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Utilization of pumpkin, pumpkin powders, extracts, isolates, purified bioactives and pumpkin based functional food products: A key strategy to improve health in current post COVID 19 period: An updated review

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A B S T R A C T

Progression of today’s world has been given setback due to the adversity of a novel, viral and deadly outbreak COVID 19, which raised the concerns of the scientists, researchers and health related officials about the inherent and adaptive immune system of the living body and its relation with healthy diet balanced with pharma foods. Choice of right food can help to build and boost adaptive immunity and pumpkin due to excellent profile of functional and nutraceutical constituents must be the part of both infected and non-infected person’s daily diet. Vitamins, minerals, phenolic acids, essential oils, peptides, carotenoids and polysaccharides present in pumpkin could accommodate the prevailing deficiencies in the body to fought against the pathogens. Pumpkins are well equipped with nutraceuticals and functional ingredients therefore, consumption and processing of this remarkable fruit must be encouraged as pharma food due to its antihyperlipidemic, antiviral, anti-inflammatory, antihyperglycemic, immunomodulatory, antihypertensive, antimicrobial and antioxidant potential, and these pharmacological properties of pumpkin are directly or indirectly related to the COVID 19 outbreak. Utilization of pumpkin has a domain in the form of powders, extracts, isolates, and pumpkin incorporated food products. A wide range of healthy, nutritious and functional food products has been developed from pumpkin, which includes juice, soup, porridge, chips, biscuits, bread, cake, bar and noodles. In recent times some innovative and novel technologies have been applied to process and preserve pumpkin for its enhanced shelf life and bioaccessibility of nutrients. Need of healthy eating in current post COVID 19 period is very crucial for healthy population, and medicinal foods like pumpkin, and bioactive compounds present in this functional food could play a vital role in developing a healthy community around the globe.

1. COVID 19 pandemic, impact on population and need of pharma foods

The COVID 19, a pandemic declared by World Health Organization, is usually caused by a novel corona virus, which normally attacks the people with fragile immune response. Population with weak immunity is more vulnerable towards novel coronavirus. Plant based foods rich in vitamins, minerals and proteins play crucial role in boosting immunity as they promote beneficial bacteria in human body. Food combinations containing immunity boosting nutrients are needed to be explored and marketed in current post COVID 19 period, which can play vital role against common viruses and novel corona virus improving the immunity all around the world (Arshad et al., 2020). This ongoing outbreak is a major global challenge. People with compromised immune system and existing metabolic, respiratory and cardiac problems are more vulnerable to this infection or even death. The pharma foods generated from functional food plants with antiviral and immunomodulatory potential, might not only boost the immune system and cure respiration related infections but also can impose positive health impacts on public (Yang et al., 2020). Beside the development of allopathic drugs and vaccines the use of medicinal foods as dietary supplements or nutraceuticals could be a useful strategy to improve overall health by lowering the risks of other related diseases. Foods derived antioxidants, vitamins, minerals, peptides and metal chelating agents, prevent inflammation and oxidative stress, the conditions which play a major role in advance-

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ment of COVID 19. The presence of chronic diseases might enhance the potential risk of defective immune system resulting in attack of novel virus on a fragile defense system of the body (Lammi & Arnoldi, 2021).

The consequences of COVID 19 are long term even for those patients who have recovered from this outbreak so it is necessary to visualize in a comprehensive manner the, relationship between COVID 19 and other diseases. It is need of time to develop a relationship between COVID 19, diet, lifestyle and other diseases, this will definitely help the caregivers to attend the patients for better course of medication and recommendations (Toor & Chana, 2022). Significant evidences are present that COVID 19 resulted widespread fear, depression, anxiety and mental illness. This pandemic affected billions of people around the globe leading to millions of deaths apart of mental health illness. The impact of this viral disease on global economy shows its destruction on communities, infrastructure and institutions. Now along with the application of vaccine and curing measures it is important to investigate pharma foods, which can boost immune system and mental health of population (Chakraborty, 2020). The outbreak of COVID 19 has evolved world health crises and with current rising prevalence of obesity, diabetes and other such complications may lead to persistent derangements in immune system of humans. The role of healthy diet can eliminate these risks by minimizing the immune defences (Zhou et al., 2021).

Nutrition, a key factor affecting humans health must be the key strategy to encounter the attack of COVID 19. That is why the populations with poor diet and bad eating habits have greater chances to be affected by viral diseases especially the novel coronavirus. Food obtained from plant sources are excellent sources of essential vitamins and minerals, the agents responsible for boosting immunity all the population (Ahmad et al., 2022). Both infected and uninfected persons in the current outbreak of COVID 19 and post pandemic situation, have been advised healthy eating habits in all over the world and inclusion of pumpkin in their diet could be the positive gesture for human health (Abushal, 2021).

2. Pumpkin; a healthy pharma food with excellent nutritional profile

Pumpkin is a gourd-like fruit native of tropical and subtropical regions, well known for its excellent nutritional profile. Pumpkin belongs to the genus Cucurbita and family Cucurbitaceae with three economically common species namely Cucurbita maxima, Cucurbita pepo and Cucurbita moschata, with major producers in the world including United States, China, Russia and India. Most common natural phytochemicals present in significant quantities in pumpkin are carotenoids, phenolics, vitamins, minerals, polysaccharides, pectins, fibers, tocopherols, phytoestrogens, essential oils, proteins, peptides and amino acids. These wide range of bioactive present in pumpkin have been found involved in several pharmacological and biological activities including antimicrobial, anticancer, antioxidant, cardioprotective, antiaging, anti-inflammatory and prebiotic activities (Ezzat et al., 2022). Production of pumpkin have been recorded 22.90 million tons in 2019 with leading producers China, United States, India and Russia. Natural pigments present in pumpkin are responsible for appearance, colors and flavors of food products developed with pumpkin incorporation. Nutritional value of developed foods is also improved by addition of pumpkin. Pumpkin is considered a versatile food due to its nutraceutical and functional food properties (Sharma & Sogi, 2022).

Vegetables like pumpkin, which are loaded with antioxidant components such as Vitamin C, A, E, zinc and β carotene have high impact on COVID 19 patients. Instead of consumption of fast foods possessing bad cholesterol and saturated fats, these types of vegetables improve innate and adaptive immune system of the body (Tanmoy et al., 2020). In context of outbreak of COVID 19 the use of food as medicine has gained importance worldwide and pumpkin containing immunity boosters like omega-3 fatty acids, zinc and selenium is a remarkable food to be used (Parikh & Kumar, 2021). Relation of COVID 19 pandemic is very closely related to body immunity and in current situation protection of body from viral diseases can only be done with the use of immunity booster diets. Pumpkin has been included prominently in the selection of vegetables to be preferred during and after COVID 19 pandemic, due to its role as immunity booster (Komarayanti et al., 2020).

Conversion of agricultural wastes into valuable food products is an area of interest of industrialists. Pumpkin wastes are composed of peels and seeds byproducts, which are loaded with beneficial nutrients. Pumpkin peels are extraordinary sources of polysaccharides, pectin and carotenoids while pumpkin seeds are equipped with bioactive compounds including tocopherols, phenols, carotenes, essential oils, proteins, vitamins, minerals and fiber. Pumpkin wastes are capable of providing health benefits directly or through production of valuable nutritional food products (Noh et al., 2022). By products of seed used pumpkin include peel, flesh, seed cake and seed coat, these parts instead of wasting can be utilized to develop feed and food products, which could play health promoting role due to their nutritional values (Li et al., 2022a). Pumpkin (Cucurbita maxima) peel, flesh and seeds were dired to obtain fine quality powders and ethanolic extracts of these three pumpkin parts were tested for total phenolic, flavonoid, carotenoid, mineral and β carotene contents. The results revealed that all three fractions of pumpkin were well equipped containing comparable amounts of phytochemicals responsible for health promoting activities (Hussain et al., 2021a).

Pumpkin is considered an important vegetable all around the world due to its special nutritional profile promoting human health. Peel, flesh and seeds of pumpkin are excellent sources of carotenoids especially β carotene. Different techniques have been applied to analyze the β carotene in pumpkin parts and results were found satisfactory with higher values of β carotene in pumpkin peel as compared to flesh and seeds. The contents of β carotene in all parts of pumpkin are comparable with varied amounts in different species due to several factors including age, environment and species (Hagos et al., 2022). Physical, chemical and cooking quality parameters of freshly harvested pumpkin and pumpkin stored at ambient conditions were compared and a significant decrease in quality parameters of stored pumpkin was noticed. Freshly cultivated pumpkin was found good sources of starch, pectin, lipids, carotenoids and minerals, the attributes of interest for consumers and food processors (Theanjumpol & Maniwar, 2022). Impact of different household cooking techniques on color, antioxidant capacities and sensory properties of pumpkin was studied to find out the best possible method for good nutritional food products from pumpkin. Steaming of pumpkin reduced the loss of total phenolic contents and stir frying reduced the loss of total flavonoids thus improving the antioxidant potential of pumpkin (Mashiane et al., 2021). Pumpkin flesh is a rich source of carotenoids and upon investigations 25 different types of carotenoids and carotenoid esters have been identified in pumpkin flesh and some of them are heat sensitive and others are stable towards heat. Carotenoids play positive role as antioxidants and anticarcinogenic agents and can protect the body from viral infections (Ouyang et al., 2022).

Oil from pumpkin seeds (40 mg/kg) and zinc (4 mg/kg) were applied in experimental stressed rats along with reference drug venlafaxine (20 mg/kg), and pumpkin seed oils have been found involved in lowering oxidative stress and neuroinflammation caused by chronic mild stress in rats. Pumpkin seed oil and zinc improved the antioxidant capacity and anti-inflammatory status of rats resultanty acting as anti-depressant by producing the serotonin and norepinephrine in the blood (El-Azma et al., 2022). Pumpkin seed oil is naturally loaded with a number of bioactive components participating in human health. Phenolic compounds, fatty acids, tocopherols, minerals, carotenoids and phytosterols have been found involved in cholesterol lowering, anticarcinogenic, anti-inflammatory, antidiabetic and antimicrobial activities (Gedi, 2022). Pumpkin seeds and kernels of different cultivars were nutritionally tested for protein, fiber, fat, minerals, vitamins, sterols, tocopherols and carotenoids, which explores their further use in food and nutraceutical industry. Broad spectrum antimicrobial and antiox-
functional activities of selected cultivars seeds and seeds kernels were also observed. Valuable nutritional contents of pumpkin seeds and seeds kernels could provide the new valorization in food processing industry for development of nutritional food products (Singh and Kaur 2022). The use of pumpkin seed was tested against blastocystis, the unique protozoa involved in infection in gastrointestinal tract and satisfactory results were observed comparable with standard drug for the treatment of such parasitic infections (Salman & Ardalan, 2022). Pumpkin seeds are excellent source of protein especially free tryptophan with promising antioxidant capacity, which supports the potential of utilization of pumpkin seeds as a functional food ingredient for development of nutraceuticals (Vargas et al., 2022). The presence of biologically active components valorize pumpkin seeds an attractive choice for the food industry. Oil extracted from pumpkin seeds have been found involved in many biological activities due to its unique fatty acid composition and tocopherol contents responsible for anti-parasitic activities (Chellini et al., 2022). Important functional constituents of pumpkin and their pharmacological activities related to COVID 19 have been presented in Table 1.

3. Pumpkin powders; concentrated sources of nutrients and phytochemicals

Pumpkin powder can be obtained by different combination of drying techniques including connective drying, microwave drying and microwave-connective drying, the obtained powders from different pumpkin fruits when were tested for physicochemical properties, color, bioactive compounds and antioxidant potential, optimal results were found, which indicates that pumpkin powder can be added in different food products without any negative physicochemical changes but on the other hand the bioactive compounds will definitely enhance the nutritional status of the food products (Izli et al., 2022). Pumpkin peel, flesh and seeds were separated and dried using hot air drying to obtain fine quality powders and these powders from three fractions of pumpkin were tested for total phenolic, flavonoid, carotenoid and mineral contents. The results revealed that every part of pumpkin is heavily loaded with bioactives (Hussain et al., 2021b). Pumpkin was dried by hot air oven and grinded to obtain fine quality powder, which possessed pleasant color, smell and texture. This powder could be used as a concentrated source of nutrients like fiber, minerals, vitamins and proteins to fortify food products especially bakery and dairy products (Johari et al., 2022).

Pumpkin pulp flour was produced using different techniques and physicochemical and nutritional analysis of developed flours were carried out in a comparative manner. Fermentation technique positively impacted the protein, fiber, total carotenoids, vitamins and mineral contents, while boiling improved the crude fiber contents of the flours. Application of different techniques to produce pumpkin pulp flours did not affected the shelf life of flour (Adelrin et al., 2022). Foam-mat drying of pumpkin puree provides 50% faster drying rates than conventional drying and also the preservation of carotenoid contents was smoothly achieved through this innovative technique. Dried flour through this modern technique exhibited excellent water holding capacity and higher solubility index as compared to conventionally dried flour. For development of different food products when hydration of this dried pumpkin puree flour was done it presented the same firmness and adhesiveness as the fresh pumpkin puree. This innovative process added value to the traditional pumpkin puree and pumpkin flour providing the base for development of nutritional pumpkin-based food products with good quality attributes (Panato & Muller, 2022). Pumpkin slices were undergone three pre-treatments blanching, freeze thawing and ultrasound pre-treatment before far-infrared drying and these treatments influenced positively on the quality parameters of pumpkin. These conditions led to the increased polyphenols and total carotenoid contents of the pumpkin slices as compared to untreated pumpkin. Resultantly it can be concluded that pre-treatments before drying of pumpkin could be the effective processing techniques to obtain good quality pumpkin products with enhanced nutritional parameters (Chao et al., 2022). Pumpkin peel, flesh and seeds powders contain good quality protein and oils, containing essential amino acids and fatty acids (Hussain et al., 2022a).

Pumpkin seeds, which are usually discarded but are excellent source of fiber, protein, oil, minerals and phenolic compounds. Nutritional quality of pumpkin seeds can be best retained and improved through different pretreatments before drying (Zalazar-Garcia et al., 2022). Seed used pumpkin was tested for influences of different drying techniques on functional properties of pumpkin and sufficient quantities of polyphenols, carotenoids and ascorbic acid were found, which was a clear indication of antioxidant and anticancer potential of pumpkin, the two conditions which are directly or indirectly related to infectious diseases (Chao et al., 2022). Seed used pumpkin flesh was dried to obtain fine quality powder and carotenoids were detected in developed powder. Particle size of the powder was important for bioaccessibility of carotenoids during in vitro study. Addition of corn oil and smaller particle size improved the antioxidant capacities of the pumpkin powder (Lyu et al., 2021). Pumpkin parts powders were found capable of antihyperglycemic and antihyperlipidemic activities in alloxan induced diabetic rats, in a controlled clinical trial (Hussain et al., 2022b).

4. Pumpkin extracts, isolated and purified bioactives

Pumpkins are extensively grown in the world and mostly consumed in cooked form by the population. Cooked texture of the pumpkins is directly related to the contents and properties of the starches present.

Table 1

| Sr. No. | Functional constituents of pumpkin | Pharmacological activities related to COVID 19 |
|---------|------------------------------------|-----------------------------------------------|
| 1       | Vitamin C                          | Destroys free radicals in the body and boost immune system |
| 2       | Vitamin E                          | Act as antioxidant by scavenging the free radicals in the body |
| 3       | Vitamin D                          | Encounter the viral infections, especially respiratory tract infections which are common in COVID 19 outbreak |
| 4       | β carotene                         | Powerful antioxidant, reduces inflammation by increasing the production of diseases fighting cells in the body |
| 5       | Zinc                               | Increases the production of white blood cells in body, the agents defending body against viruses |
| 6       | Iron                               | Necessary for normal functioning of biochemical processes in the body, Homeostasis risk of infection |
| 7       | Selenium                           | Boost both innate and adaptive immune system |
| 8       | Polysaccharides                    | Reduce level of oxidative stress in cells and tissues and play role as antioxidant, antimicrobial, antiviral, antidiabetic and antitumor |
| 9       | Proteins (peptides, amino acids and enzymes) | Act as antimicrobial, inhibit growth of melanoma, counteract intoxication, |
| 10      | Lipids (fats, oils, fatty acids, sterols) | Play role as antioxidant, anti-inflammatory, immunomodulatory, anticarcinogenic, anti-parasitic and hypotensive |
| 11      | Phenolic acids                     | Alleviate the oxidative stress by acting as antioxidant agents |


in pumpkin. Starches were extracted from pumpkin and it was observed that strong resistance towards enzymatic hydrolysis was exhibited by starch granules (Yuan et al., 2022). Pumpkin polysaccharides intake through oral administration is primary and basic way to utilize these bioactive. Pumpkin polysaccharides are clinical medications due to their health promoting properties (Li et al., 2022a). Pumpkin derived polysaccharides have been found involved in antioxidant, anti-tumor, hypoglycaemic, hepatoprotective and immunoregulatory activities. Structural analyses, extraction methods and pharmacological activities of pumpkin polysaccharides have been investigated to explore the vast medicinal uses of these phytochemicals (Ji et al., 2021). A novel low molecular mass polysaccharide with molecular weight 3.5 kDa have been detected, isolated and purified from pumpkin, displayed strong antioxidant and hypoglycaemic activities. This polysaccharide alleviated oxidative stress in tested animals (Li et al., 2021). Pumpkin paste with high content of pectin was produced with preservation of nutrients and with capacity to remove heavy metals, radionuclides and toxins from human body. This study explored the use of pumpkin paste with high amount of pectin for the therapeutical and prophylactic nutrition of people (Sukhenko et al., 2019). A new polysaccharide was extracted and purified from pumpkin, having local rod like conformation and was found involved in anti-diabetic activity in aloxan induced diabetic mice (Thanh et al., 2021).

Pumpkin seeds used for the production of oils, contain minute quantities of α-linolenic acid, bioactive phytoprostanes and phytolifuran the agents known for nutritional claims especially the antioxidant potential. Due to nutty smell and taste pumpkin seed oil is well known green colored oil used in food industry for extraction of bioactives and development of pharma foods (Vigor et al., 2022). Evaluation of pumpkin seed oil and fatty acids present in it was done for traditionally grown pumpkins and organically grown pumpkins, and results explored highest percentage of linoleic acid, linolenic acid, oleic acid, palmitic acid and stearic acid in organically grown pumpkin. From these results it can be concluded that pumpkin is a medicinal plant and can be grown organically to obtain required bioactives in sufficient quantities (Ahmed et al., 2022). Bioactive compounds, especially γ-aminobutyric acid in pumpkin seeds was enhanced by optimizing the germination parameters and ultrasonic assisted extraction, the economical and effective methods for optimal extraction yield of bioactives. These medicinal food components are associated with reduced risk of lifestyle-associated diseases like diabetes hyperlipidemia (Liang et al., 2022). Pumpkin seed oil due to its nutritional value acquires high market value and is occasionally adulterated with cheaper oils especially sunflower oil. Authenticity of retailed pumpkin seed oils was investigated through sterol composition analysis (Balbino et al., 2022). Pumpkin seed oil extracted by different techniques from pumpkins of different origins exhibits different total phenolic contents and antioxidant capacities. Among these techniques hot pressing was found the most suitable method with good physicochemical properties suitable for industrial application of pumpkin seed oil (Irinawati et al., 2022). Pumpkin seed oil is an excellent source of vitamin E, powerful antioxidant involved in anticarcinogenic and anti-inflammatory activities. Non refined, organic pumpkin seed oil was used to detect, isolate and structure verify the rare vitamin E compound γ-tocotromonoenol. Countercurrent chromatography enabled the detection of 18 different tocopherolamines in pumpkin seed oil, responsible for antioxidant capacities of pumpkin seed oil (Kropfl et al., 2022).

Pumpkin seed protein isolates can be extracted from pumpkin seeds and their functional and physicochemical properties could be improved by high intensity ultrasound processing. Functional properties of pumpkin seed proteins can be enhanced by ultrasound technology to meet the complex requirements of the food processing industries (Du et al., 2022). Texturized protein isolates from pumpkin seeds could be the alternatives of meat. These meat replacers are the agents responsible for favorable organoleptic changes and creating the products with high consumer acceptability. Hybrid meat sausages incorporated with pumpkin seed proteins presented a promising, more sustainable alternative to other meat formulations (Ebert et al., 2022). Nutritional well-balanced proteins have been found abundantly in pumpkin seeds. Protein isolates and protein fractions from pumpkin seeds were tested for biochemical, functional, and nutritional properties and essential amino acids were predominantly present in pumpkin proteins. Results confirmed the potential application of pumpkin seed proteins in functional food products (Vinayashree & Vasu, 2021). Pumpkin protein foods with high nutritional values can be developed. Different peptides from pumpkin seed proteins were purified, characterized and evaluated for their zinc-chelating capability. Effective zinc transportation and absorption in gastrointestinal tract was observed in an in-vitro study experimenting on the pumpkin seed peptide-zinc chelates (Peng et al., 2022). Pumpkin seed protein isolates were treated with high intensity ultrasonic treatment to improve the physicochemical, structural and foaming properties of protein isolates. This novel technique proved helpful in contributing the functional and nutritional properties of the protein (Du et al., 2022).

Clinical studies have proven that plant extracts are useful traditional medicines to treat mild to moderate lower urinary tract infecions. Pumpkin seed extracts were used in a randomized controlled study to investigate their healing effects on urinary tract symptoms and results revealed the health promoting capacity of pumpkin seed extracts (Vahlenkamp et al., 2022). Pumpkin peel, flesh and seeds methanolic extracts were tested for antimicrobial and antioxidant activities and results were found very promising, encouraging the use of pumpkin extracts as complimentary medicines (Hussain et al., 2021a). Copper oxide nanoparticles were synthesized using pumpkin seed extract and were tested for their anticancer activity in human colon cancer. This study opened the advancements of pumpkin seed extracts in medical, pharmaceutical and biotechnological fields (Tabrez et al., 2022). Fig. 1 summarized the possible applicable ways to utilize the pumpkin.

5. Pumpkin based pharma and functional food products

Natural pigments such as carotenoids present in pumpkin improve esthetic value and antioxidant potential of the pumpkin-based food products. Peel and pulp of pumpkin were explored for carotenoids and polyphenols, the agents responsible for antioxidant capacities of pumpkin, using different technologies and results were exhaustive for these phytochemicals presence (Sharma & Bhat, 2021). Cereal based food products including porridge, cookies and sponge cake were enriched by carotenoids rich pumpkin powder. Bioaccessibility and cell uptake of carotenoids from these bakery products were investigated using in vitro studies models and significantly high bioaccessibility of α carotene, lutein and β carotene were noticed (Rosul et al., 2022). Pumpkin flour was used as functional ingredient in formulated food, flat noodles to increase antioxidant activity of the developed product. Improved aroma, flavor, taste, texture and overall accessibility of pumpkin powder incorporated noodles were observed (Indriani et al., 2021).

Good and acceptable formulated complementary porridges can be developed from blends of pumpkin seed powder, amaranth grains, soybean and sweet potato. These functional food porridges when evaluated for their nutritional analysis proved excellent sources of iron, zinc, protein, vitamin A and vitamin C, the elements responsible to compete nutritional requirements of children especially in current post COVID 19 period as the healthy and boosted immune system could only be the key strategy to combat viral and infectious diseases. The usage and marketing of such formulated foods must be promoted in our societies to develop a healthy community (Marcel et al., 2022). Pumpkin based snacks after freeze drying of pumpkin puree were obtained with higher shape fidelity and controlled crispiness. These innovative food products meet specific texture requirements with new sensory perception and could open the new market of pumpkin-based nutritional and healthy food products for consumers (Chen et al., 2022). Pumpkin chips were developed supplemented with some aromatizing spices and significantly increased antioxidant capacities of pumpkin snacks were noticed due to high total phenolic contents especially phenolic acids. These pumpkin-
based snacks could be used as excellent alternative snack food for all ages of groups due to their health promoting abilities (Aydin, 2022). Effects of different drying treatments including hot air drying, freeze drying and explosive puffing drying were studied for their impact on physical, nutritional and textural qualities of pumpkin chips. Freeze drying and explosive puffing drying were proved the most promising techniques to produce nutritious pumpkin chips with greater retention of color, total carotenoids, total phenolic contents and antioxidant capacities (Koprualan et al., 2021).

Pumpkin juice and nectar are two valuable food products of pumpkin but due to their microbial count and perishable nature their shorter shelf life is problem towards their consumption and marketing. Pulsed electric filed was used to inactivate *Escherichia coli* in pumpkin juice and nectar. This preservation technique did not pose any negative cost on physicochemical properties of juice and nectar (Dos Santos et al., 2022). Pumpkin juice as compared to untreated sample, ultrasonic treatment significantly increased the carotenoid contents, whereas no negative impact was observed on color index of treated juice. Moreover, the storage period did not affect the color and natural pigments of the pumpkin juice. As ultrasonic processing significantly improved the nutritional, physical, rheological and chemical properties of the pumpkin juice so this technique could be applied as a potential new technology for processing of pumpkin to develop safe and nutritious food products (Suo et al., 2022). Pumpkin based beverage was produced by addition of pumpkin juice concentrate to study the carotenoids retention and degradation during different storage conditions. Proper air tight packaging and use of antioxidants optimized the pigments retention in pumpkin based colored beverage during storage (Atencio et al., 2022). Pumpkin was crushed and processed into pumpkin puree and after extraction of juice pomace was separated. The impact of different processing treatments on pumpkin juices was studied and findings revealed that 90–98% carotenoids were transferred into the juice from puree due to high pressure homogenization. Instead of artificial juices natural pumpkin juice with high carotenoid contents could be the attractive and healthy natural product for customers desired with functional and medicinal foods (Atencio et al., 2022).

Pumpkin and whey, potential sources of bioactive compounds, were used as natural ingredients in manufacturing of bread as a strategy to reduce the usage of artificial preservatives as the presence of mycotoxins in cereals and cereal-based food products has been remained a significant issue for long time. This study provoked the promising application pumpkin in bakery products (Escriva et al., 2022). Yellow pumpkin powder was produced and composite flours were developed with different proportion of pumpkin powder and wheat flour. Composite flours were tested for physical, rheological and functional properties. Breads were also developed from these composite flours and organoleptic and nutritional analysis of developed breads were performed. The obtained results revealed that composite breads with greater substitution of pumpkin powder exhibited higher total phenolic contents and higher antioxidant properties as compared to control bread. These results provided the base for development of nutritional and medicinal food products comprised of pumpkin powders to promote the health of people around the globe (Aljahani, 2022). Pumpkin flour was incorporated in wheat flour at different levels to develop nutritional bread and

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**Fig. 1.** Pumpkin constituents; possible ways to utilize pumpkin pharmacological attributes.
20% replacement level of pumpkin flour yielded the bread with excellent total phenolic contents and antioxidant activities (Wahyono et al., 2020).

Immunity booster bars have been developed for the athletes, comprised of pumpkin, flax and sunflower seeds, which proved highly effective to fight against the novel virus in this scenario of COVID 19 pandemic (Mishra & Singh, 2021). Pumpkin-orange cake was developed and different sensory methodologies were implicated to check the shelf life of cake (Miele et al., 2022). Pumpkin puree was added in wheat bran sourdough, barley bran sourdough and rice bran sourdough to develop bread fermented with lactic acid bacteria and results revealed that textural and sensory properties of bread were improved. These nutritional breads with different formulations provided new range of functional and medicinal food items with acceptable consumer preferences (Ebrahimi et al., 2022). Peel, flesh and seeds of pumpkin were incorporated in wheat flour in the form of dried powders to develop functionalized biscuits with increased total phenolic, flavonoid and carotenoid contents, the basic agents behind the antioxidation processes (Hussain et al., 2022c).

To combat nutrition related diseases and improve overall physical and mental health, belief of consumers in healthy pharma foods has raised in recent years. Pumpkin powder was incorporated in yogurt to obtain pumpkin fortified dairy product rich in carotenoids, fiber, vitamins and minerals. The addition of pumpkin powder reduced the syneresis, improved rheological behavior and boosted nutritional value of the yogurt (Johari et al., 2022). Pumpkin seed cake was fed to the lactating goats and milk obtained from them was used to prepare semi-hard cheese, which was tested for nutritional composition especially fatty acid profile and it was concluded that addition of oil seeds and their cakes to the diets of lactating goats is an alternative to supplements. The cheese prepared presented a food with health promoting properties (Klier et al., 2021). Pumpkin fruit is rich source of antioxidants such as carotenoids and polyphenols. Reduced fat mayonnaise was developed using pumpkin flour as potential stabilizer. Addition of pumpkin flour in mayonnaise was studied for its physicochemical and structural effects and positive impact was noticed (Nidhal et al., 2022). Pumpkin cream soup with addition of tempeh was developed as complementary food product for elderly to combat with their age-related diseases. The developed soup was analyzed for fat, fiber, protein, vitamins and minerals and results proved this supplementary food product as excellent, nutritious diet for elderly people (Setiawan et al., 2021). Pumpkin derived healthy, nutritious and functional food products developed and marketed in recent times, have been presented in Fig. 2.

6. Innovative technologies based pumpkin processing and utilization

Pumpkin can be marketed for consumers in the form of fresh cut pumpkin slices preserved through edible coating and vacuum packaging. Textural and microbiological analysis of preserved pumpkin slices indicated highest textural parameters, well retention of β carotene
and less microbial counts in fresh cut pumpkin slices with chitosan coating combined with vacuum packaging stored at low temperature (Yukel et al., 2022). Nutritive value of fatty foods reduces due to degradation of polyunsaturated fatty acids resultanty generating toxic aldehydes, which also poses negative impact on sensory properties of food. Shelf life of these type of foods is always reduced due to oxidation of lipids. Pumpkin oil cake provided a good alternative to plastic packaging due to barrier properties to gasses, natural origin and biodegradability. Pumpkin oil cake-based films due to excellent oxidative stability are good biofilms to preserve fatty foods (Hromis et al., 2022). Vacuum cooked pumpkin discs fortified with iron and ascorbic acid were evaluated for iron stability and bioaccessibility and results declared that after cooking and refrigerated storage of pumpkin discs no changes on physicochemical properties of pumpkin discs were observed and iron contents were significantly increased (Lencina et al., 2022). Pumpkin seed oil capsules were encapsulated with different sources of starches including maltodextrin and disaccharides from wheat, rice and maize. Oxidative stability, retention of tocophers, squalene and sterols of pumpkin seed oil was studied and results revealed that wheat starch acted as best preservative for pumpkin seed oil with enhanced antioxidant capacity and greater retention of bioactives (Ogrodowska et al., 2021). Pumpkin puree was preserved during frozen storage by the application of pectin oligosaccharides, no adverse changes in structure and taste of pumpkin puree were noticed during frozen storage. This novel technique can be utilized to market the pumpkin for the usage of consumers over the year (Li et al., 2022a). Iron nanoparticles were developed using pumpkin aqueous extract and were tested for burn treatment. Broader range of inhibition from iron nanoparticles was observed against the selected pathogenic microorganisms involved in contamination of burns and wounds (Ahmed, 2022). Controlled clinical trials on human and animal models are strongly recommended to isolate and characterize bioactives from pumpkin parts, to check their medicinal functionality. Normal consumption effects of pumpkin parts could be followed up in relation to various chronic, metabolic and viral diseases such as cancer, diabetes, COVID 19 and heart diseases. Functional foods containing pumpkin peel, flesh and seeds powders and extracts could be developed and marketed for wellness of mankind especially in current post COVID 19 period to improve immune systems in the communities (Hussain et al., 2022d).

7. Conclusion

Along with allopathic drugs and vaccines, healthy eating compartmentalised of pharma foods could be the key strategy to counter the attack of diseases, especially the immune related pandemic COVID 19. Populations with poor eating habits have been badly affected by the attack of novel coronavirus due to their fragile immune system. Pumpkin has been proved an excellent pharma food, possessed with remarkable amounts of functional and nutraceutical constituents, responsible for multifunctional roles in human body. Proteins, polysaccharides, oils, vitamins, carotenoids, minerals and phenolic compounds present in pumpkin fruits exhibits immunomodulatory, anti-inflammatory, antioxidant, antimicrobial and antiviral activities. Pumpkin powders, extracts, isolates and pumpkin derived food products are the appropriate potential ways to utilize this nutritious fruit. Utilization of innovative and novel technologies like edible coatings, vacuum packaging, nano particles and bio preservations could be the useful processes to lengthen the shelf life of this perishable food with greater bioaccessibility of nutrients. Need of the time is to incorporate these pumpkin derived constituents in humans’ daily diet to maintain a well-balanced body, armed with boosted immune system.

Ethical statement

This study does not involve any experiments on animals and humans.

Declaration of Competing Interest

The authors have declared no conflicts of interest for this article.

Data availability

Data will be made available on request.

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