INTRODUCTION

CHAPTER I
INTRODUCTION

Fruits and vegetables play an important role in human life due to its high nutrient value. Fruits are rich sources of essential nutrients, including vitamins, minerals, dietary fiber, antioxidants, and other phytonutrients. These nutrients play crucial roles in various bodily functions, supporting overall health. Regular consumption of fruits has been associated with a reduced risk of cardiovascular diseases. The fiber, antioxidants, and other compounds found in fruits contribute to heart health by managing cholesterol levels, blood pressure, and inflammation. The presence of antioxidants and phytonutrients in fruits result in lowering the risk of certain types of cancer. These compounds help in neutralizing free radicals, which can contribute to the development of deadly diseases like cancer, liver disease etc.

Fruits are easily digestible and contain dietary fiber, which promotes healthy digestion. The fiber in fruits helps to prevent constipation and to support the regularity of bowel movements. Additionally, the cleansing effect on the blood and digestive system can contribute to overall detoxification. The increasing attention on fruits and fruit juices in recent years reflects a growing awareness of their nutritional benefits. As people become more conscious of their health, there is a greater emphasis on incorporating nutrient-rich foods like fruits into their regular diets.

Vegetables are excellent sources of vitamins and minerals essential for various bodily functions. Different vegetables provide a diverse range of nutrients, such as vitamin C, vitamin A, potassium, folate, calcium, magnesium, iron etc. Vegetables are high in dietary fiber, which is crucial for digestive health. Fiber helps in preventing constipation, promoting regular bowel movements, and supporting a healthy digestive system. It also contributes to a feeling of fullness, which can aid in weight management. Many vegetables are rich in antioxidants, which help in neutralizing

free radicals in the body. Antioxidants play a vital role in protecting cells from damage, reducing inflammation, and potentially lowering the risk of chronic diseases.

Most vegetables are low in calories but high in nutrients, making them an excellent choice for those looking to maintain or lose in body weight. The high water content in many vegetables also contributes to their low calorie density. Regular consumption of vegetables has been associated with a lower risk of various diseases, including certain types of cancer, cardiovascular diseases, and age-related eye conditions. The diverse array of phytochemicals in vegetables contributes to these protective effects. Some vegetables, especially those high in fiber, can help in regulating blood sugar levels. This is beneficial for individuals with diabetes or those aiming to prevent insulin resistance. Consuming a variety of vegetables ensures a broad spectrum of nutrients. Different colors in vegetables often indicate different phytonutrients, each with its unique health benefits. Including a colorful array of vegetables in the human diet can contribute significantly to overall health and well-being. The combination of fruits and vegetables provides a wide range of nutrients that support various bodily functions and aids to maintain optimal health.

Beetroot (*Beta vulgaris* L.) is cultivated throughout the world for its vegetable and juice value. It is cultivated annually across 0.069 lakh ha nationwide, with Tamil Nadu contributing 3332.79 ha and an annual yield of 27.23 tonnes/ha. States viz., Madhya Pradesh, Telangana and Tripura are the primary producers of beetroot (Indiastat, 2022). It contains high concentrations of betaine, vitamin A, B6 and C, folic acid, protein, carbohydrates, potassium, iron, soluble fiber, sodium and magnesium (Vali *et al.,* 2007). It has gained much attention not only because of its rich nutrient content, but also due to its medicinal significance. It helps to minimize blood pressure, manages cardiovascular health, improves stamina and muscle power, maintains blood circulation and slows the progression of dementia. According to a report by the British Dietetic Association (BDA), beetroot contains anthocyanins

which can minimize the effects of pollution on the body. The betalains in beetroot have been associated with supporting liver detoxification processes. In addition, it is used as a source of natural antioxidants which aids to protect cells against oxidative stress in humans (Kumar *et al*., 2018).

Its medicinal values have been associated with the number and amount of nutrients present in it. The amount of nutrients starts to break down after harvest. However, the rate of nutrient losses can be minimized by proper storage (Guo T *et al*., 2018). During storage, it releases heat due to respiration and subsequently loses moisture. As a result, swift softening and decay progress which decreases the shelf-life and nutritional quality (Bisbis *et al.,* 2018). In order to preserve and to increase its storage stability, numerous preservation methods have been employed. However, every preservation process decreases the amount of nutrients in it. Especially, processes that expose beetroot to high levels of oxygen, light and heat cause the greatest nutrient loss. Salting, pickling, fermenting, drying, canning, freezing, pressure canning and dry salting are the commonly used preservation methods.

Moringa (*Moringa oleifera*) leaves are highly nutritious, they are a significant source of beta-carotene, vitamin C, iron, potassium and protein. Its protein quality compares well with that of milk and eggs (Nadeem *et al.,* 2012). According to Indian economy analysis, the wholesale price index of moringa rose from 59 to 344.8 during 2012 to 2024 (Indiastat, 2024) Moringa leaves are regarded as a protein and calcium supplement (Rajangam *et al*., 2001). It is one of the most nutritioUS-Crops in the world with most of its benefits stored in the small green leaves of this unassuming plant known as the “Tree of Life”. Moringa contains more than 90 nutrients including 40 powerful antioxidants (Gardener and Ellen, 2002). The leaves of the *moringa oleifera* tree have no parallel in the plant kingdom. *Moringa oleifera* can be grown in a variety of soil conditions preferring well-drained sandy or loamy soil that is slightly

alkaline. It is considered as one of the world's most useful trees and almost every part of the tree can be used for food. The leaves, especially young shoots are eaten as green in salads, vegetable curries and pickles. The leaves are considered to offer great potential for those who are nutritionally at risk of protein and calcium deficiency diseases (Mbah B.O *et al.,* 2012). Moringa leaves can be eaten fresh, cooked or stored as dried powder for many months without refrigeration (Gaman and Shenngton. 1996).

Moringa leaves are commonly consumed as a nutritious food source and have gained popularity for their potential health benefits. Moringa leaves are rich in essential nutrients, including vitamins (such as vitamin A, C, and E), minerals (like calcium, potassium, and iron), and amino acids. They are a good source of antioxidants, which can help protect the body against oxidative stress. Moringa leaves are considered highly nutrient-dense, making them a valuable addition to a balanced diet. Moringa leaves have anti-inflammatory effects, which can be beneficial for overall health. The antioxidants in moringa help in neutralizing free radicals in the body, potentially reducing the risk of chronic diseases. Moringa leaves can be used in varioUS-Culinary applications. They can be consumed fresh, cooked, or dried and powdered. They are often used in soups, stews, salads, and as a green vegetable in various dishes.

Moringa has a history of traditional use in Ayurvedic and traditional medicine for its purported medicinal properties. It has been used to treat varioUS-Conditions, such as arthritis, anemia, and digestive issues. Moringa leaf powder and extracts are also available in supplement form. These supplements are promoted for their potential health benefits and nutritional content. While moringa leaves offer various health benefits, excessive consumption should be avoided, especially during pregnancy as it may have uterotonic effects.

Freshly harvested food products (fruits and vegetables) usually have high water contents. It provides conditions to grow and reproduce microorganisms, leading to irreversible damage to food products. Thus it is necessary to reduce the moisture content and nutrient loss by using appropriate preservation methods. Food preservation is characterized as the procedure or method used to control both the internal and external elements that could lead to lower food spoilage, quality loss and growth of microorganism. There are various methods of food preservation, each designed to target specific factors that lead to the food deterioration. Commonly used preservation methods are refrigeration, freezing, canning, dehydration or drying, fermentation, salting, smoking, pickling and use of preservatives. Choosing the appropriate method of food preservation depends on the type of food, desired shelf life, and the specific qualities to be preserved. It is necessary to follow proper procedures and guidelines to ensure the safety and quality of preserved foods.

Drying of fruits and vegetables is one of the oldest methods of food preservation. Drying is an energy intensive as well as a cost intensive process, it is a simultaneous heat and mass transfer process accompanied by phase change, it is still indispensable in the food industry. Drying methods are divided into natural and artificial methods. A natural method of drying includes open sun drying which uses solar heat energy to remove moisture from the food materials (Toshniwal and Karale, 2013). Sun-drying involves many unhygienic practices and requires a larger drying area and longer drying time. The artificial drying methods are categorized into four generations based on the methodology of drying (Kumar and Karim, 2019). The first generation included convective, belt, kiln, cabinet, conveyor dryers, second as spray and drum dryers and third as freeze and osmotic drying (VegaMercado *et al.,* 2001). . Even though the forced convection hot air-drying method is largely being used in many food industries, it is not energy efficient and requires more time for complete drying and uneven moisture removal resulted in case hardening of the dried produce. Although drying extends shelf life, it also leads to undesirable changes in color and

texture, and causes partial loss of nutritive components (Mothibe *et al.,* 2011). Therefore, to maintain quality, it is necessary to improve existing traditional methods and explore new technologies for the food industry. Hence fourth generation technologies viz. IR, microwave and radio frequency were developed.

Using innovative technologies to improve and optimize existing techniques, the quality of dried products has improved to a large extent. However, several disadvantages of these dehydration methods have been identified, such as the relatively large energy consumption and quality deterioration of the final product etc. Thus, pre-treatment is often employed before drying. Pre-treatment prior to drying is a well-explored area, and many methods have been developed. The chemical (salt, acid, alkali etc) and physical (milling, cutting, freeze thaw etc) pretreatments of fruits and vegetables, which were extensively used, had many drawbacks.

Non-thermal technologies can be a better alternative to overcome the drawbacks of physical and chemical pretreatments. Non-thermal technologies refer to food preservation and processing methods that do not rely on traditional heat-based techniques such as pasteurization or sterilization. These technologies aim to extend the shelf life of food products while minimizing the impact on their nutritional and sensory qualities. It includes high pressure processing, pulsed electric field, ultraviolet light treatment, ozone treatment, pulsed light, ultrasound technology, osmotic dehydration and microwave processing. Non-thermal technologies are gaining interest in the food industry as they offer the potential to preserve food while retaining desirable attributes like taste, texture, and nutritional value. Ultrasound pre-treatment of food products before drying has been a hotspot in recent years and has shown potential in greatly decreasing the drying time (Wiktor *et al.,* 2019). Ultrasound waves can be used for various purposes in food processing, such as extraction, emulsification, and microbial inactivation. The application of ultrasound can enhance mass transfer processes without the need for high temperatures.

Infrared drying is a non-contact food drying technique that uses infrared radiation to remove moisture from food products (Tyagi *et al.,*2020). Infrared drying has gained popularity as an alternative drying method for agricultural products. Infrared drying offers many advantages over conventional drying under similar drying conditions. When infrared radiation is used to heat or dry moist materials, the radiation impinge the exposed material, penetrate through it and the energy of radiation converts into the heat (Hebbar and Rostagi, 2001). Unlike conventional drying methods that rely on hot air or other heated mediums, infrared drying directly transfers heat to the food surface through electromagnetic waves in the infrared spectrum. This targeted approach allows for more efficient and rapid moisture removal while minimizing the potential for thermal damage to the product. Infrared drying has been investigated as a potential five methods for obtaining high quality dried foodstuffs, including fruits, vegetables and grains (Sakare *et al.,* 2020).

Hybrid drying technology combines different drying methods or energy sources to achieve more efficient and effective drying processes. The technology helps to leverage the strengths of multiple drying techniques while minimizing their individual limitations. Hybrid drying systems often integrate both conventional and advanced drying technologies, resulting in improved energy efficiency, reduced processing time, and enhanced product quality. Furthermore, most of the existing drying techniques are utilizing high energy or leading to carbon emissions. In this study we focussed on the alternative method for preservation of fruits and vegetables using an ultrasonic pretreatment prior to infrared drying. Hence the study is proposed to develop an ultrasound assisted infrared dryer for food products viz moringa leaves and beetroot.

The present study entitled “Development of Semi-Continuous Ultrasound Assisted Infrared Dryer for Food Products” was undertaken with the following objectives.

- Optimization of process parameters of ultrasound pretreatment for moringa leaves and beetroot.
- Development of a semi-continuous ultrasound assisted infrared dryer for moringa leaves and beetroot.
- Optimization of process parameters of infrared dryer for moringa leaves and beetroot.
- Performance evaluation of the developed dryer based on capacity, thermal efficiency and specific energy consumption.