Medical and Life Sciences (2024) 3(2): 54–70
ISSN (E): 2976-7245

Utilization of Kinnow Pomace Powder as a Functional Dietary Fiber in Cookies: Effects on Physicochemical Characteristics

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How to cite this article:

Mumtaz, M. S., Nadeem, Z., Abubakar, M., Ishaq, A., Kauser, S., & Tabassum, A. (2024). Utilization of kinnow pomace powder as a functional dietary fiber in cookies: Effects on physicochemical characteristics. *Medical and Life Sciences, 3*(2), 54–70.

Received: 8 August 2024 / Accepted: 7 November 2024 / Published online: 30 December 2024

Abstract

Citrus juice processing by-product Kinnow pomace is a functional food ingredient rich in dietary fibers, bioactive constituents and nutrients. This review examines the application of Kinnow pomace powder as a fiber in cookies and its effect on their physicochemical properties. The addition of Kinnow pomace powder not only boosts the fiber content but also the antioxidant capacity, mineral and vitamin content of cookies. However, it affects key physicochemical characteristics, such as moisture content, texture, color, spread ratio and acceptability. A moderate replacement (10-15%) appears to be a good compromise for improved nutritional properties and sensory quality. High inclusion rates may cause a darker appearance, increased hardness and slightly lower acceptance. In addition, the use of Kinnow pomace can contribute to sustainable development in the food industry by utilizing agricultural waste and increasing the value of the food. To summarise, Kinnow pomace powder has the potential to be used as a bakery product ingredient, particularly for cookies, to address the demand for healthful and sustainable foods.

Keywords: Kinnow pomace powder; functional foods; physicochemical properties; antioxidant activity; food fortification

1 Introduction

Food is the most basic human need for survival, along with physiological and social needs. Traditionally, studies on food consumption have been concentrated on a nutritional approach. This is based on the analysis of food in terms of the nutrients it contains and how it can support the different functions of the human body. Such research focuses on these instrumental factors, aiming to develop an understanding of how various nutrients promote health and wellness. Fruits are a significant component of a well-balanced diet and offer many key nutrients, vitamins, minerals and antioxidants that contribute to good health and protection from chronic disease. They constitute a rich source of dietary fibers, which promote digestive health and aid in the prevention

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of cardiovascular diseases and some forms of cancer (Slavin, 2013). Fruits such as apples, berries, citrus, and grapes are rich in antioxidants and act as antibacterial agents against oxidative stress, which reduces inflammation (Liu et al., 2022). Citrus fruits, such as oranges and lemons, provide a significant amount of vitamin C, an important nutrient for boosting immune competence and skin health (Carr & Maggini, 2017). The present work has explored various phytochemicals present in fruits: flavonoids, carotenoids, and polyphenols. For instance, berries contain anthocyanins and may enhance brain function; they also reduce the risk of heart disease. Apples are a major source of quercetin, a flavonoid with anti-inflammatory and antioxidant properties. Moreover, resveratrol, a grape component and its derivatives, such as wine, are said to be related to cardiovascular and longevity features (Baur & Sinclair, 2006). Fruits contain numerous bioactive compounds that are inversely associated with the risk of many chronic diseases, such as hypertension, diabetes, and obesity (Aune et al., 2017). Indeed, the many bioactive compounds in fruits play a functional role as foods that contribute more to basic nutrition than to overall well-being and health. An interest in fruit waste, particularly pulp, has recently developed because it may be used to improve food products in terms of quality and sustainability. Pulp is a by-product of juice extraction with dietary fibers, vitamins, and bioactive compounds that are potentially useful in food fortification and health purposes. The nutritional profiles of bakery products, beverages, and functional foods can be enhanced through the incorporation of fruit pulp, including the provision of further health benefits by reducing risks of chronic diseases and improving digestive health (Marín et al., 2007). Reduced waste and less environmental impact during disposal represent benefits to food production by using fruit pulp (Lucarini et al., 2021). Innovative application of fruit pulp in edible films, biodegradable packaging, and animal feed is being done, reinforcing the circular economy and the efficiency with which resources are used (Ajila et al., 2010; Gullón et al.,2007). The valorization of fruit waste not only enhances the economic value of the fruit processing industry but also aligns with global efforts to achieve sustainable development goals by minimizing waste and promoting health (Wan et al., 2019).

1.1 Classification of Fruits:

1. **Citrus Fruits** (oranges (Kinnow), lemons, limes, grapefruits)
2. **Berries** (tomatoes, bananas, kiwis)
3. **Stone Fruits** (peaches, cherries, plums, olives)

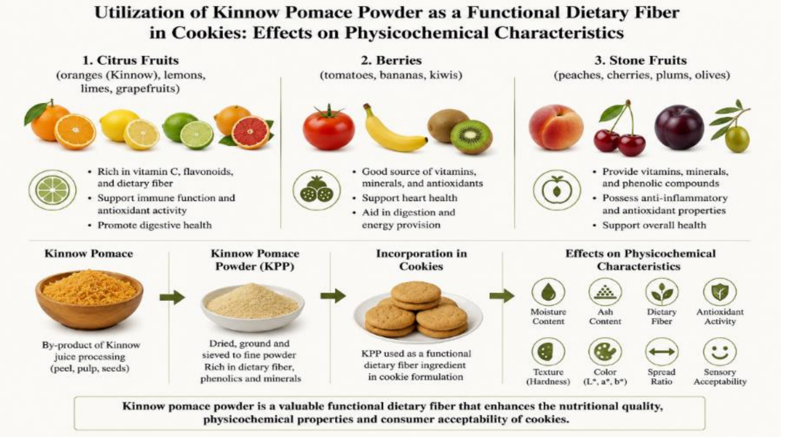

Figure 1: Classification of Fruits & Use of Kinnow Pomace in Cookies

1.2 Citrus fruits

Citrus fruits, which belong to the genus Citrus, are known for their bright flavors, high vitamin C content and various health benefits, as shown in Figure 1. Oranges, lemons, limes, grapefruits, and tangerines are examples of these fruits, as shown in Table 1. Citrus fruits are highly antioxidant, with flavonoids as one of their main components, which have shown anti-inflammatory and cardiovascular properties (Gironés-Vilaplana et al., 2014). They are also valued for their essential oils and are used in many culinary, medicinal and industrial applications. Etebu and Nwauzoma (2014) reported that regular consumption of citrus fruits is associated with an enhanced immune system and a lower risk of chronic diseases. Citrus fruits are mainly grown in the subtropical and tropical regions because they grow and bear fruit well in these climates.

Table 1: Scientific classification of Kinnow

Classification Level	**Details**
Kingdom	Plantae
Subkingdom	Tracheobionta
Super division	Spermatophyta
Division	Magnoliophyta
Class	Magnoliopsida
Subclass	Rosidae
Order	Sapindales
Family	Rutaceae
Genus	Citrus
Specie	Citrus nobilis x Citrus deliciosa

Kinnow (*Citrus nobilis x Citrus deliciosa*) is an important hybrid mandarin cultivar which is a cross of King (*C. nobilis*) and Willow Leaf (*C. deliciosa)* mandarins (Table 1). It was first introduced in California way back in 1935 by H.B. Frost and thereafter got widely cultivated in South Asia, mainly in Pakistan and India, because of its good climatic adaptability and high yield characteristics (Jatoi., et al 2022). Kinnow has been entrusted with a sweet, tangy flavor, and high nutritional value, having huge contents of vitamin C, flavonoids, and dietary fiber that give it health benefits like boosting immunity and acting as an antioxidant. The peeling and pulp of the fruit also contain quite a considerable number of essential oils and pectin, hence of value for industrial use in the food industries and cosmetics. Cultivation of Kinnow is of high economic importance as it generates good money to the farmers of Punjab in Pakistan and India. The harvesting time is basically from December to March, and the fruit is in maximum demand during this season as reported by (De Camargo et al., 2014). Also, post-harvest management of Kinnow has been studied; it is found that with suitable handling and storage practices, its storage life can be increased, which is quite necessary in export markets quality maintenance and was reported by (Ali et al., 2014).

2 Components of Kinnow Pomace

2.1 Vitamin C (Ascorbic Acid)

Kinnow is exceptionally high in vitamin C, a powerful antioxidant essential for the growth, development, and repair of all body tissues. It plays a significant role in collagen synthesis, the immune system, wound healing, and the maintenance of cartilage, bones, and teeth (Khan et al., 2011).

2.2 Flavonoids

Kinnow is rich in a broad spectrum of flavonoids, including hesperidin, naringin and rutin. They possess antioxidant and anti-inflammatory properties and are excellent cardiovascular compounds. They decrease oxidative stress and prevent chronic diseases (Ysrafil et al., 2023).

2.3 Dietary Fiber

Kinnow pulp and skin contain a lot of dietary fibre. Fiber helps digestive system, decreases constipation and helps keep weight in check. It helps to reduce the risk of heart diseases and type 2 diabetes (Purewal & Sandhu, 2020).

2.4 Essential Oils

The peel of the kinnow is a valuable source of essential oils with limonene, myrcene and linalool. Antimicrobial, antifungal and anti-inflammatory properties of the oils lead to their use in food preservation and cosmetics (Purewal & Sandhu, 2020).

2.5 Pectin

Kinnow peel is rich in a polysaccharide called pectin, which acts as a gelling agent for food products such as jams and jellies. Many dietary advantages like reducing blood cholesterol and improving gut health are associated with pectin (Muskan, 2022).

2.6 Carotenoids

The carotenoids found in Kinnow include β-carotene, lutein, and zeaxanthin. These compounds benefit eye health, help reduce the risk of macular degeneration, and exhibit strong antioxidant properties (Khalid et al., 2021).

3 Minerals

Kinnow is a good source of the essential minerals, namely potassium, calcium, magnesium, and phosphorus. These have several critical activities within the body, like maintaining proper balance in electrolytes and bones, plus muscular function (Khan et al., 2011).

3.1 Phenolic Compounds

The various phenolic compounds in fruit impart the capacity for antioxidant activity. These compounds generally seem to be involved in the reduction of inflammation and in protecting against several chronic diseases (Purewal & Sandhu, 2020).

3.2 Origin of Kinnow

Kinnow *Citrus nobilis* × *Citrus deliciosa* is originated from California, developed by H. B. Frost in 1935 as a hybrid between King (*C. nobilis*) and Willow Leaf (*C. deliciosa*) mandarins. It was introduced to the combined territory of Pakistan and India; due to favorable climatic conditions, it flourished and became a major citrus crop. At present, Kinnow is grown enormously in these areas and plays a vital role in their agricultural economy (Khalid et al., 2021).

3.3 Production of Kinnow

Kinnow is a hybrid citrus fruit that comes from the King and Willow Leaf mandarins. It is grown throughout South Asia, chiefly in Pakistan and India. According to the Food and Agriculture Organization, Kinnow production in Pakistan accounts for a large share of the country's citrus output, as shown in Table 2. According to estimates for 2023, Pakistan produced about 2.1 million tonnes of Kinnow, ranking among the world's largest producers of the crop. Kinnow is an important economic activity, supplementing livelihoods, as it provides a living for thousands of farmers and significantly raises the agricultural GDP of the area (Food and Agriculture Organization of the United Nations [FAO], 2023).

Table 2: Worldwide production of Kinnow

Country	Production (Tons)
India	1,250,000
Pakistan	950,000
China	300,000
United states	50,000
Mexico	45,000

Kinnow cultivation offers many advantages in its production. It provides high economic returns to the farmers through its demand and popularity in local and foreign markets. It is also an essential source of vitamin C and antioxidants, thus providing a healthy environment and sustaining public health. It promotes agro-industry development and generates employment. The waste products of

Kinnow are used to develop products with added value, thereby promoting and sustaining agriculture on sustainable grounds (Khan et al., 2011).

4 Minerals in Kinnow

4.1 Potassium:

Potassium helps maintain the proper balance of body fluids and electrolytes. It is an integral constituent of muscles. It lowers blood pressure and acts against the negative effects of sodium on cardiovascular health (Khan et al., 2011).

4.2 Calcium:

Calcium is important for healthy bone growth and Kinnow provides calcium, which is quite essential for developing and maintaining strong bones and teeth. It is essential for blood clotting, nerve transmission, and muscle contraction, as demonstrated by Khalid et al. (2021).

4.3 Magnesium:

This mineral plays a crucial role in over 300 enzyme reactions within the body, including energy production, protein synthesis and muscle and nerve function. Magnesium is essential for supporting cardiovascular health and bone integrity (Purewal & Sandhu, 2020).

4.4 Phosphorus:

Besides its role in bone and tooth formation, phosphorus also plays a crucial role in the body's use of carbohydrates and fats. It is an element required for the synthesis of ATP, the body's energy storage molecule. As indicated above, these minerals not only enhance the nutritional value of Kinnow but also support various physiological functions, thereby making Kinnow an important fruit to include in a balanced diet (Yaqoob et al., 2021).

5 Properties of Kinnow:

5.1 Carcinogenic activity of Kinnow:

Kinnow is a citrus fruit, a crossbreed of Kin and Willow Leaf Mandarins, and reportedly has anticarcinogenic potential. Being high in antioxidants like vitamin C, flavonoids, and limonoids, Kinnow not only helps in neutralizing the free radicals, which are regarded as the most potent potential parameters for the development of cancer, but also prevents the rapid division of the cancer cells and promotes apoptosis, particularly in colon, breast, and prostate cancers, according to the scientific results. The limonoids, especially, demonstrated the ability to block the formation of compounds that cause cancer. Kinnow has a high fiber content, which supports digestive health and reduces the risk of colorectal cancer. There are also ongoing research studies to explore other potential uses of Kinnow, including its role in preventing and as a tool for cancer treatment strategies (Purewal & Sandhu, 2020).

5.2 Antioxidant activity of Kinnow:

This research was done to study the in vitro antioxidant potential of Kinnow powder. The studies showed Kinnow powder enhanced the overall antioxidant capacity of products under test. High contents of vitamin C, flavonoids, and phenolic compounds in Kinnow powder contributed to reducing oxidative stress and improving lipid oxidative stability. The study further showed that incorporating Kinnow powder into food products can effectively reduce their lipid content while improving nutritional value. The results thus established the potential health benefits of Kinnow powder as a natural antioxidant additive in food processing (Gupta et al., 2020).

5.3 Antimicrobial activity of Kinnow:

A study on Kinnow powder was undertaken to test it for antimicrobial activity. The results showed that Kinnow powder had considerable inhibitory activity against different strains of bacteria, such as *Escherichia coli* and *Staphylococcus aureus*. These antimicrobial activities could be attributed to the bioactive compounds, including flavonoids, phenolic acids, and essential oils present in Kinnow, which disturb the cell wall of bacteria, leading to the suppression of microbial growth. The present research concluded that Kinnow powder can act as a potential natural antimicrobial agent in maintaining food preservation and safety with bright prospects for applications in shelf-life extension (Muskan, 2022).

5.4 Difference between cookies and biscuits:

A cookie is an American English name whose origin is from the Dutch word 'koekje'. The meaning of this word is "little cake". Cookies are mainly encumbered with flavors. These take more time to bake due to thick batter and dense ingredients like nuts, oats, resins etc. Cookies are mostly moist and chewy in nature (Gebreselassie & Clifford, 2016). Biscuit is a British English word derived from a French word 'bescuit,' which also originated from two Latin words bis (twice) and coquere (to cook, cooked). The meaning of these two words is 'Twice Cooked'. The texture of the biscuits is very light. These are also thinner than cookies. While they share some common ingredients, cookies and biscuits differ in their preparation and qualities. The cookie dough is usually softer than biscuits. The soft dough helps create the chewy, tender quality of the cookies, unlike biscuits, which tend to be firmer. In addition, generally cookies have a higher density and are heavier than biscuits. The extra weight is partly because cookies contain more sugar than biscuits; they are often sweeter, which helps boost flavor and make them softer (Gebreselassie & Clifford, 2016). In addition, cookies are often adorned with intricate designs or filled with extras like chocolate chips, nuts or icing while biscuits are typically simpler and more straightforward. Biscuits are easy to make, so they don't require as much decoration or complexity as cookies. The sensory properties and overall appeal of cookies compared to biscuits are due to these differences in dough consistency, sugar content and decoration (Guiné, 2022).

6 Ingredients of cookies

A cookie is a blend of various variable ingredients such as flour, baking soda, baking powder, butter, white sugar, eggs, salt and flavor.

6.1 All-Purpose flour

While flour is mainly used in cookie manufacturing to create the structure and texture of the cookies, it can also be used to add color and flavor. This structural integrity comes from gluten, a protein which creates an elastic network in the dough that keeps it from collapsing and allows the gases and bubbles produced during the baking to remain. This network is crucial for providing the necessary structure to make sure the cookies are shaped and textured as intended. When making cookies, generally lower protein flour is used because it will form less gluten (Dedey, 2021). Lower gluten content is important in helping to bake a more tender, light crumb in cookies, a significant attribute of baked goods. The type of flour used, therefore, will affect the texture and quality of the cookies, and will play a significant role in the development of recipes and product formulation. The choice of flour allows bakers to achieve the right degree of softness and strength in their baked goods. Although cookies need a little salt, it is important because it helps to balance the sweetness, adds flavor, and enhances the texture in the cookie by strengthening the gluten network, which is essential to the cookie's shape and texture during baking (Puspitasari & Kok, 2025).

6.2 Baking Powder

It is a chemical that acts like a leavening agent that helps in the combining of baking soda, a moisture absorber and cream of tartar the main thing to note about the baking soda is that it becomes active when it is heated (Neeharika et al., 2020).

6.3 Baking Soda

It is a leavening agent and mostly used in recipes that contain acids like sour cream, vinegar, molasses etc. It reacts with other ingredients, and the principal benefit of baking soda is that it doesn't need heat to become active (Niharika et al., 2020).

6.4 Butter

Fat is a very essential ingredient in the development of cookies as it gives tenderness, crispiness, color and a unique flavor which cannot be produced by any other method. Butter or fat is the most responsible ingredient to add desirable taste, texture and appearance to the cookies (Devi & Khatkar, 2016).

6.5 Sugar

There are many roles that sugar plays in the development of cookies. It helps with the retention of moisture which plays an important role in tenderness of cookies. It gives sweetness and typical brownness to the cookies. The crystal in the sugar also helps to form structure of the cookies as leavening agents react (Mancebo et al., 2015).

6.6 Eggs

There are many different functions that egg plays in the formation of cookies. They contribute to flavor, color, structure and act as an emulsifier. Egg yolk contains fat which imparts a light texture and results in a tender final product on the other hand the egg white acts as a leavening agent and provides volume to the product (Luo et al., 2023) as shown in table 3.

Table 3: Nutritional composition of a whole egg.

Nutrients	%Age
Fat	4.98
Carbohydrates	0.39
Proteins	6.28
Calories	75 Cal

6.7 Salt

Salt is an essential ingredient in cookie making, contributing not only to flavor enhancement but also to the strengthening of the gluten structure in the flour. Although the salt content in cookies is relatively low, it is essential to balance the sweetness of the dough and to tighten up the overall taste and texture of the cookie by helping to reinforce the network of gluten, which is important in maintaining the shape and consistency of the cookie during baking (Dapčević-Hadnađev et al., 2022).

7 Types of cookies

Cookies can be categorized into many types, but the major types are six, which are discussed here: Molded cookies, dropped cookies, rolled cookies, pressed cookies, refrigerated cookies and bar cookies, all shown in Figure 2. (Tiwari et al., 2023).

7.1 Molded cookies

It is a type of cookie that is usually made by rolling the dough in your hands in a round form. These can be made flat by using a fork. In the making of these cookies all the utensils should be dusted with flour to prevent the cookies from sticking (Tiwari et al., 2023).

7.2 Dropped cookies

These can be said to be the easiest kind of cookies to make. This type of cookies is made by just dropping a spoon which is full of the dough onto the cookies spread sheet. The only thing to remember is to leave sufficient space between the cookies. Most commonly 2-inch space is left between the cookies (Davidson, 2019).

7.3 Rolled cookies

It is a type of cookie which is usually made by using stiff dough. Rolling of the dough is done on to a surface that is lightly floured and it is then cut into different shapes with the help of knife. If you want to make the cookie crispy then the dough should be rolled thinner and if you want the cookies to remain softer, then a relatively thicker dough is used (Figoni, 2018).

7.4 Pressed cookies

These are also known as spritz cookies. In the making of this cookie two things should be kept in mind that the dough should be softer enough so that the cookie can be pressed easily and secondly the dough must be stiff enough so that it can hold its shape. To achieve these two things following things can be done, If the dough is too soft, it can be refrigerated for a while to help it firm up. Conversely, if the dough is too stiff, adding an egg yolk can soften it to achieve the desired consistency (Sang et al., 2020).

7.5 Refrigerator cookies

These are also described as sliced cookies. These are made by a method in which the cookies are rolled in the form of a thick bar. Then in the next step, these cookies are being put into a refrigerator for some time and then these are allowed to go for baking. Only thing which should be kept in mind while preparing these cookies is that the rolls should be wrapped efficiently so they do not get any kind of odor from the refrigerator. The dough can be kept in the refrigerator for one week and then slicing and baking will be done (Bezerra et al., 2016).

7.6 Bar cookies

It is a cookie that resembles cake and is softer than any other type of cookie. Brownies can be taken as an example of bar cookies. They have distinct characters of crispiness and chewiness. These cookies are cut after baking according to the desired size (Arepally et al., 2022).

Figure 2: Types of Cookies

8 Fortification/ Enrichment

Fortification is a method in which the shortage of an essential nutrient in a particular group of people is prevented by the addition of that nutrient to the food that they consume. Enrichment practices add micronutrients to foods to address deficiencies or restore function (Darnton-Hill & Nalubola, 2002). Enrichment of food has limited advantages over other nutritional interventions, as it is regarded as an economical approach, with great potential to achieve major goals and minimal sensory changes. There are mainly 3 types of fortification commonly used these days. (Allen et al., 2006).

8.1 Mass fortification

It is defined as the incorporation of more than one important nutrient that the total population normally consumes, like milk and cereal-based food. It is when a group or population lacks or is scarce in the best choice for micronutrients (Allen et al., 2006).

8.2 Targeted fortification

Foods have been given to specific population groups to improve them, rather than the entire population. For example, if cookies are fortified for pregnant women and children. In this case, it meets the daily micronutrient requirements of a particular group (Allen et al., 2006).

8.3 Market-driven fortification

This type of fortification involves adding a limited amount of one or more micronutrients to foods. It is being done to improve the food, mainly for public health. This type of fortification can also be used to replenish micronutrient supplies and achieve large-scale fortification. It is mostly used in industrialized countries (Allen et al., 2006).

9 Utilization of Kinnow pomace powder in bakery products

According to Kumar and Kumar (2011) bakery products like cookies, biscuits, muffins, rusk, bread etc. are the fast and convenient way for the proper use of Kinnow pomace powder. For the diversification of baked items, they are utilized as the foundation for the combination of various nutritional constituents. Incorporation was done to provide various useful functional food components and nutrients. As bakery items are consumed by all age groups. Wheat flour and Kinnow pomace powder-based cookies are developed by some researchers. Various children's feeding programs that are managed by State Departments of Health and voluntary agencies are increasingly using cookies and bread due to which the consumption of cookies and bread is growing gradually. Cookies are being used in different verities as tasty, nutritious and ready-to-eat snacks (Hooda & Jood, 2005).

9.1 Sensory and nutritional enhancement of cookies

In addition, consumers want healthy foods with better sensory properties (Dutra et al., 2014). Sensory characteristics of food are important factors in consumer selection of food. Cookies stand out in the global food market for their better sensory and commercial acceptance, being well-received by youngsters and adults. Due to the long shelf life of cookies and their great production, marketing and consumption at the commercial level, it involves products of commercial interest. A study was conducted in which fenugreek flour was replaced with cookies at a 10% level. The results obtained that the cookies showed better puffing, protein content increased, and the concentration of dietary fiber, iron and calcium was also improved in cookies. (Yaqoob et al., 2021) carried out a study in which he explored the effect of addition of defatted mustard oil into the biscuits at concentrations of 5%, 10%, 15%, and 20% and the results showed 2.5 times more protein than the normal one along with an increase in fiber content and the fat content was also reduced.

9.2 Antioxidant activity and lipid stability in bakery products

A study was performed to investigate the antioxidant activity of Kinnow pomace powder in flour dough. The oxidation of frying oil and lipids present in fried products was examined. The results obtained highlights that the lipid oxidation stability significantly improved with the addition of Kinnow pomace powder. This improvement was linked to the presence of bioactive compounds, such as flavonoids and phenolic acids, in the Kinnow pomace. These substances are well-known for their powerful antioxidant qualities, which help in reducing oxidative stress and enhancing the shelf life of fried products (Gupta et al., 2020).

9.3 Mineral content and moisture control in bakery goods

Mineral use from Kinnow pomace powder was assessed on Kinnow pomace powder-set cakes with different replacement ratios. The outcomes indicated that the color of the cakes was significantly altered, likely due to the natural pigments present in the Kinnow pomace. Vitamin C content increased with increasing levels of Kinnow pomace powder, thereby improving the nutritional value of the cakes. The study further found that the introduction of Kinnow pomace powder significantly reduced the moisture content of the cakes. The reason for this drop in moisture could be the high fiber in Kinnow pomace, which is expected to alter water retention characteristics in the cakes (Muskan, 2022). In this research, studies were conducted using replacement ratios of eggshell powder (0-7%) and Kinnow pomace powder (0-30%). It was observed that adding incremental amounts of Kinnow pomace powder softened the cakes, made them more porous, decreased the L-value and the value of the cakes, whereas moisture, ash, density, mineral content, total fiber, and overall acceptability increased. The eggshell powder reduced the moisture and overall acceptability. The overall results revealed that Kinnow pomace and eggshell powders can increase the nutritional profile and acceptability of gluten-free cakes. In the present study, an evaluation regarding the effects on the incorporation of Kinnow pomace powder in various ratios into the bread making was carried out (Kaur et al., 2023).

9.4 Impact of fruit and vegetable powders on cookie quality

Several studies have been highlighted in the current literature regarding the replacement of various levels of Kinnow pomace powder as source of dietary fiber and antioxidants in bakery products. It was noted that an increase in replacement concentration of Kinnow pomace powder in the product, i.e., 0-5-10-15%, positively affects the dietary fiber content and overall antioxidant activity of bread, with only slight deterioration in the sensory properties. Bread with higher addition levels of Kinnow pomace powder resulted in denser texture and a darker crumb color. However, the general acceptability remained high, which indicates that Kinnow pomace powder can be a very useful functional ingredient in bread making (Sharma et al., 2019). Biscuits were also made by incorporating dehydrated pomace powder of carrot and germinated chickpea flour. Soft wheat was replaced by the pomace powder of carrot because the production of soft wheat is very limited. Refined wheat flour is low in essential amino acids, lysine, and dietary fiber, while carrot pomace contains high amount of dietary fiber and carotenes. The results showed that ash, fiber, and protein contents increased with additions of these two powders; biscuits containing 8% of these two powders were most accepted regarding their sensory characteristics

9.5 Innovative ingredient substitutions in bakery products

A study about the replacement of whole wheat flour with multi-grain flour (Whole grain finger millet and sorghum) in cookies was carried out. Herein, the multi grain flour was used in the ratio of 10- 30% and the sugar was also replaced with fructoligosaccharide at the levels of 40%, 60% and 80%. The quality attributes were evaluated which showed that the cookies prepared with at least 50% multi grain flour and 60% Sugar replacer showed the best results and accepted by majority of the persons (Handa et al., 2010). A study in which the Shortening content in cookies was replaced with apricot kernel flour at the levels of 10%, 20%, 30% and 40% respectively and then the results were being analyzed. The results showed that apricot kernel flour is the rich source of dietary protein, oil and fiber. It has also increased the hardness of the cookies. By sensory evaluation, it was found that all the test cookies were accepted by the panelist but the most suitable concentrations of apricot kernel flour as fat replacers were 10% and 20% (Seker et al., 2010).

A study which aimed the enrichment of cookies with pumpkin powder and carrot pomace powder at the levels of 10%, 15%, 20% and 25%. The effect of increased pumpkin powder and carrot pomace powder was studied which showed that the water absorption ability of the dough was increased as confirmed from the farinograph. The color of the cookies became darker due to the presence of more fiber content. Sensory analysis indicated that the cookies enriched with more pumpkin and carrot pomace powder showed less acceptability as the concentration of these powders increased (Turksoy & Ozkaya, 2011).

A Study involving the replacement of whole wheat flour by mango kernel flour in biscuits was conducted owing to the superior nutritional and phytochemical properties of mango kernel flour. As from the previous studies we conclude that mango kernel can be a fair reservoir of starch, protein, dietary fiber, minerals and vitamins. Mango kernel powder was used at the levels of 10%, 20%, 30% and 40% in biscuits with maintaining all the other ingredients constant. The results showed that the biscuits prepared with up to 30% mango kernel flour were acceptable and didn't show any kind of bad effects. There was an increase in the mineral content of the biscuits due to the addition of mango kernel flour, especially potassium (Bankar et al., 2024).

According to Yaqoob et al. (2021) orange pulp supplemented cookies were produced at the levels of 3%, 6% and 9% by taking orange pulp as supplement. Results obtained indicated that development time and stability of dough decreased due to an increase in water absorption and dough mixing index. The nutrient content and the overall acceptability results indicated that orange pulp can be a good source of nutrients if used in cookies. Cookies were produced by replacing whole wheat flour with passion fruit epicarp flour in a concentration ranging from 3% to 9%. Results showed there was no significant difference in the acceptability between the cookies prepared with 3% and 6% passion fruit epicarp flour. The acceptability of the cookies was, however, drastically reduced for the 9% samples. On the other hand, it was noted that an increased level of passion fruit epicarp flour added to the cookies increased their antioxidant activity (Ning et al., 2021).

A study was conducted whose main aim was to increase the nutritional quality of the cookies in which the wheat flour was replaced by the mushroom *Calocybe indica* powder. This powder was used in the concentration of 5%, 10%, 15%, and 20%. The outcomes obtained from this study showed that there was an increase in content of the protein, fiber content, and minerals. Flavonoid and antioxidant activity also increased. Based on sensory and nutritional evaluation of CIP fortified cookies, it was concluded that 10% level of CIP cookies was more suitable for us (Rathore et al., 2019).

The consumer acceptability and nutritional value of the cookies was tested in a study where flour is replaced in the proportion of 5% and 10% by Banana peel flour and Avocado peel flour. The results showed that cookies supplemented with avocado peel flour had the highest ash content compared to those made with banana peel flour and whole wheat flour. Results also provided evidence that the mineral content in avocado and banana peel flour supplemented cookies was higher than in standard whole wheat flour cookies. Their acceptability was high due to higher nutritional value as well as it will being very fruitful and economical as fruit waste was being used for production (Olaoye et al., 2024).

A study involving the whole wheat flour substitution with the pineapple flour to improve the organoleptic and nutritional qualities of cookies was conducted in which the proportions of pineapple flour used were 5%, 10% and 15%. The results showed that the ash, fiber and protein content increased than the standard cookies. The cookies having 5% of pineapple flour were more acceptable by the consumer. The cookies also maintained their basic attributes after four weeks of storage (Gebreselassie & Clifford, 2016). Previous studies showed that dietary fiber, lipids and minerals are present in large amounts in date seeds, so a study was conducted to check their effect on cookies. Whole wheat flour was replaced with 5%, 10% and 15% of ground Ajwa seeds. The results indicated that there was decrease in the moisture content due to ground Ajwa seeds which ultimately increased the shelf life of cookies. The fiber content was also increased, which was approximately equal to the daily requirements of the body. All the panelists gave a go ahead to this new product by evaluating its sensory properties (Abushal et al., 2021).

9.6 Functional ingredients in gluten-free and nutrient-enriched cookies

A study involving the potato peel supplementation in the cookies was conducted in which the potato peel was substituted with flour in the proportion of 10%, 15% and 20% and the results were being analyzed by the researchers (Wang & Flores, 2000). The results obtained showed that as the proportion of potatoes increased then the spread ratio of cookies also increased. Cookies produced from 10% of potato peel showed a decrease in the hardness. Overall acceptability results of the cookies indicated that the cookies made up of 10% of the potato peel were more acceptable by the consumers as their taste, flavor and all other characteristics were good enough to get a go-ahead. A study was conducted in which the saffron extract having two different concentrations was used for the preparation of cookies. These were being stored for 9 months, and their color, texture and sensory attributes were analyzed during this storage period. The results obtained showed that spread ratio and hardness of the cookies reduced non- significantly in the cookies due to saffron extract. There was a significant increase in L and b-values while the, a-value decreased non-significantly. It was also revealed that there was no loss in the quality attributes of the saffron supplemented cookies up to the storage period of 6 months (Bhat et al., 2018).

A study involving the substitution of flour with lotus leaf powder in the proportions of 1%, 3%, 5% and 7% in cookies was conducted and then the quality attributes of the cookies were analyzed by the researchers. The findings from the study revealed that for all the levels of lotus leaf powder the pH of the dough decreased significantly. The spread factor values decreased as the concentration of lotus leaf powder increased. Whereas the color values also showed an inverse relation with the concentration of lotus leaf powder. The measurement of texture also showed an increase in hardness, cohesiveness and springiness of cookies. By sensory evaluation it was concluded that the cookies having 1% to 3% lotus leaf powder were more acceptable (Kim & Park, 2008).

Bamboo leaf powder was used in the cookies as a study was undertaken to explore the possible variations in the quality attributes of the cookies. The proportion of the bamboo leaves powder used in the cookies were 3%, 6%, 9% and 12 %. The findings obtained reveal a significant increase in the overall acceptance of the cookies up to the proportion of 9% bamboo leaves powder. There was an inverse relationship between cookies hardness and the bamboo leaves powder. Overall acceptability was highest for 6% and 9% samples (Karanja, 2017).

A study whose main purpose was to enrich the cookies was conducted in which the gram flour was used in the preparation of cookies. Five samples having the proportion 10%, 20%, 30%, 40% and 50% of gram flour were produced and then the results were analyzed. The protein content was mainly analyzed by an experiment conducted on albino rats in which they were fed on these gram flour enriched cookies for 10 days. The results showed significant results as there was an increase in protein, fat, ash and crude fiber content of the cookies. Thickness and spread factor of the cookies differed significantly. Instead, the width of the cookies did not show any change. From the results it was also analyzed that the gram flour cookies prove to be very useful for the rats and the most acceptable sample of the gram flour cookies was the one having 40% of gram flour (Arshad et al., 2019).

It was studied that quinoa can be a good source of protein, omega-3 and 6 fatty acids, fiber, vitamins, minerals and carbohydrates. For this reason, a study was designed to incorporate quinoa into the cookies due to their high nutritional value. Quinoa flour was used at 10%, 20%, 30%, 40%, and 50% in cookies. The quality attributes of the cookies were then thoroughly analyzed. There was a minor increase in the thickness of the cookies. While there was a decrease observed in the diameter of the cookies as the level of quinoa flour increased. Quinoa flour also affected the colorimetric values of the cookies, as the sample having 50% of quinoa flour showed the highest a and b values. On the other hand, the cookies having 0% quinoa flour showed the highest L-value. The proximate analysis of the cookies showed increases in ash, crude protein, crude fat and total phenolic compounds. The mineral content was also analyzed, and the outcomes indicated that as the concentration of quinoa flour increased, the minerals like potassium, magnesium, iron, calcium and zinc also increased. There was also an increase in the sensory score of the quinoa flour cookies. So, with the help of this study, it was concluded that quinoa flour proved to be very useful for cookies and it can be launched in the market for the betterment of human beings (Demir & Kılınç, 2017).

A study in which the effect of moringa leaves on the rheological, microstructural, nutritional and quality characteristics of cookies was studied. In this study dried moringa leaves were used in different proportions of 5%, 10% and 15%. The results obtained from this study showed that with the increase in the concentration of dried moringa leaves the water absorption of the dough was increased along with the dough stability. There was an increase in the hardness of the dough and a decrease in spread ratio. The cookies were also analyzed on the sensorial scale and with the help of the obtained results it was concluded that the cookies fortified with 10% of moringa leaves were most acceptable to the panelists. With the help of microstructure results it was concluded that calcium oxalate crystals were found both in cookies and moringa powder. There was also an increase in protein, calcium, iron and dietary fiber contents as the concentration of moringa leaves increased from 0% to 15% (Zungu et al., 2020).

9.7 Diet health paradigms

Human life depends on the value of modes of nutrition and diet which affect health throughout the life cycle. Inactive lifestyle and junk food increasing style have created digital health- related issues. Heart disease is the cause of death for variety of age groups throughout the world followed by several diseases like osteoporosis, cancer, arthritis and diabetes. Advances in medicine and the rising new technologies have launched a new treatment of these diseases in the developed world. However, these technologies are very costly to benefit everyone (Zhang et al., 2019).

Recently scientific research has put health and food care as an important way to protect beside lifestyle- related diseases. Although the latest medical technology of dietary interventions gaining more status due to its long- standing management of reliability and against various effects of drugs. Here environment, health products and functional foods are measured to be further prudent and sustainable. (Das et al., 2011).

10 Functional and Nutraceutical foods

Functional and nutraceutical foods promote health and disease treatment in addition to providing the basic nutrients. Functional foods for their health-promoting phytochemicals were earlier consideration (Bech-Larsen & Scholderer, 2007; Espin et al., 2007). Phytochemicals are essentially founded on biologically active components of the plant, showing antioxidant properties and free of charge radical scavenging. In advanced countries the universality of the disease is the installation of different age groups in the population day by day (Barta et al., 2006). To produce commercially accessible functional foods the main selling properties are lowering blood cholesterol, antioxidants, anti-carcinogenic and lowering blood sugar. They also include biologically active ingredients to impart physiological effect on the threat to the human body (Nguyen & Chen, 2005).

10.1 Potassium (k) deficiency

Potassium is a vital mineral essential for numerous physiological functions, including maintaining fluid balance, nerve transmission, and muscle contraction. Potassium deficiency, also known as hypokalemia, can lead to severe health issues such as hypertension, kidney stones, bone loss, and cardiac arrhythmias. The global distribution of potassium deficiency is a major health issue especially in areas where potassium rich foods consumption is low. Fortification of food has been identified as a possible solution to deal with micronutrient deficiency (Kumssa et al., 2022).

One of the innovative methods is to use Kinnow pomace as a food fortifier. Kinnow (*Citrus reticulata*) is a hybrid citrus fruit which is loaded with potassium and other essential nutrients. The pomace or residue left behind after juice extraction is rich in fiber, vitamins and minerals and is a great fortificant. The use of Kinnow pomace in food fortification has been shown to be beneficial (Mahawar et al., 2020).

Sharma et al. (2019) found that use of kinnow pomace in bakery products resulted in higher potassium content, along with higher fiber and antioxidant contents. This fortification not only helps reduce potassium deficiencies but also adds to the nutritional makeup of the food, offering other health benefits. Moreover, the possible application of Kinnow pomace for food fortification may be an effective measure to minimize food waste. Use of kinnow pomace, which is usually thrown away as an industrial waste, can be utilized to support more sustainable food production (Singla & Kapoor, 2024).

As mentioned by Singh et al. (2020), the valorization of citrus waste via food fortification is an eco-friendly and economical answer, which includes economic benefits. K deficiency is a public health problem that is well suited for innovative food fortification strategies. Fortification of foods with Kinnow pomace does not only provide nutritional benefits but also contributes to sustainable food consumption habits (Yaqoob et al., 2021). With more development and research in this area, this could be adopted widely and reap great health benefits to the world.

11 Conclusion

Incorporation of Kinnow pomace powder into bakery product formulations is an effective method to enhance the nutritional and functional properties of bakery products. Kinnow pomace powder is rich in fiber, antioxidants and micronutrients that increase the nutritional quality of cookies and help enhance lipid stability and shelf-life of the product. The review reveals that incorporation of Kinnow pomace influences the physicochemical properties of texture, moisture content, colour and density. Low incorporation levels lead to fortified cookies with acceptable sensory properties, but high incorporation levels could affect the texture and taste. Most importantly, Kinnow pomace contributes to reduction of waste and sustainability in the food industry by converting citrus waste into a valuable product. Thus, Kinnow pomace powder can be successfully incorporated as a functional dietary fiber ingredient in cookies, while ensuring suitable formulation levels.

11.1 Future Aspects

In cookies, formulation techniques to improve the acceptability of cookies containing a higher level of pomace powder should be investigated when Kinnow pomace powder is added. New processing methods such as microencapsulation, enzymes and particle size reduction, can help to reduce the adverse effects on texture and colour. Also, interaction of Kinnow pomace and other functional ingredients should be studied to achieve synergistic benefits in nutraceutical and functional foods. Furthermore, clinical trials should be conducted to evaluate the storage stability, glycemic response and health benefits of Kinnow pomace cookies. The use of Kinnow pomace in other bakeries and gluten-free products should also be explored. Moreover, industrial scale production and economic feasibility analyses are required to promote industrial production. And from an environmental point of view, the incorporation of Kinnow pomace in circular food system may help to mitigate food waste and environmental impacts. Thus, there is a need for further studies to focus on new, acceptable and sustainable uses of Kinnow pomace in functional products.

12 References

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