of the individual, 93 per cent accepted that it improves the eating habit of the children and 92 per cent accepted that the product reduces oxidative stress.
- Thus, with this survey it was concluded that the edible cutlery formulated were nutritious, health promoting, cost effective, easily accessible, attracts children, eco- friendly and consumer friendly product and also accepted by the community that it can be marketed and they will buy it as they liked the product and their specifications.

Conclusion

In conclusion, the study revealed that the antioxidant enriched edible cutlery prepared by incorporating dehydrated guava powder at 30 per cent and dehydrated banana powder incorporated at 10 per cent is more acceptable. The cutlery made using banana did not came out well in hydraulic pressure method and also did not have strong and rigid physical properties and nutritional benefits when compared with dehydrated guava powder prepared edible cutlery. The dehydrated guava powder incorporated edible cutlery at 30 per cent has positive significance at 5 per cent in all aspects such as method of preparation, sensory characteristics, physicochemical properties, antioxidant properties, nutritional properties, microbial count, cost effective and accepted by the community. Thus, among all variations of edible cutlery prepared with dehydrated guava powder incorporated at 30 per cent was the most accepted variation. As they are

antioxidant rich with high FRAP value and antioxidant capacity, it was proven that antioxidant rich edible cutlery has potentials to prevent and overcome oxidative stress, prevent environmental pollution as it reduces the plastic usage and ecofriendly. Even if the edible cutlery is not consumed, disposal of the cutlery is environmental friently. However, there is a need in customization of the machineries for formulation of edible cutlery with less molding thickness, temperature, preparation time, etc as like waffle makers.

Recommendations for further research

The recommendations that emerge out from the present study are

- studies using other millet and cereal combination
- analysis of antinutritional factors present in the edible cutlery
- encapsulation of antioxidants to incorporate active components into the cutlery
- *in vitro* studies for bioavailability of nutrients and antioxidants
- fabrication of customized machinery exclusively for production of edible cutlery

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APPENDIX I

Avinashilingam Institute of Home Science and Higher Education for Women

Coimbatore- 43

Department of Food Science and Nutrition

Development and evaluation of antioxidant enriched edible cutlery

Name: Product name:

Date: Time:

CRITERIA	SCORE	STANDARD	VARIATION		
			1	2	3
Flavour					
Highly acceptable	5				
Partially acceptable	4				
Acceptable	3				
Unacceptable	2				
Off flavour	1				
Colour					
Creamish brown	5				
Creamish white	4				
Brownish white	3				
Dark brown	2				
Blackish brown	1				
Appearance					
Most attractive	5				
Attractive	4				
Normal	3				
Sobber	2				
Dull	1				
Texture					
Strong andCrunchy	5				
Crispy	4				
Brittle	3				
Hard	2				
Too hard	1				
Taste					
Excellent	5				
Very good	4				
Good	3				
Fair	2				
Poor	1				
Overall acceptability					
Excellent	5				
Very good	4				
Good	3				
Fair	2				
Poor	1				

Signature

APPENDIX II

Avinashilingam Institute for Home science and Higher Education for women, Coimbatore-43

Development and evaluation of anti-oxidant enriched edible cutlery
Feed Back Questionnaire

1. Do you think the product developed will be useful to the community? ☐ Yes ☐ No
2. Do you think the product developed will reduce the environmental pollution? ☐ Yes ☐ No
3. Is the taste and the quality of the product acceptable? ☐ Yes ☐ No
4. Do you think that the product developed can replace the plastic usage? ☐ Yes ☐ No
5. Do you agree that the product developed will be cost effective? ☐ Yes ☐ No
6. Do you accept the product developed will reduce the oxidative stress? ☐ Yes ☐ No
7. Do you agree that these cutlery will attract the children? ☐ Yes ☐ No
8. Do you think this product can be more affordable and accessible for daily use? ☐ Yes ☐ No
9. Do you think the cutlery developed will improve the eating habit of the children? ☐ Yes ☐ No
10. Do you think the cutlery developed will improve the nutritional status of the children? ☐ Yes ☐ No
11. Do you accept that these cutlery can be promoted for marketing? ☐ Yes ☐ No
12. Does the combination of the cutlery and the food suits? ☐ Yes ☐ No
13. While using these cutlery do you find any change in the taste and flavour of the food? ☐ Yes ☐ No
14. While using these cutlery do you find any characteristic change in the cutlery? ☐ Yes ☐ No
15. Do you accept that these cutlery will help to regulate the body functions? ☐ Yes ☐ No

APPENDIX III

ETHICAL CLEARANCE CERTIFICATE

INSTITUTIONAL HUMAN ETHICS COMMITTEE

Avinashilingam

Institute for Home Science and Higher Education for Women

Deemed to be University Under category 'A' By MHRD, (Estd. u/s 3 of UGC Act 1956)

Re Accredited with 'A' Grade By NAAC, Recognised by UGC Under Section 12 B

Coimbatore - 641043, Tamil Nadu, India

Chairman
Dr. S. Ramalingam
Principal, PSG Institute
of Medical Sciences
& Research, Coimbatore

Member Secretary
Dr.S.Uma Mageshwari
Professor,
Dean Student Affairs,
Department of Food Service
Management & Dietetics

Members
Dr.P.R.Padma
Mr. K.Arulmoli (Legal Expert)
Dr. N.S. Rohini
Dr.Subhashini K. Sripathi
Dr.A. Saraswathy
Ms.D.Kavitha
Dr.S. Muthulakshmi
Dr.G.Victoria Naomi
Dr. Judith Justin
Dr.Anitha Subash

3rd June 2019

To
Mrs. Agilandeshwari.AT,
Department of Food Science and Nutrition
Avinashilingam Institute for Home Science and
Higher Education for Women
Coimbatore – 641 043

Dear Madam,

Ref : Your presentation of the proposal No. IHEC/18-19/FSN/28 entitled "Development and Evaluation of Antioxidant Enriched Edible Cutlery" to the IHEC on 24th May 2019

The Institutional Human Ethics Committee of our University hereby grants approval to your research proposal No. IHEC/18-19/FSN /28 entitled "Development and Evaluation of Antioxidant Enriched Edible Cutlery" submitted and presented by you. The Approval number for the same is AUW/IHEC-18-19/FSN/FHP-05.

We wish you all the best in your research endeavours.

Regards,

Dr.S.Uma Mageshwari
Member Secretary