Effect of Different Drying Strategies on the Physicochemical and Microbiological Properties of Citrus Peel Powders

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in

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Dear Sir,

I have great pleasure in forwarding the thesis entitled **"Effect of Different Drying Strategies on the Physicochemical and Microbiological Properties of Citrus Peel Powders"** submitted by **Ms. Omi Singh**, **I.D. No. 17412FST011** in partial fulfillment of the requirements for the degree of **Master of Science** in **Food Science and Technology,** from Centre of Food Science and Technology, Institute of Agricultural Sciences, BHU Varanasi.

I certify that the entire scheme of investigation, presented here in, was planned and carried solely by the candidate under my guidance. To the best of my knowledge, the data presented in the thesis are genuine and original.

Thanking you.

FORWARDED

(Coordinator)

YOURS FAITHFULLY

Dr. ABHISHEK DUTT TRIPATHI
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Effect of Different Drying Strategies on The Physicochemical And Microbiological Properties Of Citrus Peel Powders

by

Ms. Omi Singh

Thesis submitted in partial fulfillment of the requirements for the degree of

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Date:

Place: Varanasi **Omi Singh**

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ABBREVATIONS AND SYMBOL

F	:	Fvalue
g	:	gram
h	:	hour
HCL	:	hydrochloricacid
Kg^{-1}	:	perkilogram
Ppm	:	parts permillion
DPPH	:	2, 2-diphenyl-1-picrylhydrazyl
TPC	:	Total PhenolicContent
Aw	:	wateractivity
GAE	:	Gallic acidequivalents
BHA	:	Butylatedhydroxyl anisole
BHT	:	Butylatedhydroxyl toluene
LD	:	lethal Dose
AAS	:	Atomic Absorption spectrophotometer
LSD	:	Least Significant Difference

INTRODUCTION

Citrus fruits are edible fruits that lie in the genus Citrus, and "Family Rutaceae". Citrus fruits grow on flowering tree and shrubs. They are defined by a leathery rind and white pith that shut in juicy segments. This class of fruits includes lemons, limes, oranges, and grapefruits as well as many more hybrids and varieties.

In early times, countries in the Mediterranean region where leading producers of the citrus fruits, but in the present scenario, their production is carried out in many more countries all over the worldwide. Tropical and sub-tropical regions I.e. warm climatic regions are mostly preferred for their cultivation. Citrus fruits are native to Australia, New Guinea, New California and maybe Southeast Asia. Major production hubs include Spain, Brazil, China, the United States, Mexico and India.

The processing industry produces a large number of waste by-products in the form of peel, seeds, rag (the membrane between the citrus segments) and pulps (juice sacs) representing 50-60% of whole fruit being cast-off after juicing (Siles et al., 2010). It represents more than 1.5 million tons per year of waste.

Peel is the main by-product receive from the citrus juice processing industry and it is highly perishable which may lead to environmental pollution due to its bad disposal and accumulation. By-product recovery from fruit wastes can improve the overall economy of processing units.

Peel is loaded with many bio-active components. Citrus fruit peel comprises of carbohydrates, pectin, and fiber that giving it to better functional properties, that is why it is utilized in the food industry for many applications. Citrus peels have been notable for their higher content of

Vitamin C and its associated health benefits. Citrus peels extract containing polymethoxylated flavones (PMFs) may help prevent diabetes as well as reducing the level of serum triglycerides (TG) and cholesterol. Citrus peels contain a high level of antioxidants more than vitamin E that contributes to the protection of DNA from cancer-causing damage.

Orange (Citrus sinensis) is known as the king of citrus fruits, less in calories with full of nutrients which boost clear, healthy skin. Orange peel comprises of the high level of flavonoid, phytochemicals, antioxidants along with vitamin B, A, C, calcium, copper, and magnesium. Orange peel also contains a high content of carbohydrates, fiber and phytonutrients.

Over 170 different phytochemicals and more than 60 flavonoids present in orange fruit. Many of these have been shown to have anti-inflammatory properties and strong antioxidant effects.

Sweet lime (Citrus limetta) is well known as "Mosambi" Resemble to lemon in perception, it features a sweeter taste much like an orange. Being an indigenous to southern Asia, Mosambi is also cultured in the Mediterranean basin. As it is termed as "sweet lime" the flavor of the juice is mild that works as a detoxifying agent for cleaning body, also in treating constipation, peptic ulcer, and digestive disorders.

To preserve the citrus fruits peel for further processing, the best two-step process is a) Drying, b) grinding of the peel. Different drying methods are sun drying, hot air oven drying, and solar drying, spray-drying, microwave drying, vacuum oven drying, freeze drying, etc.

Sun drying is one of mankind's oldest, simplest, cheapest, environment-friendly preservation technique. It is used in ancient Egypt and Mesopotamia. Sun drying is gentle and slow process whose benefits more than balance for its time-intensive nature. It relies on the sun on to permit

the refined product to reach optimum moisture and quality level. In sun drying technique, the product is heated directly by the sun's rays and moisture is abstracted by natural circulation of air due to density differences.

Tray drying technique in which peel could be dried by a hot air dryer. Air is blown into the electric heater or radiator by the mean of the fan, heated & passed to the drying chamber of the hot air drying machine. Forced ventilation and adjusted air distribution plates ensure the temperature equilibrium in the oven, the materials can dry evenly.

Vacuum oven drying is one of the most effective and gentle drying method known. During vacuum oven drying, high energy water molecules diffuse to the surface and evaporate due to the low pressure. In the absence of air, vacuum drying prevents oxidation along with this also maintains the color, texture, and flavor of the dried peel.

Freeze drying also named as ''lyophilization'' or'' Cryodessication'' i.e. a low-temperature dehydration process. Freeze-drying techniques adopt vacuum freeze-drying techniques. Product is pre-frozen encourage the water converts directly from vapor state to a solid state (sublimation) under low pressure.

Freeze-dried product has good re-hydration capability and could keep the original shape, color, and taste after re-hydration. A high-quality product is obtained by freeze-drying strategies because of processing of low temperature.

The aim of this study to describe the comparative study on four different drying techniques on the physical, chemical and microbiological properties of the orange peel powders and sweet lime peel powders.

Keeping in view, the present research work analysis on the comparative study **on "Effect of different drying strategies of physicochemical properties on citrus peel powders**" has been carried under the following objectives:-

1. Comparative study of different drying strategies on the citrus peel powders to analyses it's the effect on their physical, chemical and microbiological characteristics.
2. To check the quality aspects of the citrus peel powders in different drying strategies.
3. To study the shelf of the citrus peel powders on different drying strategies.

*****

Review of Literature

Fruits of the citrus group known as "hesperidium" is a science word used to define the fruit structure. Citrus fruits are one of the biggest and most significant fruit crops in the world, having an annual output of about 120 million tons, in which oranges make up about 60% of the total manufacturing, followed by tangerines with about 20%. To obtain multiple products, citrus fruits are processed, primarily juice. In addition, citrus peel is an interesting source of phenolic compound and ha s discovered excellent complete radical antioxidant potential **(Chen et al., 2 012).**Citrus fruits are the first fruit crop to have significance in international trade in the first amount. Various species and their hybrids, deemed to be of excellent business importance under the more general term citrus, include lemons (Citrus lemon), limes (Citrus aurantifolia), sweet oranges (Citrus sinensis), mandarins (Citrus reticulata), Satsuma's (Citrus unshiu), clementines (Citrus clementina), grape fruits (Citrus paradisi), and pummelos (Citrus maxima) **(UNECE, 2010)**.

Current global annual citrus production amounts to over 105 million tons, more than half of which are oranges. Approximately one-third of citrus fruit cultivation is used for processing and more than 80% of orange juice manufacturing.

Around the globe, citrus fruits are made. There are 140 nations producing citrus according to the **FAO (FAOSTAT, 2006).** Approximately 70 percent of the world's total citrus production is grown in the northern hemisphere, especially in Brazil, Mediterranean countries, and the United States. Spain is the largest producer in Europe, accounting for over 55% of European citrus production. The main nations producing complete citrus are China (24%), Brazil (24%), and the United States (11%). Brazil leads for

oranges with 29%, followed by the United States (11%), India, and China (8% each).

Consumption of citrus fruits is discovered by consumers worldwide to be well-accepted due to their appealing colors, pleasant flavors and aroma, as well as their well-known nutritional and health-promoting values.

Scientists have recently been able to create high value products from such by-products as cosmetics, medications, and the regeneration appears to be economically appealing **(Ashoush and Gadallah, 2011).**

Fruit processing sector by-products regarded as fruit waste primarily consist of heart, seeds, pomace and peels, contain big quantities of water and are in a moist and readily fermentable form. Unless further processed, these agro wastes generate odor, soil pollution, and insect harbor and can cause severe pollution of the environment **(Shalini and Gupta, 2010).**

Citrus fruits are an outstanding source of vitamin C, as well as having large quantities of other vitamins and minerals that your body necessarily needs to operate correctly, including B vitamins, potassium, phosphorous, magnesium and copper. These compounds consider more than 60 varieties of flavonoids, carotenoids and essential oils and are responsible for many of the health benefits of citrus fruits.Citrus fruits are a groovy source of dietary antioxidants that are essential in promoting health as well as interfering with and treating several chronic and degenerative diseases in humans. The most extensive phenolic compounds found in citrus fruits are flavonoids. Hydroxycinnamic and hydroxybenzoic acids are other phenolic compounds often found in Citrus. In order to safeguard against certain cancers and cardiovascular diseases, these compounds, and mostly anthocyanin, reduce oxidative stress in diabetic patients and defend DNA against oxidative damage.

Oranges

Citrus sinensis, also renowned as Lincheng (Liucheng sweet orange is an important fruit). Orange fruit comprises 50% of juice content and the remaining 50% is the rind, albedo, sacs and seeds which contain abundant amount of fiber. **(Saenz C. et al., 2007).** Because of their natural sweetness, range of kinds and diversity of uses from juices, marmalade to face masks, and candied orange slices, orange is a common fruit.

Oranges known for their abundance of vitamins, antioxidants and minerals and biologically active non-nutrient compounds such as phytochemical antioxidants, soluble and insoluble dietary fiber works to reduce the risk of cancer, chronic diseases such as arthritis, obesity and coronary heart disease.

Orange peel

Orange peel is the primary waste portion quantity to almost 50 percent of the fruit mass **(Braddock, 1999)**.Citrus sinensis extract contains flavonoids associated with antioxidant activity **(Kanaze et al 2008).**

A major class of secondary metabolites in orange peel is flavonoids that comparatively greater in peel in respect of other part. According to their structure, they are of 6 types are - flavnones, flavonols, isoflavones, anthocyanin's and flavones **(Senevirathne et al., 2009).**

Tannins in orange peel are specialized in forming irreversible complexes with wealthy proline proteins that help inhibit the synthesis of cell proteins.Orange peel includes vital oil high in monoterpenes, and D-limonene(96.62%)as the main element, making up about 90% of this oil. Citrus essential oil is a combination of volatile compounds consisting primarily of hydrocarbon monoterpene compounds which can be estimated in three parts: terpene hydrocarbons, oxygenated compounds and non-

volatile compounds **(Sawamura et al.,2004)**. Citrus peels are crowded with immune-boosting vitamin C, bone-building calcium and anti-inflammatory, antioxidant bioflavonoids.

They also provide potassium, which helps in checking blood pressure, and limonene, a phytochemical that can have anti-cancer impacts and can help with heart burning.

Nutritional benefits of dried orange peel

Dried orange peel contains 14% of the RDA of vitamin C and 525 calories and 5,00 g of protein per 100 grams, based on the nutritional facts given by the dried orange peel **USDA Food Composition Database.**

Nutrient composition in dried orange peel

Six calories in one tbsp., or 6 g, of dried orange peel and zero fat or sodium, 13 mg potassium, 1.5 g carbohydrates, 0.6 g dietary fiber, and 0.09 g protein. Some vitamins, including vitamin C and calcium, have 1% of the daily allowance or RDA recommended for vitamin A and small amounts of B vitamins. It has 1 mg of magnesium and phosphorus as well as some zinc.

Health benefits of dried orange peel

- ✧ Vitamin C initiate healthy cell growth and **repairs tissues**. Vitamin C is effective for the **eyes and cardiovascular system**, and it may help inhibit certain cancers.
- ✧ A source of potassium, a mineral that helps reduces **muscles and blood pressure.**
- ✧ Potassium also helps in **changing blood sugar into glycogen**, which is stored in muscle tissue and converted into energy.

- ✧ Orange peels have active compounds which provide regulatory effect on immune system. It suppresses **allergic reactions** and lower strain on body's defenses.
- ✧ Orange peels are enriched with antioxidants and vitamin E that helps to **clear spots** caused by burns, exposure and toxins.
- ✧ The consumption of orange peel extract in powdered form or tea can cure **inflammation in respiratory tracts**.
- ✧ Peels contain fiber that stimulates bowel function and also prevent **constipation.**
- ✧ Extracts acts as a **protective barrier against harmful effect of infections** and bacterial plaque so chewing orange peel is fabulous to freshen up breath, control bacteria and also avoid yellow spots on teeth.
- ✧ Flavonoids and limonene that has anti-carcinogenic properties works as blocking agent and **detoxification.**

Sweet Lime

Citrus limetta is a range of citrus fruits, the cultivator of 'citrus limon' is the species of mousambi or sweet lime, lucky with many health advantages. Sweet lime is served in India, Pakistan and Bangladesh as a nutritious juice. During the summers, the juice is mostly used-up as the presence of potassium and vitamin C is rejuvenating and delicious to combatsun strokes. Unlike lemon, it has a sweet taste, flavor and offers a variety of beauty benefits as well. Essences and extracts from fresh limes are used in the host of cosmetic care products like soaps, hair oils, body oils, mouth washes, tooth pastes and deodorants.

Nutritional value

According to the United States Department of Agriculture (USDA) National Nutrient Database, the juice of one lime that weighs approximately 44 grams (g) contains:

- 11 calories
- 3.7 g of carbohydrate
- 0.74 g of sugar
- 0.1 g of fiber
- 0.13 g of protein

One lime can provide 32 percent of the vitamin C needed in a day.

The nutrients in limes can influence heart, lessen the risk of asthma, and boost healthy skin.

Drying of Citrus Peels powder

Fresh citrus peel powder is highly perishable so having shorter shelf life. Preserving of products is carried out by drying, canning, pickling, freezing and smoking. In case of citrus peels, drying is superior option because of future utilization in any work. Drying is an ancient method used to maintain and extend the shelf life of multiple food products. The primary objective of drying food products is to remove water in the solid to a point at which microbial spoilage and deterioration arising from chemical reactions are considerably decreased. This allows the item to be stored for longer periods as the activity of microorganisms and enzymes is inhibited by drying. In general, drying includes the application of thermal energy that causes water to evaporate into the stage of vapor. However, drying

outcomes in structural, chemical and phytochemical modifications that can influence quality characteristics such as texture, color and nutritional values.

Simal et al.,(1997)proposed that the most important cause for the popularity of the dried products are better shelf life and product diversification as well as substantial volume reduction to decrease transportation cost. The effect of air drying temperature has been evaluated on the functional properties of dietary fiber obtained from orange by-products **(Garau et al., 2007).** Implementation of high-intensity ultrasound, high-speed drying and solar drying on orange peel drying kinetics and their antioxidant activity has been assessed **(Garcia-Perez et al., 2012; Senevirathne et al., 2009; Slama and Combarnous (1997).**

The most effective and economic ways of preserving foods of all varieties by removing the water using heat as medium **(Chen and Mujumdar).**

Preserving of different products is due to prevent them from deteriorate, to keep the quality attribute high and free from any microbial activity.it can be achieve by different drying techniques. The final quality of dried by-products may be determined by structural and compositional changes that may happen during the pre-treatment and drying phase **(Garau et al., 2007).**Drying was performed until the water activity (a w) of the samples was less than 0.6 due to the possibility of preventing micr obiological spoilage of dried samples **(Ramaswamy and Marcotte, 2006).**

SUN DRYING

Drying is the procedure practiced from the time of immemorial stated by **Fellow 1997.** The conventional method of drying is sun drying which is most cost efficient in terms of capital & operation and weather dependent, time consuming and prone to contamination process. Sun drying is a

traditional practice that involves exposing the skins to the impacts of sun and wind. Usually, the practice is managed by spreading the citrus peel on the floor. Sun drying also involves spreading the citrus peel in shade as well as on elevated surfaces (e.g. panels positioned on blocks). By putting the citrus peel on a raised surface, a farmer can guarantee better air circulation and thus enhance the drying process.

Direct exposure of food by sunlight decreases the quality of food prod ucts such as color, vitamin content, etc.Another notable benefit of sun dryin g is that the practice is entirely natural and eco friendly. Thus, farmers who are entirely dedicated to sustainability generally practice this drying techniq ue.

Hot air oven drying

Hot air oven drying is common for drying multiple products owing to comparatively brief drying time, uniform heating and more hygienic characteristics. The temperature varies from 45-70c and this decreases drying time by less than 20 hours. This temperature range provides maximum color value and minimizes the loss of volatile oils and discoloration **(Minguez-Mosquera et al., 1994 Diaz Moroto et al., 2004 Ibrahim et al., 1997 Berke and Sheih 2001).**

Bakshipour et al (2012) observed that drying the warm air oven is th e most viable technique for drying the food product without losing the nutrie nts as well as being simple to manage and economical as well.

Principle and Mechanism

The dryers are produced of trays kept in a cabinet that are attached to an air source heated by gas, diesel or bio-mass such as rice husk. Air temperature is generally governed by a thermostat that is normally placed between 50 and 70oC. The air reaches the bottom of the room below the

trays and then rises, through the trays of drying food, and exits from an opening in the top of the chamber. In the Practical Action Systems, the trays are intended to force the air to follow a longer zigzag path that raises the air/ food contact time and thus enhance its effectiveness. This system also decreases back stress, which implies that it is possible to use cheaper, lower fans.The tray dryer as it is made of trays kept in a cabinet that is attached to an air source heated by electric, gas, diesel or bio mass such as rice husk. The air temperature is generally regulated by a thermostat that is normally set between 45 and 70 C as explained **(Brett et al., 1996).**

Vacuum oven drying

Vacuum drying (VD) has some unique features such as greater drying speed, reduced drying temperature, and oxygen-deficient handling environment. These characteristics are useful and help enhance the quality and nutritional value of dried fruits and vegetables, and therefore VD has been used to dry a number of fruits / vegetables **(Amellal and Benamara, 2008; Long et al., 2007; Rahman et al., 2009).** Vacuum drying is conceptually the perfect technique for drying heat and/or oxygen-sensitive products owing to the benefit of reducing moisture at low temperatures and minimizing the likelihood of oxidation responses. Vacuum drying is the perfect technique for drying heat- or oxygen sensitive products (such as microorganisms and enzymes) owing to the benefit of red ucing moisture at low temperatures and minimizing the likelihood of oxidation responses.

Freeze Drying Technique

Freezedrying is a technique of removing water from frozen material by sublimating ice crystals. Appropriate process implementation parameters en able us to acquire products of the highest quality compared to products

dried using traditional techniques**.**

Chou and chau (2001) observed that lyophilizer is one of the best ways to remove water by retaining the nutrients as much as possible as a new product.

Lyophilization is prevalent, but cost-intensive and therefore one of the main goals during freeze-drying process development is to minimize drying time (primarily main drying time, which is the longest of the three freeze-drying steps). However, raising the shelf temperature into secondary drying before removing all the ice from the item is probable to cause collapse or eutectic melting. Thus, from the point of view of product quality as well as process economics, detecting the end of main drying is very critical. This review concentrated in the near future on latest developments and their goals.

Freeze drying appears to be a stronger technique of conservation than other techniques of dehydration, such as air drying or drum drying reported by **Brown (1999).**

Lyophilization cycle design has traditionally been split into three components:

1. Freezing in which the liquid sample is cooled until pure crystalline ice is created from the liquid fraction and the remainder of the sample is frozen into a glassy state in which the viscosity is too large to permit further cry stallization.
2. Primary drying in which the ice produced during freezing is removed by vacuum sublimation at low temperatures, leaving an exceptionally porou s structure in the remaining amorphous solution, typically 30% water. This step is performed at 10-4 to 10-5 atmospheres and a product temperature of –45 to 20 ° C; sublimation during main drying is

the consequence of combined procedures of thermal transfer and mass tr ansfer.

3. Secondary drying in which most of the remaining water is desorbed from the glass as the sample temperature increases gradually while keeping low pressure. Ideally, a dry, readily reconstituted cake with an elevated surface area (approx. 10 m2/g) [23] is the final product.

*****

Material and Methods

In both the laboratory and the pilot plant, the current study envisaged fundamental studies. In this section, it includes the equipment used and the analytical method used in the research job. All elements of physical, chemical, antimicrobial assessment, microbial analysis, characteristic of microscopy, shelf life are discussed.

The titled research **"Effect of different drying strategies on physic-chemical properties of Citrus peel powders**" were carried out in the Centre of Food Science and Technology, Institute of Agricultural Sciences, Department of Animal Husbandry & Dairying, Institute of Medical Sciences and Central Instrumentation Facility, IIT, Banaras Hindu University, Varanasi, India.

3.1 Materials:

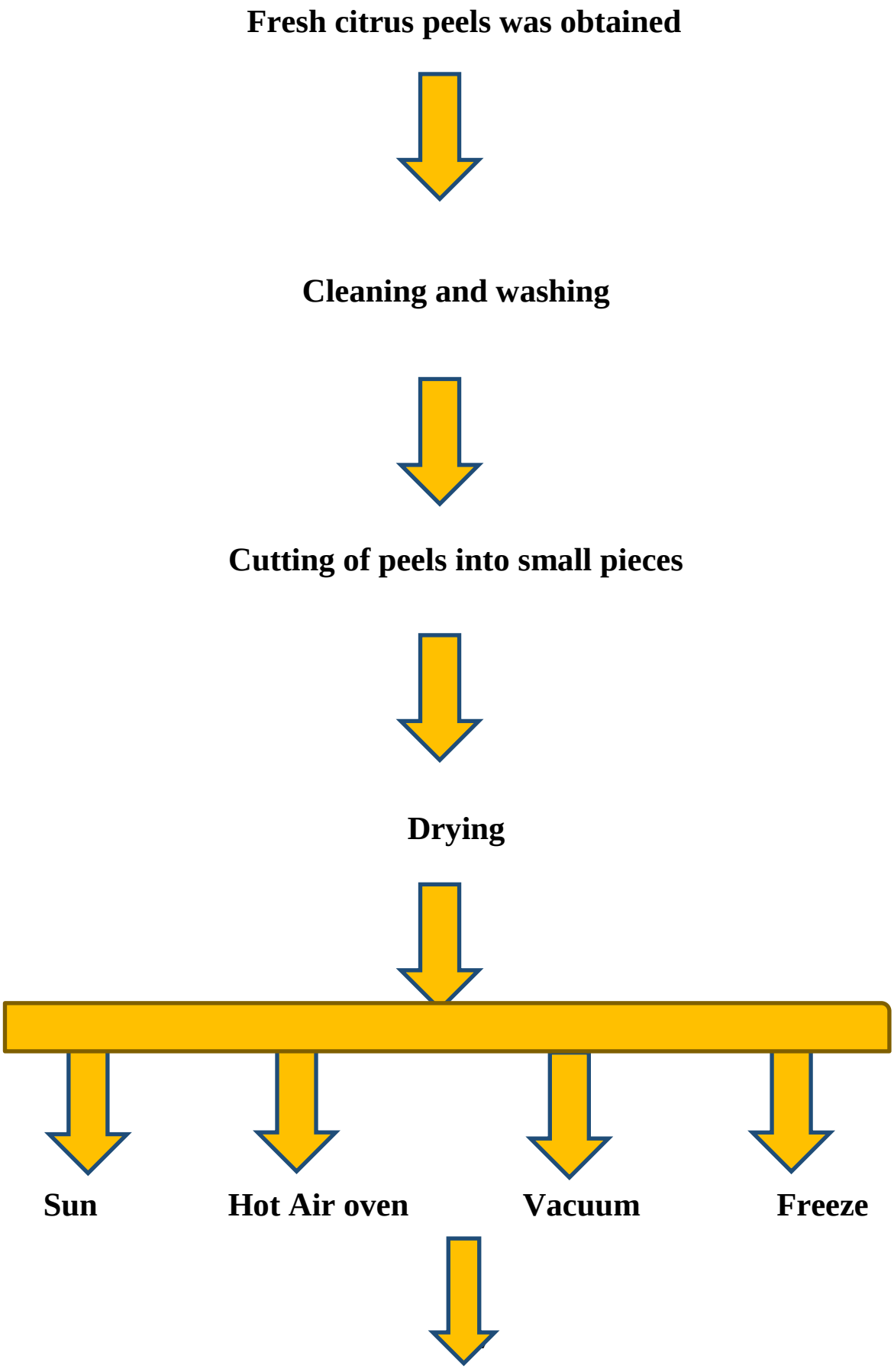
3.1.1 Orange peels:

Fresh orange peels of two type's viz.,
Citrus sinensis var Nagpur & Citrus sinensis var Kinnow were collected throughout the Banaras Hindu University Campus from fruit suppliers and fruit juice corners.

3.1.2 Sweet lime peels:

Citrus limetta var Mosambi fresh sweet lime peels were acquired from the local fruit juice corner across the University Campus of Banaras Hindu. The flow chart (Fig.3.1) shows how Citrus peel powder is prepared.

Fig 3.1 Flow chart of citrus peel powder



Dried peels was grinded into powder

Grinded powder was sieved by sieve

Fine powder of Citrus peel powders were ready

Peel powder was packed in plastic bags

Sealing

Storage in Deep Freezer

3.1.3 Chemicals and Reagents:

Certain food grades chemicals and analytical grade chemicals were used during research work.

3.1.4 Packaging Materials:

For the shelf-life
study, polyethylene pouches and LDP bags were used to package citrus peel powders.

3.1.5 Basic laboratory Requirements:

The fundamental specifications include glassware such as beaker, test tu be, conical flask, glass rod, petriplates, funnel, measuring cylinders, pip ette, burette, volumetric flask, reagent bottles, etc. Other vital specificati ons include tubes, cuvettes, test tube stands, micro-
pipettes, sucker, tray, sieve, knife, dropper, distilled water.

3.1.6 Instruments:

Name	Company, model&country
Electronic weighing balance	MetllerToledo,JB1603-C/Fact,Switzerland
Microwave-Oven	IFB 25SC2, India
Vortex Shaker	Macro scientific norks Pvt. Ltd. Delhi
Hot air Oven	Perfit, 992/10, India
Laminar Air Flow	Labtech LCB 1201V, Daihan Pvt. Lmt, India
Centrifuge Machine	Sigma,3-30K,Germany

High pressure steam sterilizer	Tony,SX-500,Japan
Spectrophotometer	Shimadzu, Japan
Soxhlet apparatus	SOCS PLUS,SCS-4 Chennai
Cold Centrifuge	Thermo fisher biofuge statos centrifuge
Hunter lab Colorimeter	ColorFlex EZ
Incubator	Remi,India
Weighing Balance(gm)	Oriental,sales corporation
Deep Freezer	LTI-700, Japan
Water Bath	Vision Scientific co. Ltd
Tray Dryer	Khera industries, Mysore

3.2 Processing of citrus peel powders:

Citrus peels were permitted to dry using multiple drying techniques. Fou r techniques were chosen to preserve Citrus peel powders- sun drying, Vacuum oven drying, Hot air oven drying, Lyophilizer dryi ng.

3.2.1 Sun drying:

Citrus fruit peels have been cleaned and cut into tiny pieces. They have been put in a tray and retained for sun drying outside.

3.2.2 Vacuum oven drying:

Fresh citrus fruit peels were cleaned and then grinded in pulp form using a mixer grinder. After grinding, pulped peels were spread on a stainless steel tray and dried at 500^0 C temperature in a vacuum oven dryer until t he peel became free of moisture, fragile and crisp.

3.2.3 Hot air Oven drying:

Slices of peels were put on an stainless steel tray in a single layer and dr ied in tray dryers at 50^0C,55^0C & 60^0C temperature, respectively, until c risp.

3.2.4 Freeze drying (Lyophilize drying)

Freeze drying methods are divided into two sections, i.e., a vacuum pump to minimize ambient gas pressure in a vessel containing the drying substance. (ii) A condenser to remove moisture through condensation on a cooled surface to-40^0C to-80^0C. To dry the lemon peel powder, the lyophilized drying tool was used. The method consists of 3 steps-internal freezing (30^0 C for 2 hours), sublimation (-20^0C, 0.66 Pa for 12 hours) & desorption (25^0C, 0.66 Pa for 12 hours), pre-frozen Citrus peel pulp put in lyophilizer in a conical flask.

3.3 Grinding

The dried citrus peel powder was grinded using the grinder machine and then sieved to obtain the fine powder required**.**

3.4 Packaging

The powders of lemon peel generated by multiple drying techniques were packed in polyethylene pouches.

3.5 Storage

Chemicals were subjected to packed samples of citrus peel powder, microbi ological modifications at separate intervals to assess their shelf life. At 4^0C the Citrus peel powders were kept in deep refrigerator for 3 years.

3.6. Proximate Analysis of citrus peel powders:-

3.6.1 Moisture content (AOAC,2000)

Procedure:-

Exactly weighed 2 g of the sample in smooth dried petridish. The sampl e was heated for 2-4 hrs in a 105^0C warm air furnace. The petriplates were transferred to a dessicator and were allowed to cool.

Calculation:-

$$\textbf{\% Moisture content} = \frac{\textbf{Wt.after drying- Wt.of empty petriplate}}{\textbf{Wt. of sample}} \times 100$$

3.6.2 Ash content

Procedure:-

Ash content was determined according to (AOAC,1990).Approximately ,5 g of the sample was weighed correctly and taken in a earlier weighed clean, dried crucible. The crucible was put on a warm tray until the char ring and smoking were discontinued. It took about 2hrs. Then, the sampl e was transferred for ashing in a muffle oven at 550^0C for 2hrs.

Calculation:-

$$\textbf{Ash\%} = \frac{\textbf{Weight of ash(g)–Weight of empty cruible}}{\textbf{Wt. of Sample taken}} \times 100$$

3.6.3 Fat content(IS:1011:2002)

Method of Soxhlet as outlined in (AOAC, 1990).

5 g of the samples were evaluated in the thimble and fitted in a soxhlet extractor earlier weighed. Then the soxhlet beaker was poured with

approximately 90 ml of petroleum ether and its tops were draped with cotton plugs. The flask content was heated at 700C for 2 hours, then further temperature was increased for 25 minutes to 1300C for evaporation. Then the soxhlet extractor was carefully removed from the apparatus.

Calculation:-

$$\textbf{Fat \%} = \frac{\textbf{Wt. of beaker after drying–Wt. of empty beaker}}{\textbf{Wt. of sample taken}} \times \mathbf{100}$$

3.6.4 pH Determination

In a beaker, 5 g of the sample was added to 100 ml distilled water. The p H was evaluated by direct electrode immersion into the sample. A digita l pH meter was used and must be calibrated at 300C before use with a co nventional buffer solution.

3.6.5 Titrable Acidity

5 g of the samples were drawn in a conventional flask and up to 50 ml of this quantity was taken in a conical flask as an aliquot and 3 drops of ph enolpthalein was added. It was titrated against 0.1N NaOH until purple had reached the end point.

Calculation:-

A = (N x V1 x W) / (V2 x 10)

Where,

A = Percentage of Acid

N = Normality of Titrant

V1 = Volume of Titrant

W = Equivalent Weight of Predominant Acid

V2 = Volume of Sample

3.6.6 Reducing sugar

Procedure

The DNS(DinitroSalicyclic acid) method was used for estimating the ion concentration of reducing sugar in a sample.Reducing sugar is one of that in a basic solution forms aldehydes or ketones.

0.3 ml of citrus peel powder extract was added into 0.9 ml of DNS reagent in the test tube and further, for 5 min in the boiling wathbath,mixture was incubated. At ambient temperature,cooling was done.

The absorbance of the supernatant was measured at 540nm using a spectro-photometer that is directly proportional to the amount of reducing sugar.

3.6.7 Total sugar content

Sample preparation

2g of sample was measured and transferred to the 200 ml of beaker and made up it to 100ml of volume with distilled water. Then the samples was boiled for 10-15 minutes into a boiling water bath with continuous stirring by using glass rod.After boiling, beaker was taken out of water bath,3 ml of concentrated H_2SO_4 was added into the sample. Again boiled for 3 minutes.Now, the sample was filtered using fluted filter paper into 250 ml of volumetric flask.

Sample dilution

2.5 ml was taken from the above prepared sample into 100 ml of volumertric flask and made up the volume upto the mark.Then 5ml from above diluted sample was taken into 50 ml of conical flask and 15 ml of conc. H_2SO_4 was added along with 5 ml of phenol(5%) was also added. Now the absorbance at 492nm using UV-visible spectrophotometer was taken with respect to color development.

Calculation

Total CHO % in the sample = (Sample concentration× Dilution factor)/10000

3.6.8 Ascorbic acid

Principle

Ascorbic acid is a water soluble and heat labile vitamin. It is also known as Vitamin C. It is abundantly present in citrus fruits. Ascorbic acid decreases indophenol from 2,6-dichloro phenol to a leucoform colorless. Ascorbic acid is oxidized to ascorbic acid dehydro. While the dye is a blue colored compound, the endpoint is a purple colored appearance. In acidic medium, they are colored pink.

Oxalic acid is used as the medium of titration.

Materials :

1. Oxalic acid-4%

2. DCPIP

3. Stock Standard Solution

4. Working Standard Solution

Procedure:-

Standard

5ml of standard solution was pipetted out into conical flask. 10 ml oxalic acid of concentration abont 4 % was added and measured against the dye. The end point was detected by occurance of pink colour which persists for a few minutes. The amount of dye used-up is equivalent to the amount of ascorbic acid.

Test

5ml of test sample was pipetted out into a 100ml of conical flask.An oxalic acid of 4% concentration of 10 ml was added and quantify against the dye. The appearance of pink colour which persists for sometime consumed was noted was remarked as endpoint.

Calculation:-

The amount of ascorbic acid in given sample=

volume of dye required to titrate test × conc. of std × Dilution factor/Volume of dye required to titrate std

3.7 Chemical Analysis of Citrus peel powders:-

3.7.1 Total Phenolic Content Assay

Total phenolic compounds were determined using the Folin-Ciocaltean reagent and the Gallic acid as a standard(Slinkard and Singleton,1997).

Sample extraction-

0.2g citrus peel powder sample was taken and made up the volume up to 100 ml in conical flask with methanol(80%w/w). Now,shaking them

properly in the centrifuged tubes and cold centrifugation was done at 10,000 rpm for 15 minutes.The supernatant was separated out and made up volume to 10 ml with distilled water and I ml of extract was taken and diluted 10 times with distilled water.

Further by taking 2 ml of diluted extract and mixed it with 10 ml of FC reagent. Kept in a dark place for 15 minutes and then add 8 ml of 7.5% Na_2CO_3. Allow to incubate for 50 minutes at 35^0C and the absorbance was measured at 750nm. The total phenolic content equivalent to Gallic acid was determined from standard graph.

3.7.2 Antioxidant activities by Diphenyl-2-picryl-hydrazyl(DPPH) assay

In 50ml of methanol(80%w/w)was mixed with 1g of citrus peel powder that was accurately weighed and kept them at 37^0C temperature .The cold centrifugation at 10,000 rpm for 15 minutes was done and supernatant was separated out in a tube and made up volume to 10 ml with distilled water.Dilution up to 10 times was done with 1 ml of extract.

Free radical scavenging activity was done according to the technique described by (Mensor et al.,2001).3 ml of DPPH solution and 1ml of sample extract was mixed and sample was kept in dark place for 30 minutes at room temperature.

The absorbance was recorded at 517nm against ethanol as blank and sample.

Calculation:-

Antiradical activity% = $(A_{BLANK} - A_{SAMPLE}) \times 100$

Where,

A_{BLANK} =absorbance of control

A_{SAMPLE}=absorbance of citrus peel powder

3.8 Analytical methods

3.8.1 Color analysis

The color of citrus peel powders were analyzed by using colorimeter(Hunter Lab) to get their L, a and b values.The parameters are L* a* b*,where L* indicates lightness(0 to 100) with 0 being black and 100 being white. The coordinate a* is for red(+) and green(-) and b* is for yellow (+) and Blue(-) [Silva et al.,2014}. To know the object colour, all three values were needed.

3.8.2 Bulk density

The bulk density was determined by the method described by (Goula et al.,2004). 2g of citrus peel powder was transferred to 10 ml of graduated cylinder and calculated as the ratio between the mass of powder and the volume occupied in the cylinder.

Calculation:-

Bulk density = Mass of the powder/

Volume of the powder

3.8.3 Tapped Density

2g of the powder was taken in a 10 ml graduated cylinder and was tapped on a bench for 100 times from a height of 10 cm and calculated by dividing mass of the powder with new volume occupied y the sample.

Calculation:-

Tapped density = Mass of the powder/ Volume after tapping

3.8.4 Water solubility index

2.5g of powder in 30 ml distilled water in previously weighed 50 ml centrifuge tube followed by intermittent stirring for 30 min at 30^0C and then centrifuging at 3000g for 10 minutes. The sediment left after pouring the supernatant into a tarred petriplate was weighed and was dried overnight in hot air oven at 100^0C and dried solids obtained were weighed.WSI was expressed as percentage of dried solids over initial dry sample weight(Schoch 1964).

Calculation:-

% WSI = Weight of supernatant×100/ Weight of sample

3.8.6 Water Absorption index

20 ml of distilled water was mixed with 2.5 of sample at 25^0C for 24 hrs.The centrifugation was done at 3000rpm for 15 minutes and sediments was collected and weighed.

Calculation:-

WAI = Weight of wet sediment /Weight of sample

3.9 Microbial Analysis of Citrus peel powder

For analyzing the citrus peel powders,the microbiological tests were done at an interval of 25 days.

Preparation of sample

0.2g of sample was measured in centrifuge tubes and was filled with distilled water up to the mark. Then centrifugation at 5000rpm for 10

minutes was done to extract out the supernatant and volume was made up to 10 ml. Now, 1 ml of extract is diluted with 9 ml of normal saline solution (0.9% NaCl) and samples were diluted up to 10^{-3} dilution.

3.9.1 Yeast and mould Count

Yeast and mould counts were determined by the method of speck(1992) with the help of Potato Dextrose Agar (PDA) after incubating at 25^0C for 2 days.

PDA was prepared by adding accurately measured 4.8g of potato dextrose agar broth,5g of agar agar and final volume was made up to 200 ml with distilled water in a conical flask. The conical flasks were covered with the cotton plugs and sterilized by autoclaving for 30 minutes at 15 Psi.the melted media was poured into the sterilized petriplates inside the laminar air flow chamber and allow to solidify.100µl of diluted extracted sample was plated on the solidify agar plate and aerobically incubated at 25 C for 2 days and colonies were counted and results were expressed as colony forming units (CFU)/g of powder.

Yeast and mod count = No. Of colonies /Dilution factor×0.1

3.9.2 Total plate count (TPC)

Determined by using Plate Count Agar after incubation for 1 day at ambient temperature.

3.5g of plate count agar,2g of agar agar were mixed and dissolved in conical flask of 200 ml.Sterilization and autoclaving of conical flask that were cotton plugged was same as yeast and mold count.

Total plate count was obtained with the help of standard procedure given by Indian standard(SP:18(part XI)-1981). The 100µl of diluted

samples were plated on solidified media and spread with sterile spreader.Incubation at ambient temperature in inverted position for 1 day was required.

TPC(CFU/ml) = No. Of colonies/Dilution factor×0.1

Where,

CFU= colony forming unit

Amount taken=0.1g

Washing of Citrus Peel

Cutting of Citrus Peels into pieces

Dried Peels

*****

Result and Discussion

The present study was undertaken to study the effect of drying strategies on physicochemical characteristics and microbiological properties of citrus peel powder The different drying technique viz, Sun Drying, Tray Drying, Vacuum Drying and Freeze Drying were used to study their effect on the physicochemical and microbiological aspects of the two citrus fruits peels namely; *Citrus sinensis (Orange) and Citrus limetta (Mosambi).*The result are untaken and discussed in accordance with the objective:-

4.1Study on the physical, chemical and microbiological attributes of Citrus peel powders

4.1.1 Proximate analysis of Citrus peel powders

The Citrus peel powder was analyzed on proximate basis viz, Moisture, Ash, Fat, Reducing sugar, Ascorbic acid, Total sugar content, Titrable Acidity, total phenolic content (TPC), flavonoids and pH.

Table 4.1 represents the physicochemical properties of fresh Citrus sinensis (Orange) and Citrus limetta (Mosambi).

Parameter	**Orange** (Citrus sinensis)	**Mosambi** *(*Citrus limetta)
Moisture content (%)	7.91 ±0.007*	6.37±0.027*
Ash content (%)	5.15 ±0.019*	5.79±0.026*
Fat content (%)	0.87 ±0.008*	0.71±0.015*
Reducing sugar (%)	0.33±0.035*	0.48±0.003*
Ascorbic acid (%)	18.41 ±0.097*	13.47±0.054*
pH	6.53±0.011*	6.55±0.078*
Titrable Acidity (%)	1.19 ±0.006*	1.03±0.041*
Total Sugar content (%)	16.90 ±0.004*	17.79±0.074*

*Standard deviation ± 0.05, n = 3

The pH, reducing sugar, total sugar content , fat of dried citrus peel powder were pointedly different amongst the lime but the moisture content, titrable acidity, reducing sugar, ascorbic acid, ash content, were not significantly analogous among the varieties due to varietal C*itrus sinensis (Orange) and Citrus limetta (*Mosambi)variation.

The overall results of proximate chemical composition of Citrus peel powder are in agreement with results achieved by Sosuleki and Wu (1988), Camire and flint (1990), Ralet et al., (1993); Camire et al (1997); Chantara et al (2008).

The proximate analysis of orange peel powder presented in table 4.1 disclosed that it contained 7.91 percent humidity, 0.87 percent fat and 16.90 and 5.15 percent complete sugar content ash content. These findings are similar to the findings reported by Humaira et al (2013).

4.1.2 Microbial analysis of Citrus peel powder:-

Total plate count (TPC) and yeast and mold count (YMC) have been explored and the findings are presented in table 4.2. Both Citrus variety's microbial count has a negligible or slight distinction.

The number of microbial relies on the phase of planting, harvesting, maturity and agro-ecological situation.

Table 4.2 Microbial analysis of Citrus peel powders

Samples	Total Plate Count Log_{10} CFU/g	Yeast and mold count Log_{10} CFU/g
Orange (Citrus sinensis)	10,000 ± 0.03*	3000 ± 0.08*
Mosambi (Citrus limetta)	10,000 ± 0.07*	4000 ± 0.01*

*Standard deviation ± 0.05, n = 3

4.1.3 Yield of Citrus peel powder from fresh citrus peel:-

Fig 4.1 shows the output of Citrus peel powders. The yield range of Citrus peel powder was discovered by freeze drying technique from 31–30,79 percent compared to tray drying technique valued at 29,85–29,12 percent, whereas the yield of Citrus peel powder generated by vacuum drying ranged from 28,38–27,41 percent.

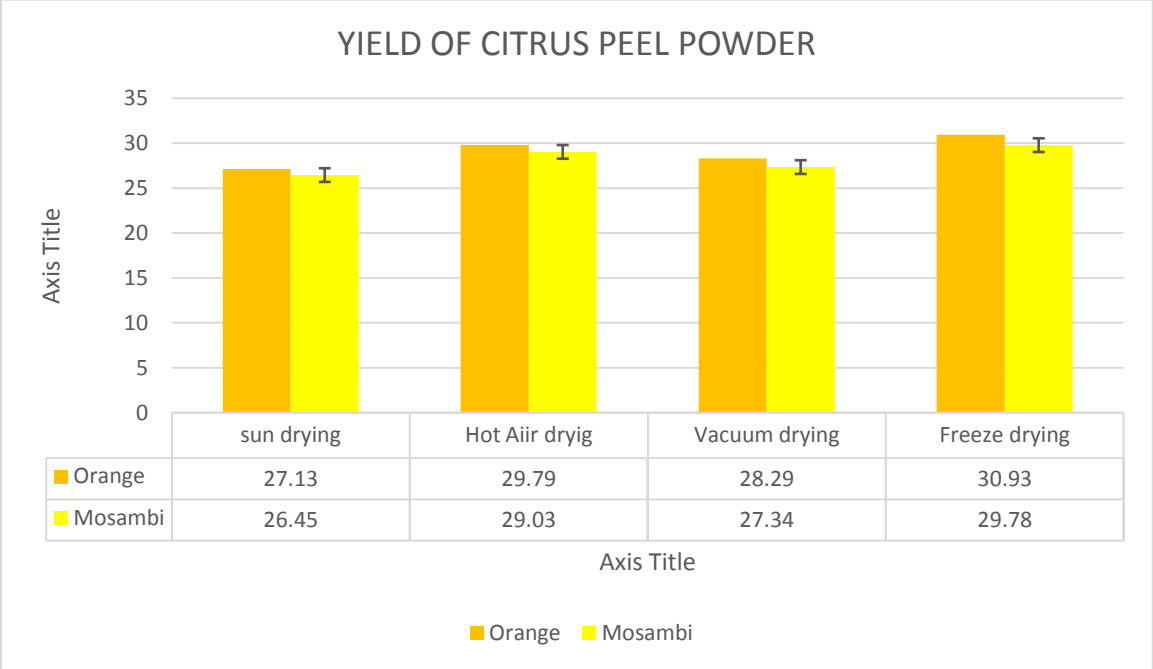


Fig 4.1 Effect of different drying strategies on the citrus peel powder yield

(SD±0.05, n=3)

4.2 Determination of the physical, chemical, microbiological properties of Citrus peel powders

4.2.1 Physical analysis

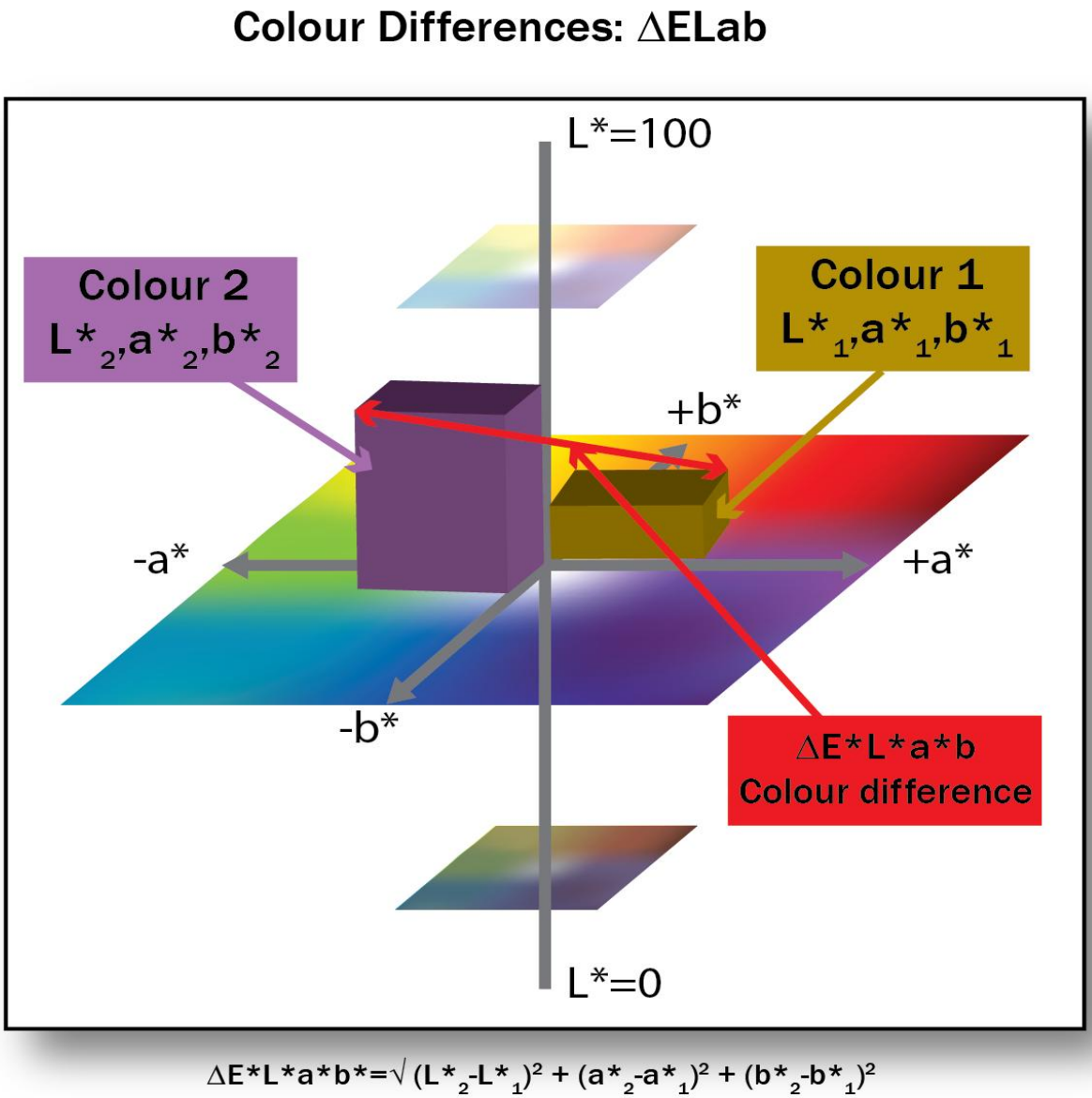
4.2.1.1 Color

Table 4.3 presents the impact of the drying technique on the color of the Citrus peel powder. Hunter lab spectrophotometer measured the color by showing L, a, b values. The color shift observed throughout the sample was

due to color browning as a result of mallard reaction compounds created during peel drying. This can also be explained by the corruption and degradation of carotenoids and flavonoids pigments responsible for the color of the orange peel, as well as mallard and non-enzymatic browning reactions during microwave drying.

The freeze drying method was found more considerably than other drying strategies due to the low temperature of the drying process, loss of carotenoid content is minimized and color was retained.

L* (lightness), a* (green/ red) and b* (blue/yellow)



$$\Delta E^*L^*a^*b^* = \sqrt{(L^*_2 - L^*_1)^2 + (a^*_2 - a^*_1)^2 + (b^*_2 - b^*_1)^2}$$

L- Lightness and darkness, a- greenness and redness, b- blueness and yellowness

4.3 Table Effect of different drying strategies on Hunter lab colors values of Citrus peel powders

Samples	**Sun drying strategies**		**Hot air drying strategies**		**Vacuum drying strategies**		**Freeze drying strategies**	
	Orange Mosambi		Orange Mosambi		Orange Mosambi		Orange Mosambi	
L*	66.51± 0.75	75.92± 0.98	68.95± 0.07	80.15± 0.29	57.37± 0.35	69.81± 0.12	64.79± 0.01	73.59± 0.12
a*	13.03± 0.69	-3.35±0.75	18.52± 0.27	-0.17±0.84	13.73± 0.14	3.53 ±0.09	19.77± 0.01	-1.63±0.31
b*	77.56± 0.09	40.62± 0.43	70.94± 0.58	38.54± 0.40	25.55± 0.07	40.29± 0.01	65.53± 0.09	33.87± 0.26

L*- lightness, a*-green/red, b*-blue/yellow

*Standard deviation ± 0.05, n = 3

4.2.1.2 Bulk Density

A powder's bulk density is the mass ratio of an untapped powder sample and its quantity including an inter-particulate volume contribution. Therefore, the bulk density relies on both the powder particle density and the particle and peel paper spatial structure.

The bulk density is expressed in grams per milliliter (g/ml) although the International unit is kilogram per cubic meter (1g/mc=1000g/m).The bulk density of citrus peel powders is presented in table 4.4. The bulk density of the powder is primarily dependent on particle size which particle size distribution and particle shape, which might be reason for significant changes in bulk density of powder. Similar finding were observed by Pla et al., (2012). The bulk density was found to be maximum in the freeze dried powder as compared to other drying strategies.

Table 4.3 Effect of different drying strategies on bulk density of citrus peel powders

Sample	Sun drying strategies (g/cc)	Hot air drying strategies (g/cc)	Vacuum drying strategies (g/cc)	Freeze drying strategies (g/cc)
Orange (Citrus sinensis)	0.51± 0.08*	0.50±0.02*	0.53±0.07*	0.55±0.17*
Mosambi (Citrus limetta)	0.37±0.03*	0.33±0.11*	0.35±0.04*	0.39±0.05*

*Standard deviation ± 0.05, n = 3

4.2.1.3 Tapped density

The tapped density is an enhanced bulk density achieved by tapping a container containing the sample of powder mechanically. A graduated measuring cylinder or vessel containing the powder sample is mechanically tapped to obtain the tapped density. The measuring cylinder or vessel is mechanically tapped after observing the original powder quantity or mass and quantity or mass measurements are taken. The tapped density of citrus peel powder is showed in table 4.4 below. The result of tapped density ranged from 0.55 to 0.73 g/cc. Freeze drying strategies was found to be best one in comparison to other drying strategies having lowest value of tapped density.

Sample	Sun drying strategies (g/cc)	Hot air drying strategies (g/cc)	Vacuum drying strategies (g/cc)	Freeze drying strategies (g/cc)
Orange (Citrus sinensis)	0.55±0.007*	0.57±0.010*	0.53±0.015*	0.50±0.002*
Mosambi (Citrus limetta)	0.47±0.014*	0.51±0.003*	0.46±0.005*	0.45±0.019*

*Standard deviation ± 0.05, n = 3

Table 4.4 Tapped density of citrus peel powders

4.2.1.4 Porosity

The powder porosity is the relationship between the powder's tapped and particle densities as stated in (Jinapong et al., (2008).During drying, the sample porosity first risen to a critical value, at which point further reduction in moisture resulted in pores collapsing. A third-order polynomial correlated the porosity of the orange peel with humidity. The best result came out in freeze drying strategies in orange as well as in mosambi.

Table 4.5 Porosity of different variety of Citrus peel powders by different drying strategies is shown below:

Sample	Sun drying strategies (%)	Hot air drying strategies (%)	Vacuum drying Strategies (%)	Freeze drying strategies (%)
Orange (Citrus sinensis)	41.19±0.009*	42.01±0.007*	41.79±0.076*	40.85±0.019*
Mosambi (Citrus limetta)	48.95±0.013*	49.27±0.023*	48.72±0.082*	47.63±0.001*

*Standard deviation ± 0.05, n = 3

4.3 Physicochemical characteristics of Citrus peel powder:-

For moisture, pH, ascorbic acid, titrable acidity, ash, fat reducing sugar, complete sugar content, the two types of citrus peel powders (freeze drying, hot air oven drying, sun drying, vacuum drying strategies) were evaluated. The outcome is shown in Table 4.6 below.

Table 4.6 Results

Table 4.6 presents the pH of Citrus peel powder. The pH range was smaller in pH values between the vacuum samples than the other drying samples. Toontem et al. (2012) decided to find outcomes.

The content of moisture was discovered on dried citrus peel powder and low on dried citrus peel powder with hot air. Singh et al. (2018) also decided to find outcomes with Krishnamurthy and Natarajan.

Analyzed the ascorbic acid. The findings of orange and mosambi ascorbic content in this research were consistent with 32.6±5.2 mg.g-1 in lemon fruit peel (Lopez et al., 2004; Barros et al., 2012).

Table 4.6 shows the amount of ascorbic acid in lemon peel powder acquired from various drying strategies

Drying Strategies	Moisture (%)		pH		Ascorbic acid ($mg.100g^{-1}$)	
	Orange	Mosambi	Orange	Mosambi	Orange	Mosambi
Sun drying strategies	.78±0.01*	6.10±0.08*	6.53±0.76*	6.55±0.01*	18.43±0.33*	13.57±0.29*
Hot air drying strategies	7.73±0.07*	6.07±0.19*	6.20±0.32*	6.09±0.25*	21.76±0.09*	15.83±0.06*

Vacuum drying strategies	8.35±0.09*	6.92±0.37*	4.34±0.19*	4.69±0.08*	26.97±0.70*	11.29±0.18*
Freeze drying strategies	6.78±0.11*	5.49±0.89*	5.20±0.83*	5.33±0.56*	32.7±0.01*	16.54±0.005*

*Standard deviation ± 0.05, n = 3

The titrable content of acidity in citrus peel powder ranged from 1.20% to 0.79%. Table 4.7 provided the outcomes. i.e. Freeze dried sample was smaller than drying warm air oven, sun drying, and vacuum samples in acidity values. Toontem et al. (2012) decided to find results.

The findings were more or less comparable to those reported by Singh et al, (2009). Table 4.7 showed the outcome as 5.59-4.19 percent.

The findings ranged from 0.92 to 0.63 percent of both types of fat content citrus peel powder. We also agreed with singh et al, (2015).

Table 4.7 Result

Drying Strategies	**Ash**		**Fat %**		**% Titrable acidity**	
	Orange	**Mosambi**	**Orange**	**Mosambi**	**Orange**	**Mosambi**
Sun drying strategies	5.27±0.010*	5.74±0.082*	0.81±0.054*	0.59±0.037*	1.17±0.044*	0.98±0.011*
Hot air drying strategies	4.53±0.013*	5.03±0.088*	0.83±0.010*	0.63±0.067*	1.11±0.086*	0.86±0.053*
Vacuum drying strategies	4.98±0.003*	5.59±0.013*	0.87±0.045*	0.67±0.090*	1.20±0.030*	1.04±0.086*
Freeze drying strategies	4.19±0.068*	4.93±0.005*	0.92±0.085*	0.71±0.001*	1.07±0.016*	0.79±0.090*

*Standard deviation ± 0.05, n = 3

Table 4.8 result continued				
Drying Strategies	**Reducing sugar (mg/100g)**		**Total sugar content**	
	Orange	**Mosambi**	**Orange**	**Mosambi**
Sun drying strategies	0.35±0.046*	0.50±0.052*	16.86±0.007*	21.03±0.080*
Hot air drying strategies	0.28±0.094*	0.42±0.014*	16.07±0.077*	20.41 ±0.0898
Vacuum drying strategies	0.32±0.063*	0.47±0.004*	16.35±0.009*	20.74±0.049*
Freeze drying strategies	0.23±0.032*	0.39±0.097*	15.86±0.031*	20.13±0.006*

*Standard deviation ± 0.05, n = 3

Table 4.8 above showed the outcome of decreasing the sugar content of citrus peel powder. The findings range from 0. 50 –0.23 mg per 100 g. The outcome was comparable to Kumar et al. (2012) recorded results. Highest value of reducing sugar was in sun drying and lowest in freeze drying method of both citrus peel powders.

The total sugar content of the citrus peel powder was resulted and analyzed. The result were ranging between 21.03 – 15.86 % of both variety of citrus peel powder. The sun drying method was with higher reading than other drying method then follows vacuum, hot air oven drying and least value of freeze drying method. Result finding agreed with Garau et al., (2008).

4.4 Total phenolic content

The TPC were resulted and analyzed and ranging between 1.51 – 1.84. The result of total phenolic content of citrus peel powder done by different drying method was shown in table 4.9 and finding was agreed with

Tummala et al. (2008). This result is more analogous to the report of Khan et al, (2010).

With the increase in drying time, there was decrease in phenolic content in citrus peel powder. Shorter the drying time, preserves the maximum phenolic content Ghanem et al., (2012).

Table 4.9 Total phenolic content of citrus peel powder

Drying strategies	Total Phenolic Content (mg/100g)	
	Orange	Mosambi
Sun drying strategies	1.95±0.004*	1.60±0.061*
Hot air drying strategies	2.05±0.037*	1.69±0.019*
Vacuum drying strategies	1.87±0.012*	1.51±0.008*
Freeze drying strategies	2.25±0.005*	1.77±0.054*

*Standard deviation ± 0.05, n = 3

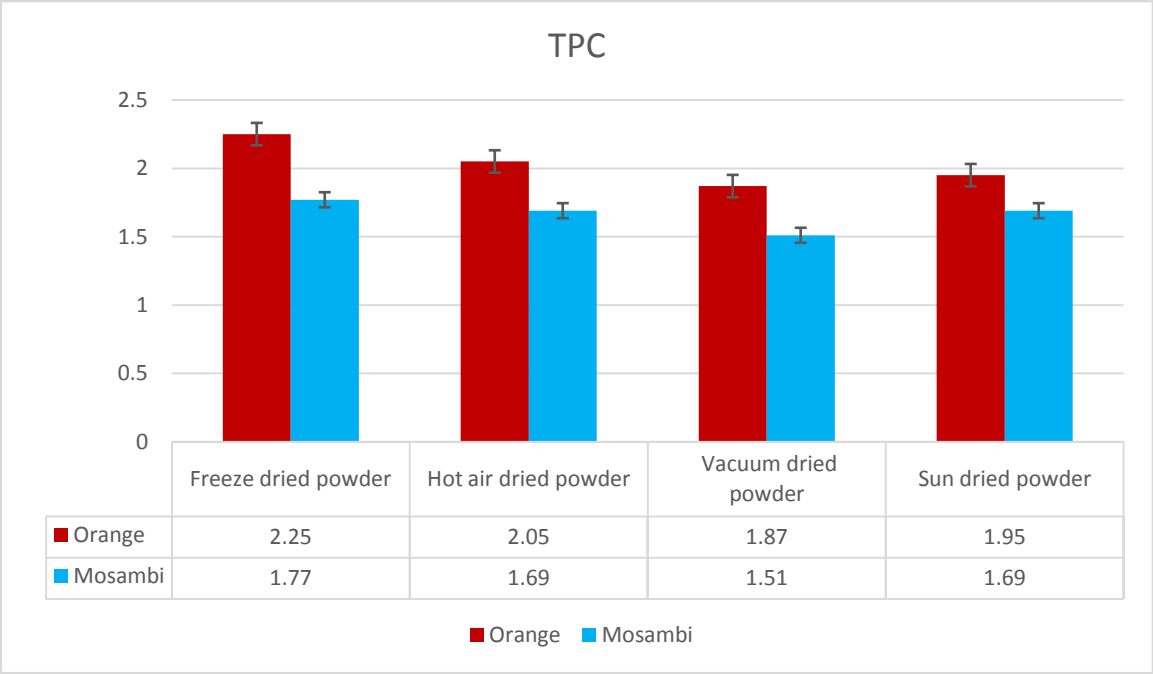


Fig 4.2 Total phenolic content of citrus peel powders of different drying methods

4.5 Antioxidant property by DPPH inhibition:-

The free radical scavenging activity was obtained according to El-aal and Halaweish (2009). The existence of phenolic, vitamin C, carotenoid and flavonoid compounds relies on radical scavenging activity.The findings presented were similar to EL-aal and Halaweish (2009), which reported 65 - 72 percent of the radical scavenging activity of citrus peel powder. The drying method could ruin some of the phenolic compound Li et al. (2006), especially elevated temperature (warm water drying) and lengthy drying time.

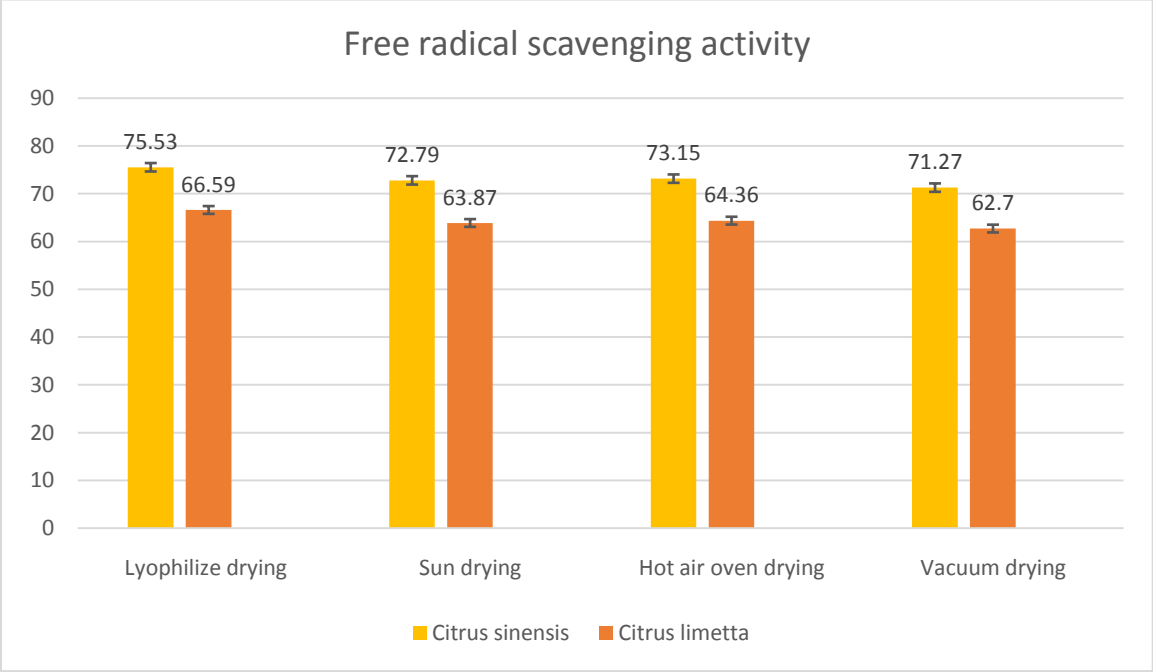


Fig 4.3 shows the effect of different drying method on antioxidant activity of citrus peel powders.

4.6 Water solubility Index

The impact of the drying technique on the water solubility index (WSI) of citrus peel powder is shown in table no.4.10. Depending on the drying temperature observed for both types of Citrus peel powder, the table showed the difference in solubility index.

The solubility index extended from 80-90 percent of all citrus peel. The overall pattern of the outcomes stated that there was an inverse relationship between the solubility temperature and the solubility index, where the higher the degree of therapy used for solubility temperature, the less the solubility coefficient value.This was in correlation with the previous findings of Wang et al, 2015 who reported 95 % WSI of orange and 99 % of mosambi.

Table 4.10 Effect of different drying strategies on Water solubility index of Citrus peel powders

Drying strategies	Water solubility Index (%)	
	Orange	Mosambi
Lyophilize drying strategies	93.59 ±0.067*	98.86±0.003*
Hot air oven drying strategies	89.82±0.018*	96.99±0.098*
Sun drying strategies	83.74±0.047*	95.45±0.011*
Vacuum drying strategies	80.37±0.006*	94.78±0.005*

*Standard deviation ± 0.05, n = 3

4.7 Water absorption Index (WAI):-

The effect of drying methods on swelling capacity of citrus peel powder of water g-1 dried sample is presented in table 4.11.

In case WAI, the observation of Citrus limetta (Mosambi) is higher than Citrus sinensis Orange peels powder.

The results are in agreement with the work of Pla et al., (2012) who reported the Water holding capacity of citrus peel powder.

Drying of peel increases WAI and lower sugar content results in increasing the value of water solubility index. (Lario et al, 2004).Water absorption index is higher in lyophilize drying strategies.

Table 4.11 Water Absorption index of citrus peel powders affected by drying strategies

Drying strategies	Water Absorption Index (ml/g)	
	Orange	Mosambi
Lyophilize drying strategies	5.7±0.011*	6.7±0.025*
Hot air oven drying strategies	5.4±0.083*	6.2±0.056*
Sun drying strategies	4.7±0.006*	5.9±0.001*
Vacuum drying strategies	5.1±0.019*	6.0±0.047*

*Standard deviation ± 0.05, n = 3

All values are means of triplicate determinations

Freeze Dried
Orange Peel Powder

Hot Air Oven Dried
Orange Peel Powder

Sun Dried
Orange Peel Powder

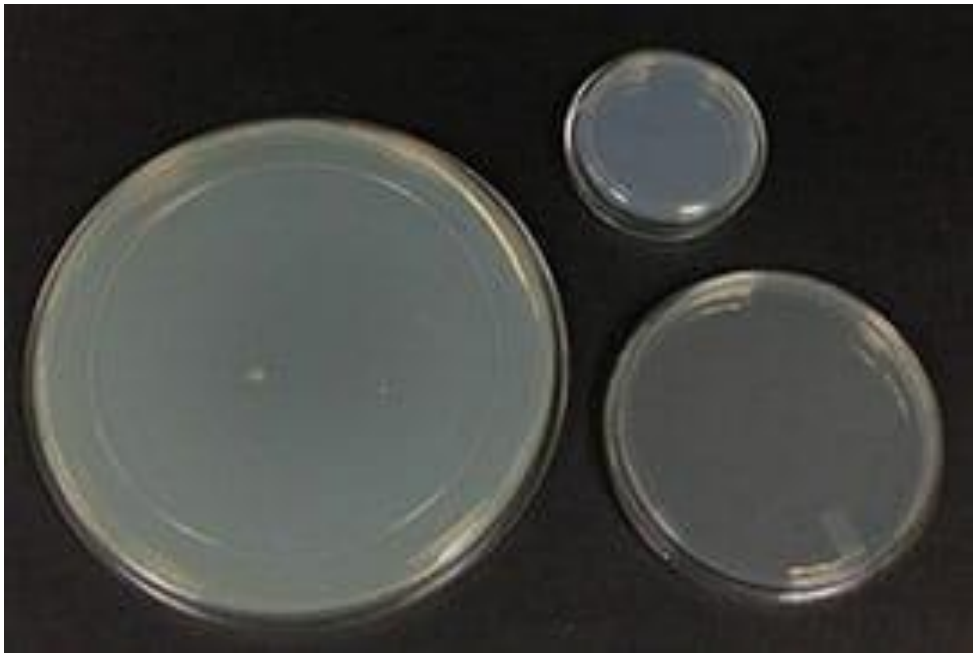
Vacuum Dried
Orange Peel Powder

Freeze Dried
Mosambi Peel Powder

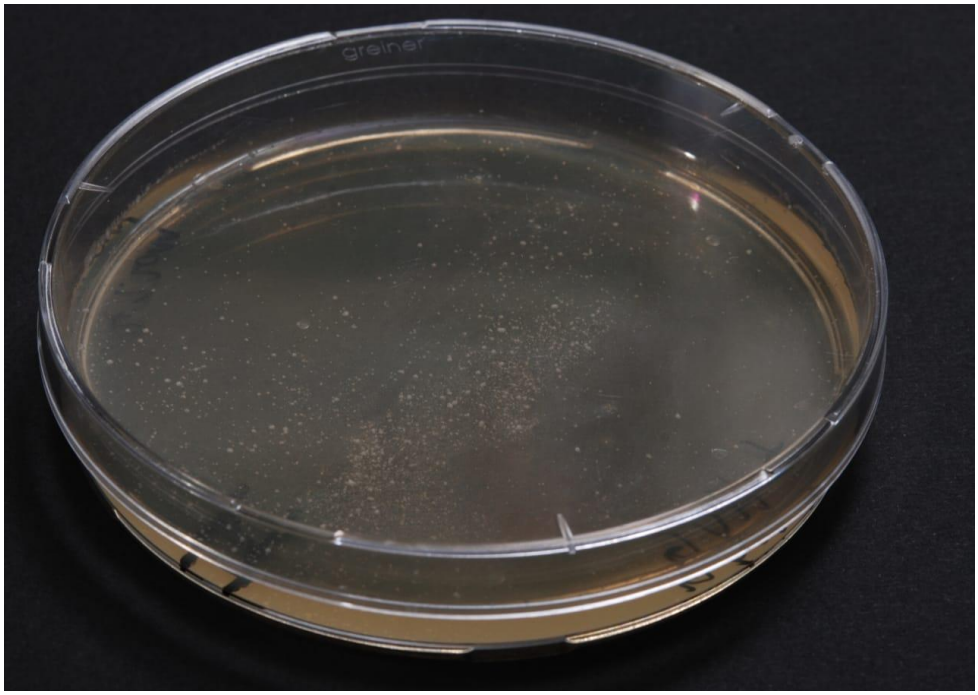
Vacuum Dried
Mosambi Peel Powder

Sun Dried
Mosambi Peel Powder

Hot Air Oven Dried
Mosambi Peel Powder



Total Plate Count of Orange Peel Powder



Total Plate Count of Mosambi Peel Powder

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Summary and Conclusion

The main aim of this research was to analyze the "Effect of different drying strategies of physicochemical properties on citrus peel powders" by preparing powder from fresh citrus peel. The three main motive were taken at the initiation of the research work. The whole study was portioned into 4 chapters. In the chapter 1, reason of choosing up this research is nutritional benefit of citrus peel powder and its impact on health. In the chapter 2, which is the review of literature comprises of its whole history, origin, distribution, nutritional aspects, composition, healthbenefits. In chapter 3, that is material and method deals with the methodology employed for carrying out the research work.Chapter 4, tell out result and discussion i.e. the result of this research work illustrated with the help of tables and figures and the discussion which describes the results obtained with appropriate reasons and support.

The result of pre- study were summarized as follows:-

- **To determine the physical, chemical and microbiological aspects of Citrus peel powder.**

- Citrus fruit peels viz. Citrus sinensis (Orange) and Citrus limetta (Lime) were selected and prepared.

- Cleaning and washing of fresh citrus peels of orange and Mosambi was done after that peels were cut into small pieces for drying purpose viz.Sun and tray drying while the paste of peel was prepared for Vacuum and Freeze drying Method.

- The temperature for sun drying was kept at 32-41^{0}C for about 3 days whereas in Hot air oven drying, the three different range of temperature were taken as follows :- 50^0 C, 55^{0}C and 60^{0}C for 1 days.
- Vacuum drying was carried out at 50^{0}C for 20 hours while the temperature of freeze drying in frozen stage (-20^{0}C) under 0.66 Pa vacuum.
- The color was retained in citrus peel as yellowish or orangish-yellow in Citrus sinensis and creamish- green or green in Citrus limetta in Freeze drying method comparatively to other drying method.
- The functional aspects namely water solubility Index, water absorption Index, bulk density and tapped density of citrus peel powder were analyzed and compared.
- Analyzed results of physical properties of citrus sinensis has bulk density 0.53g/cc, porosity 41.13%, particle density 0.89g/cc, water solubility index 80.31 % and water absorption index 5.4 ml/while mosambi Citrus limetta has bulk density 0.38 g/cc, porosity 63.91 %,particle density 1.06 g/cc, water solubility index 89.15 % and water absorption index 6.7 ml/g.
- Mosambi has the lowest density of bulk but the largest ability for water absorption relative to orange peel. Orange peel powder has the largest density of bulk, but the smallest porosity proportion.
- From the analyzed result, it was observed that citrus limetta (Mosambi) possessed the highest value of Water solubility Index and Water Absorption Index due its hydrophilic nature.

- ✧ The bio-active compound viz. ascorbic acid, total phenolic content, antioxidant activity and carotene content were best resulted in lyophilizer drying method as compared to other drying technique.
- ✧ Chemical attributes of citrus peel powder were analyzed and resulted i.e. Moisture 7.91%, ash content 5.15%, fat content 0.87 %,ascorbic acid 18.41 %, total sugar content 16.90 %, titrable acidity 1.19% and pH 6.53.
- ✧ The morphological properties of citrus peel powder were analyzed by SEM,it was reported that orange peel powder has rough and contains some fibers that spread throughout the surface whereas mosambi shows irregular surface with minute pores.
- ✧ The microbiological studies like TPC, yeast and mold of citrus peel powder were analyzed.
- ✧ The TPC was found as high as in powder of citrus sinensis (Orange) and it was also high in vacuum dried powder.YMC was noticed in tray dried and freeze dried powder.
- ✧ The study resulted that the superior drying technique in all criteria, aspects and attributes of preparing citrus peel powder was Freeze drying method.

Conclusion

In the present study, Citrus peel powders were made by different drying method and effect on their properties were comparatively analyzed. The results showed that the citrus peel powder had significant effects on the functional and technological properties. Moreover, it is a good source of total polyphenols and has good antioxidant properties which will make it a useful ingredient in the preparation of various food products. Overall, the

results suggested that citrus waste could be used as a raw material for many products. So, among the all four drying method Lyophilizer drying will be the best method to convert the wet citrus peel into dried powder keeping all physicochemical aspects of better quality. From industrial point of view, citrus peel which is the residues from processing industry could be further processed for value addition of various food products as well as medicinal purpose for health goodness.

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