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FROM ORCHARD TO SHELF: MINIMIZING WASTE AND MAXIMIZING NUTRITION SECURITY.

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ABSTRACT

Fruits and vegetables play an essential role in the human diet, providing vital micronutrients, fiber, and antioxidants. As the world's largest producer of these crops, India has a thriving food processing sector aimed at reducing post-harvest losses and enhancing the availability of nutritious, affordable food products. Recent innovations have focused on creating preserved fruit products that retain the beneficial compounds of fresh produce, such as polyphenols, vitamins, and flavonoids, while offering a longer shelf life. These products, including fruit leathers, serve as convenient, nutrient-rich alternatives to fresh produce, aligning with Sustainable Development Goals to improve food security and nutrition.

Techniques like blanching and vacuum drying are employed to maintain organoleptic properties, while innovative packaging such as BOPP materials further extend product shelf life. Research highlights the nutritional advantages of processed fruit leathers, with increases in essential minerals like magnesium and potassium, though some vitamin losses occur during processing. The production of these value-added products not only addresses food waste but also makes nutritious options more accessible to economically disadvantaged populations. Such preserved products support healthy lifestyles, offer convenience, and are a valuable tool in combating food insecurity**.**

Key words-: fruit preservation, food and nutrition security, antioxidants, sustainability, SDGs.

INTRODUCTION

Fruits and vegetable form a crucial component of the diet pyramid, fulfilling essential dietary requirements such as fiber, carbohydrates, fats, proteins, and, most importantly, micronutrients. Defined as the edible part of a plant containing seeds and pulp, fruits and vegetables play a vital role in nutrition (Press, I. A. R. C. (2003)). India, as the leading producer of fruits and vegetables globally, boasts a robust and versatile food

processing sector. This sector not only plays a significant role in bolstering the agricultural industry but also creates new avenues for agro-food products while enhancing the quality of food available to the public.

Sakina, M. (2019) stated; in recent years, as individuals become more aware of the importance of balanced diets, changes in food habits are increasingly discernible. One way to facilitate this shift is through food processing, which alters the form of raw produce to make it more appealing and convenient for consumers. India's National Policy on food processing aims to increase the proportion of food that is processed in the country to 25% by 2025. Popular fruits grown in India include mangoes, grapes, apples, apricots, oranges, bananas, avocados, guavas, litchis, papayas, sapotas, and watermelons. As part of the effort to reduce post-harvest losses, India has seen a positive growth in the processing of food products, including ready-to-serve options, preserved fruit pulps, marmalades, and other preserved items.

One such innovative product being developed is a “preserved fruit product” made from fruits and seeds that enhance both the nutritional value and flavor. This product could serve as a valuable alternative to fresh fruit and vegetable, offering a rich source of micronutrients. Fruits and vegetables naturally provide various health benefits due to their bioactive compounds, such as polyphenols, flavonoids, carotenoids, and vitamins. By preserving both, it becomes possible to retain these beneficial compounds in a dried and packaged form, which can serve as a convenient supplement for individuals who require antioxidants, anti-inflammatory agents, anti-carcinogenic, anti-diabetic, and anti-viral nutrients in their daily diets.

In addition to their nutritional benefits, preserved fruit and vegetable products have economic advantages, particularly in terms of reducing food waste. According to a report by the Food and Agriculture Organization (FAO, 2024; UNEP, 2021), approximately 1.3 billion tonnes of food produced for human consumption is wasted each year. By processing and preserving both fruits and vegetables, these inefficiencies can be mitigated, ensuring that more of the harvested produce is utilized, leading to value-added products.

Preserved fruit and vegetable products, such as leathers, offer an affordable alternative to fresh fruit and vegetable. Given the often-inflated prices of fresh produce, many consumers are unable to afford the recommended daily intake of fruits and vegetable. Fruit leathers provide a viable solution by delivering the same essential micronutrients in a more accessible format. This product aligns with the goals of Sustainable Development Goal (SDG) 2, which seeks to promote food security, improved nutrition, and sustainable agriculture. Specifically, SDG 2 aims to end hunger and ensure that everyone has access to safe, nutritious, and sufficient food.

According to Institute of Development Governance, 2024, fruits and vegetables have been declared an indispensable part of a balanced diet, delivering essential vitamins, minerals, flavonoids, antioxidants, and polyphenols that support overall health and prevent premature aging. This proposed fruit and vegetable preserved product would also address the need for better health, in line with SDG 3, which focuses on ensuring healthy lives and promoting well-being for all. For those who may not enjoy consuming whole

fruits or vegetable but still need the nutritional benefits, preserved fruit and vegetable product can serve as a convenient supplement.

In addition to serving as a nutrient-rich alternative to fresh fruit and vegetable, the preserved product is a versatile snack that can be consumed in a variety of settings, such as offices, schools, hospitals, and social gatherings. The product could also benefit economically disadvantaged populations, who often lack access to nutrient-dense foods. By offering such products at an affordable price, these communities could access the essential nutrients that they may otherwise miss out on.

Such products may particularly appeal to children and teenagers, thanks to its pleasant taste and visually appealing presentation. This product not only meets their dietary needs but also encourages healthier eating habits among younger populations. Moreover, the product offers several health benefits, including being rich in fiber, low in calories, portable, and convenient, without added sugars, and packed with micronutrients.

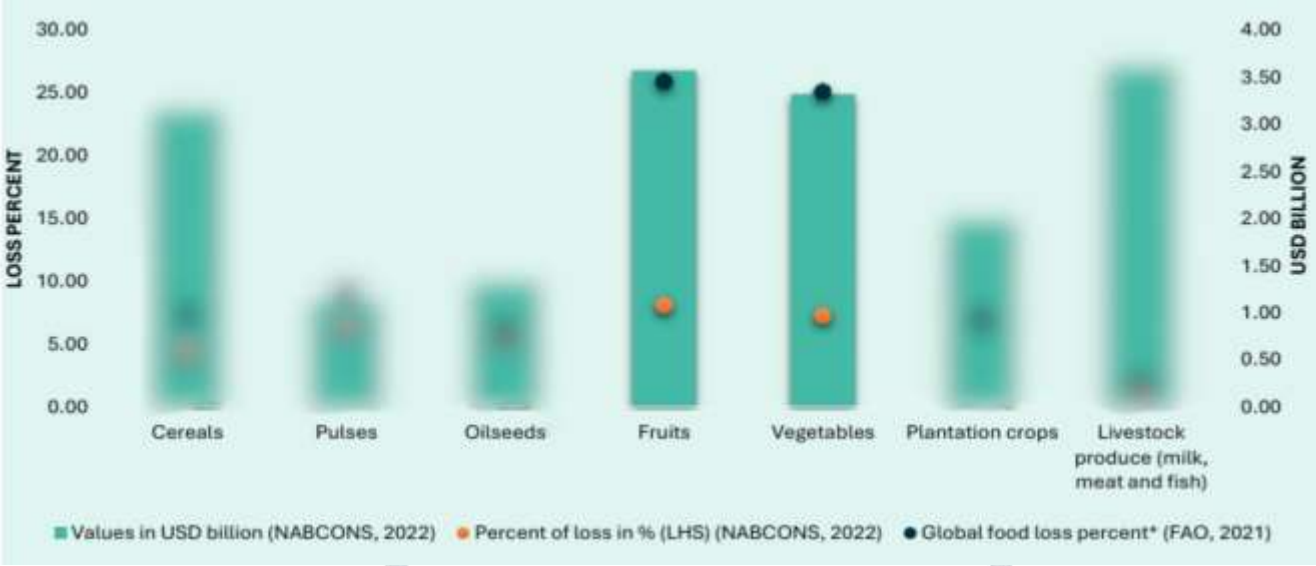
Reducing fruit/vegetable and financial losses is a pressing concern today. One major challenge is the high rate of post-harvest fruit/vegetable wastage, particularly in a country like India, which has diverse agro-climatic conditions suitable for growing a wide variety of tropical, subtropical, and temperate fruits. It is estimated that between 20% and 30% of India's horticultural produce is wasted before it reaches consumers (Ranjan, et al. 2023). This wastage is primarily due to the perishable nature of fruits/vegetables, the country's ambient high temperatures, and inefficient post-harvest handling, storage, transportation, and marketing processes.

By processing fruits and vegetables into value-added products like fruit leather, much of this wastage can be avoided. The dehydration of fruit and vegetable purees into preserved product not only preserves the produce but also increases its nutritive content, making it a more valuable food item. Moreover, the product pertains a longer shelf life than fresh produce, further enhancing its economic and nutritional value. The process of dehydrating and preserving helps to slow down microbial growth and reduce the oxidation of fats and oils, preventing rancidity and maintaining the product's quality over time.

LOSSES AND ECONOMIC COST

The increasing production of grains, fruits, and vegetables (F&V) in India presents a significant challenge in reducing post-harvest losses (PHL), especially in light of limited mechanization and weak logistics from storage to retail distribution. Despite these advancements, the country still experiences an immense annual loss of Rs. 1.53 trillion (USD 18.5 billion) due to PHL of crops and agri-allied produce, as revealed by a 2022 NABCONS (NABARD (national agriculture and rural development) consultancy services) study covering the years 2020 to 2022. Interestingly, while the percentage of post-harvest losses is higher for F&V compared to grains and oilseeds, India’s losses in this sector remain lower than the global average. However, Indian surveys on PHL are often limited in scope, focusing primarily on quantifiable losses while neglecting quality degradation during post-harvest activities such as threshing, winnowing, and transporting produce

from farms to homes, mandis, or retail outlets. This oversight means that the actual impact of PHL is likely underestimated, as significant quality deterioration occurs throughout the supply chain. Addressing both quality and quantity losses will be crucial for optimizing agricultural output and mitigating the economic impact of PHL on India's agri-sector (Gulati, A., *et,al*. 2024).



Source: NABCONS 2022, FAO, 2021 (Gulati, A., *et,al*. 2024).

CLASSIFICATION OF FRUITS AND VEGETABLES

Botanically, fruits are the mature ovaries of flowering plants, typically containing seeds. They can be classified into three main types: simple fruits, which develop from a single ovary and include examples such as fleshy fruits like mangoes, apples, and grapes, as well as dry fruits like almonds; aggregate fruits, which form from multiple ovaries of a single flower, such as strawberries and raspberries; and multiple fruits, derived from a cluster of flowers (inflorescence), examples being pineapples and figs. In addition, fruits are classified based on their ripening behaviour. Climacteric fruits, like bananas, apples, and tomatoes, continue to ripen after harvest due to a surge in ethylene production, while non-climacteric fruits, such as grapes, cherries, and citrus, do not undergo ripening post-harvest. This classification has implications for post-harvest handling and shelf life, with climacteric fruits being more perishable and requiring specific storage conditions (Fukano Y and Tachiki Y. 2021).

However, vegetables are defined as the edible portions of plants that are not classified as fruits, are categorized based on the plant part consumed. Root vegetables consist of the nutrient-dense underground parts, such as carrots, beets, and radishes. Stem vegetables, including asparagus and celery, are harvested for their soft and edible stems. Leafy vegetables, such as spinach, lettuce, and kale, are prized for their fiber content and rich supply of vitamins. Flower vegetables refer to the edible blooms of plants, with common examples being cauliflower, broccoli, and artichokes. Additionally, certain plant products classified botanically as fruits, like tomatoes, cucumbers, and peppers, are commonly prepared and consumed as

vegetables in the culinary context. Lastly, seed vegetables, such as peas and beans, are legumes consumed for their protein-rich seeds. This classification aids in understanding the diverse nutritional benefits and culinary uses of various vegetables (Dhaliwal, 2017).

TABLE.1 CLASSIFICATION OF FRUITS AND VEGETABLES

FRUITS*	Based on Morphological Condition	Simple fruits (lemon, lime, citrus, peach, apple, pear)
		Aggregate fruits (raspberries, strawberries, blackberries)
		Multiple fruits (pineapple)
	Based on Ripening Behaviour	Climatic fruits (bananas, tomatoes)
		Non-climatic fruits (grapes, cherries)
VEGETABLES**	Root Vegetables	carrots, beets, and radishes.
	Stem vegetables	asparagus and celery.
	Leafy vegetable	spinach, lettuce, and kale
	Flower vegetable	cauliflower, broccoli, and artichokes
	Fruit Vegetable	tomatoes, cucumbers, pumpkin and peppers.
	Seed vegetable	peas and beans.

Source-: * Naseer.B. *et al.*, 2021

** IARC Handbooks of Cancer Prevention Volume 8: Fruit and Vegetables,2003)

TECHNIQUES FOR PRESERVING ORGANOLEPTIC PROPERTIES

The study denotes about several preparation methods of a fruit leather which actually starts with lye peeling technique (the technique in which fruit is boiled in 0.5% NaOH for 2 minutes to avoid browning effect.) followed by hand peeling post washing. Further ascorbic acid (100mg/100g) added t prevent browning. Then it is pulped and sieved. To preserve the material KMS (potassium metabisulphite) at 600pmm is added because it helps to achieve lower enzymatic browning (Singh L.J Tiwari R.B, 2019; Chen and Martynenko, 2018 and Tontul and Topuz, 2017).

A study highlights the crucial role of blanching before applying heat treatment to vegetables, emphasizing its necessity in the drying process. It is recommended to wash vegetables in cool water prior to drying, followed by blanching, which is essential for preparing certain vegetables for this method. Blanching helps

destroy enzymes by subjecting the vegetables to high temperatures, thereby preventing loss of color and flavor during drying while also reducing drying and storage times. The findings indicate that water blanching typically results in greater nutrient loss; therefore, steam blanching is suggested as a preferable alternative, even though it is more time-consuming. The residual heat retained in the vegetables post-blanching accelerates the drying process. It is important to monitor the vegetables closely towards the end of the drying period, as they tend to dry more rapidly and may scorch if not watched carefully. Before packaging, it is critical to ensure that all moisture is completely eliminated to prevent mold growth, ensuring that the food remains dry and free from insects. This careful attention to the blanching and drying process is vital for maintaining the quality and safety of the final product (Paul L. *et al*., 2017).

In a study conducted by Dharma A.S.B. *et al.* (2024) various evaluation methods are employed, including texture analysis, water activity assessment, syneresis analysis, statistical analysis, and hedonic testing (Just About Right - JAR). The texture of the product is analyzed using a Shimadzu EZ-SX texturometer, which applies both pressure and movement to provide detailed insights into the surface texture. For water activity measurement, the sample is placed in a cup container positioned within an Aw meter chamber. The lever is then shifted to initiate the process, allowing for water migration until equilibrium is reached. It is important to note that samples with lower moisture content may take several hours to provide an accurate water activity reading, with measurements being repeated three times for reliability. Similarly, for the hedonic test, a panel of selected individuals evaluates the developed product based on specific organoleptic parameters and provides feedback. In this study, a 7-point hedonic scale is utilized for rating the product, where each rating corresponds to a defined value. Finally, statistical analyses are performed using the mean and standard deviation for the data collected, and the resulting information is processed using software to conduct a one-way analysis of variance (ANOVA).

DRYING TECHNIQUES

In a study, three distinct methods were employed for drying samples. The first method involved hot air drying using a cabinet-type laboratory dryer, set at temperatures between 60 and 70 degrees Celsius for a duration of 115 to 175 minutes. The second method utilized a domestic microwave oven, operating at 90 and 180 W for 16 and 60 minutes, respectively. The final method implemented was vacuum drying conducted at 60 and 70 degrees Celsius, with pressures ranging from 200 to 300 mbar for 85 to 230 minutes. Additionally, a moisture analyser was utilized to determine the moisture content of the samples. Physiochemical analyses were conducted to evaluate various parameters, including color, polyphenol extraction, in-vitro bio accessibility, total phenolic content, and antioxidant capacity, alongside organoleptic properties. Several authors within the study noted that increasing drying temperatures accelerates the drying process, thereby reducing the overall drying time (Suna S., 2019).

Another study discusses the potential of transforming seasonal fruits into value-added products, thereby ensuring their availability year-round. This approach is expected to significantly benefit both farmers and the

market while substantially reducing post-harvest losses. To achieve this objective, the osmotic drying method is highlighted as the most effective preservation technique, requiring minimal investment in sophisticated equipment. The study elaborates on how growers can adopt this method to convert excess fruit production into stable, dehydrated products. This technique is advantageous for producing safe, stable, nutritious, flavorful, and cost-effective concentrated products by immersing whole fruits or their chunks in a high osmotic pressure solution (Jadhav SS, 2018).

PACKAGING OF THE DEVELOPED PRODUCT

Singh L.J and Tiwari R.B, (2019) stated in a study regarding storage of fruit leather that moisture content decreased in punnet packing largely in comparison to BOPP packing. In addition to this, the ascorbic acid content of the leather sample considerably declined in both packaging materials, where 127.3 and 138.5 mg/100g ascorbic acid retained in punnet and BOPP after 4 months storage duration. The study concluded that BOPP packaging has proved to be a better barrier to ascorbic acid barrier as compared to punnet packaging.

ASSESSMENT OF PRODUCT POST PROCESSING

A study demonstrates certain chemical compositions of tamarind pulp and jaggery as follows, for tamarind the data states moisture to be 85%, crude fat was 2.36% protein0.2% and carbohydrate being 8.36% plus ash content observed was 4.08%. similarly, when jaggery liquid composition was considered, it showed respective results namely, moisture being 17.45%, crude fat and protein were 1.04% and .95% respectively including carbohydrates and ash to be 79.66% and .9% orderly. Apart from this, when microbial analysis like TPC, yeast and mould count and total coliform was done for the selected sample for at least 30 days period but nothing was found. Later as the time passed TPC increased gradually from 0 to 0.6×103 CFU/gram and 1.4×103CFU/gram after 90 days (Kurware HS, *et al*., 2023).

A study by Ofoedu Emmanuel C, Ubbaonu Nkeoma C, *et al,* (2020) illustrates certain result differences that exist between fresh fruits and fruit leathers. It states that moisture content ranged from 23.36% to 23.84% followed by protein content ranging 61.07%-62.01%. where, vitamin E and B9 decreased post drying, a significant rise was observed in trace minerals like magnesium, potassium and calcium. Also, vitamin C dropped in banana products and papaya products. This study also represents specific methods to calculate micronutrients like vitamin C, E A and B9 along with microbial analysis done by using spread plate technique with nutrient agar and colony forming unit is calculated using CFU/ml = $No.\ of\ colonies \times Dilution\ factor\ Volume\ of\ culture\ plate$ formula. Apart from this, study proves that greater acceptability of composite fruit leather on the basis of sensory score is by 7.50 followed by banana fruit leather 7.10 and papaya fruit leather had lowest sensory score that is 6.40.

A study reported by Akther S, *et al*., (2019) cites certain analysis of raw material and final products which are as follows, TSS using refractometer, pH using pH meter where 10g of each sample of leathers is suspended in 75 ml of distilled water and allowed to macerate for 30 min, followed by Titratable acidity,

determination of reducing sugar (using reagents like Fehling's solution A and B, indicator used was methylene blue, 45% neutral lead acetate and 22% potassium oxalate solution.), determination of mineral content. The microbial analysis done were Total viable count in which the colony of each petridish was counted and made average of them further multiplied to multiplying factor which results in observed number and Fungal test for which sabouraud dextrose agar is used and incubated to observe the results.

CONCLUSION

The development of preserved fruit and vegetable products, such as fruit leathers, presents an innovative solution to global challenges like food security, nutrition, health, and sustainability. The processed products help address food waste while making nutrient-rich foods more accessible, especially to economically disadvantaged populations. The study highlights the effectiveness of preservation techniques such as blanching, vacuum drying, and advanced packaging like BOPP in maintaining the nutritional and sensory quality of these products. As a result, processed fruit and vegetable product offers a healthy, convenient, and cost-effective alternative to fresh produce, particularly in regions with limited access to fresh fruits and vegetables. Moreover, these products align with Sustainable Development Goals (SDGs) 2 and 3, contributing to global efforts to promote food security, improved nutrition, and better health outcomes. To move forward, the focus should be on sustainable solution towards preservation techniques, scaling up production to serve larger populations, and increasing consumer awareness about the benefits of preserved products. Strengthening infrastructure for storage, transportation, and retail distribution will further reduce post-harvest losses, while supportive government policies can boost the food processing sector, enabling wider access to nutritious preserved foods. These measures reflect the capacity to up-scale the country's food processing industry, reduce and effectively utilize waste, and support healthier lifestyles, making preserved fruit and vegetable products a valuable tool in addressing hunger and malnutrition.

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