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Research Article

Pumpkin Halwa Pudding: Not Just Dessert, A Bioactive Powerhouse to Boot as Well

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Abstract

Pumpkin (Cucurbita Maxima) is a famous member of the Cucurbiteacea family, which is eaten both as a vegetable meal and as a dessert. The dessert form prepared in India is a type of pudding, called *Halwa*, made by cooking the pumpkin pulp in ghee (clarified butter) and milk. High in nutritional content, *halwas* also possess the capability to efficiently deliver the phytochemicals present in the basic foods from which these are made. This phytochemical delivery is accomplished by ghee and milk proteins, which behave as phytochemical carriers, and transport both the hydrophilic and the hydrophobic phytoactive molecules. The pulverization of the food items alongwith encapsulation of the phytonutrients within micro vesicles makes the phytoactive compounds more bioavailable Accentuated absorption of the hydrophobic (lipophilic) bioactive molecules via the lymphatic system provides the immune, cardio-vascular and respiratory systems with a rich supply of these phytochemicals, enhancing the functions and capabilities of these bodily systems.

Keywords: Vegetable pudding, phytochemical carriers, milk proteins , ghee, pumpkin phytochemicals

Introduction

Pudding made from pumpkin is a traditional Indian delicacy, usually prepared during celebrations and feasts. In Ayurveda, the variety of Indian pumpkin called *Kushmanda (Benincasa hispida)* is extolled for its beneficial effects on the brain [1,2]. Several pumpkin varieties are grown and harvested worldwide due to their nutritional & economical benefits [3]. In India, pumpkin vegetable *subzi* is served during religious festivals, while the *halwa* pudding is served at celebrations. Gastronomically delightful, this delectable pudding is prepared in various ways. The traditional method of preparation involves the use of milk as base. After boiling and softening the pulp in milk, the halwa is sauteed in vegetable oil or ghee (clarified butter). The full process is lengthy and requires extra effort, hence *halwas* are usually made only during special occasions, like marriages, social functions and fasts.

The use of ghee for frying the vegetable and the added garnishments like raisins and pumpkin seeds, make the halwas a valuable food item – expensive to make and rich in nutrition (Figure 1). Appraised in classical nutritional terms, halwas can be considered a good source of calories, vitamins, minerals, fats and carbohydrates, but their nutritional and health benefits go much further, and are not generally recognized [4]. These unrecognized benefits are attributable to the enhanced bioavailability of the phyto-active compounds contained in pumpkin, which are otherwise unavailable due to their being confined within the tough cell walls of the vegetable pulp. The enhanced transport and bioavailability is due to the use of ghee and milk in cooking the pumpkin pulp, and which are now recognized as an effective carriers of phytoactive biocompounds [5-10].

Figure 1: Pumpkin halwa is a nutritionally rich dessert, made from pumpkin pulp, milk, sugar, Ghee, Pumpkin seeds, almonds, raisins and condiments like cardamoms.

POTENTIAL HEALTH BENEFITS OF PHYTOCHEMICALS FOUND IN PUMPKIN FLESH & SEEDS

Pumpkin (flesh & seeds) contains different substantial phytonutrients such as carotenoids [11], Tocopherol [12], flavonoids, phenolic acid [13], phytosterols [14], polysaccharides & fibers [15], and also amino acids [16], vitamins and minerals [17]. These chemical groups play crucial and specific roles in the human body that are indispensable for existence of life. Furthermore, pumpkin is an active research area because of its exceptional health-promoting properties like antioxidant, anti-inflammatory [18], antidiabetic [19], antibacterial [20] and many more.

Carotenoids: Carotenoids are natural organic pigments that give characteristics color to pumpkins [11]. Carotenoids (Beta-carotene, Lutein & Zeaxanthin) have antioxidant [21], anti-inflammation [22], anti-aging, anticancer properties (inhibits the growth of cancer cells) [23] and Beta-carotene is also a precursor of Vitamin A [24].

Tocopherol: A class of organic compounds that constitute methylated phenols is termed tocopherol, and is present in pumpkin seeds in sufficient amounts [12]. The pumpkin seed oil has a therapeutic effect due to the presence of tocopherol [25].

- Alpha-tocopherol is a potent antioxidant [26] and reduces oxidative stress.
- Gamma-tocopherol: *Y*-tocopherol is the major form of vitamin E and has antioxidant & anti-inflammatory effects [27].

Phenolic acid: These are organic compounds with aromatic rings in their structures. Phenolic acids such as Protocatechuic acid, Chlorogenic acid, Sinapic acid, Caffeic acid, Ferulic acid, P-coumaric acid, Vanillic acid, Gallic acid, 4-Hydroxy-benzoic acid are present in pumpkin seeds [13]. They increase the antioxidant, antimicrobial [28], antidiabetic [29], and anti-inflammatory capacity of pumpkin seeds. Chlorogenic and caffeic acids suppress the secretion of enzymes associated with type 2 diabetes [30].

Flavonoids: Flavonoids are an important class of organic compounds, a considerable amount of which are present in the pumpkin peel, flesh, and seeds. Flavonoids such as Isoquercetin, Quercetin, Astragalin, Rutin, and Kaempferol are found in the pumpkin plant. They possess multiple medicinal benefits, such as anticancer, antiviral, anti-inflammatory, and antioxidant properties [31].

Phytosterols: Phytosterols (ß-sitosterol, stigmasterol, and campesterol) are potential anticancer agents. They suppress the secretion of 5 alpha-reductase, as a result, inhibiting the conversion of testosterone into dihydrotestosterone and reducing the chances of benign prostatic hyperplasia (BPH) and prostate cancer [32]. Phytosterols have hypotriglyceridemia properties and lower cholesterol levels [33].

Polysaccharide: Yu *et al*. analyzed the pumpkin polysaccharide and concluded that they promote gastrointestinal digestion [34]. Polysaccharides also modulate blood glucose and lipid level [35].

Protein-bound polysaccharide: *β-cells* are embedded in the pancreas, and they secret insulin hormone which regulates glucose levels. Protein-bound polysaccharides act as antidiabetic by protecting β-cells from destruction due to their free radical scavenging and antioxidant activities [36].

Phytoestrogen: Phytoestrogens (lignans & isoflavones) are found in pumpkin seeds that tend to bind with estrogen receptors in women and have potential anticancer cell activities. Phytoestrogens show effects on estradiol secretion and inhibit the growth of breast cancer cells [37].

Fatty acids: Pumpkin seeds contain fatty acids such as palmitic acid, oleic acid, linoleic acid, and polyunsaturated fatty acids. Pumpkin seed oil is effective for healing wounds due to the presence of essential fatty acids [38].

Cucurbitin: Cucurbitin is a special amino acid in pumpkin and possesses anti-helminthic (ability to eliminate intestinal worms) activity [39].

Fibers: Pumpkin flesh is enriched with dietary fibers that offers multiple benefits to human beings. Pectin modulates glycemic levels and lowers insulin demands in diabetic patients [40].

Minerals: Pumpkin flesh & seeds are also an excellent source of minerals such as zinc, magnesium, phosphorus, potassium, and selenium [41]. Zinc enhances bone density and reduces osteoporosis risks [42].

Routes of absorption of the Phytochemicals

The phytochemicals contained in pumpkin and added dried fruits and seeds are both hydrophilic and hydrophobic. Alternately, they can be called as lipophobic and lipophilic, respectively. The milk proteins and fats are able to solubilize and bind a majority of these phytochemicals. As a result, most of the bioactive compounds present in pumpkin reach the small intestine and are released under the action of proteolytic and lipolytic enzymes. The hydrophilic compounds are absorbed by the enterocytes and enter the portal circulation to reach the liver.

The hydrophobic compounds, on the other hand, are absorbed into the lacteal system, from where they reach the intestinal lymphatics. The intestinal lymphatics drain into the cisterna chyli, which continues upwards as the thoracic duct. The lipoidic or hydrophobic phytochemicals travel in the lymph upwards towards the heart in the thoracic duct, which opens into the great veins which empty into the right heart. These phyto-compounds thus escape first-pass degradation in the liver and directly reach the heart, lungs, brain and other organs.

Prebiotic effects of pumpkin pulp

Pumpkin pulp contains pectin, which has demonstrated effective prebiotic effects in several studies. Since pumpkin *halwa* traditionally contains milk, the whey proteins of milk can bind to pectin and enhance the prebiotic effects of the latter. In an animal study conducted in rats having antibiotic-induced dysbiosis, a functional mousse (dessert) made with whey protein hydrolysate (WPH) and pumpkin pectin was shown to increase the Bifidobacterium spp. by 3.7 times. This effect is known as the bifidogenic effect, which is beneficial as the Bifidobacteria increase the acidity in the intestines which suppresses the growth of pathogenic bacteria [43]. Another study by Du et al. Investigated the prebiotic potential of oligosaccharides prepared through acid hydrolysis of polysaccharides derived from pumpkin pulp. During in-vitro studies, the outcomes revealed that the oligosaccharides significantly stimulated the growth of beneficial lactobacilli, suggesting the potential of pumpkin-derived oligosaccharides as a prebiotic ingredient [44]. The oligosaccharides were found to have higher solubility a larger part of the oligosaccharides had a low molecular weight fraction in a range from 5000 to 324 Da. The oligosaccharides composed of galactose (99.03%) and glucose (0.97%) were found to significantly stimulate the growth of lactobacilli.

Moreover, another study on a Type 2 diabetic model showed that pumpkin polysaccharide modified the gut microbiota population by selectively enriching key species of Bacteroidetes, Prevotella, Deltaproteobacteria, Oscillospira, Veillonellaceae, Phascolarctobacterium, Sutterella, and Bilophila. Also, the pumpkin polysaccharide was seen to improve insulin resistance and reduce serum glucose, total cholesterol, and low-density lipoprotein (LDL) levels while increasing high-density lipoprotein (HDL) levels [45]. Another study on the effect of the consumption of pumpkin polysaccharide on the gut microbiome, found that the former increased the diversity of beneficial bacteria in the gut and decreased harmful bacteria such as Clostridium, Thermoanaerobe, Deinococcus, Vibrio haematococcus, Proteus gamma, Corio. Considered at the level of microbial family, pumpkin consumption significantly reduced the abundance of Erysipelotrichaceae and increased the Akkermanaceae of Verrucobacterium [46]. Futrthermore, a study on fermenting pumpkin juice with Rhodobacter sphaeroides (RPJ) improved gut health by increasing beneficial Lactobacillus and Bifidobacterium levels while reducing harmful Proteobacteria [47]. These studies suggest that pumpkin polysaccharides have potential health benefits for gut microbiota, and are useful prebiotics.

Summary of nutritional benefits of pumpkin halwa

Numerous research studies on pumpkin pulp have reported therapeutic role in inflammatory response, antioxidant activity, anti-diabetic potential, and even anti-cancer properties. A research study conducted to assess the anti-inflammatory effects of pumpkin reported that carotenoid extracts from pumpkin pulp can help reduce inflammation, particularly at the blood-brain barrier, where mycotoxins often cause inflammatory responses [48]. The extract reduced the abundance of the proinflammatory arachidonic acid metabolite eoxin (14,15-LTE4) and prostaglandin D2-glycerol ester in cultures treated with mycotoxins. It also exhibited protective activity against cellular inflammation triggered by these mycotoxins, suggesting potential use for conditions involving inflammation, including those affecting the brain [48].

Pumpkin pulp also exhibits antioxidant properties against free radicals and oxidative stress. Stryjecka et al. in a research study, demonstrated that the phenolic compounds in the pulp of five pumpkin species, with syringic acid being the most abundant, showed potential scavenging activity against DPPH radicals. Therefore the antioxidant potential of pumpkin pulp could prevent cellular damage and relieve oxidative stress implicated in various health conditions, including cardiovascular diseases, neurodegenerative diseases, and cancer [49].

The antidiabetic properties of pumpkin pulp have also been reported in research studies. Certain polysaccharides derived from pumpkin pulp exhibited potential glucose lowering activity in experiments with alloxan-induced diabetic mice. The polysaccharides led to decreases in blood glucose levels and increases in hepatic glycogen and insulin levels. The study suggests the significant role of pumpkin pulp in modulation of the glucose metabolism and insulin secretion in the body [50]. Another study suggested that pumpkin pulp extract significantly influences the body weight, serum insulin, and morphology of islets of Langerhans (number of islets of Langerhans, as well as the β-cell number). The extracted pumpkin polysaccharides have shown considerable α-amylase inhibition activity [51]. These findings highlight the potential health benefits of pumpkin fruit pulp extracts in the management of diabetes [52].

Interestingly, another study on the polysaccharides in pumpkin pulp also reported antibacterial, anti-inflammatory, and antioxidant properties, indicating their diverse potential applications in boosting immune response and managing health conditions [51,52]. The pumpkin polysaccharides have also displayed considerable antioxidant potential against DPPH and ABTS free radicals. Adding to these, the pumpkin polysaccharides have also shown remarkable antibacterial properties, especially against bacterial strains such as Escherichia coli. Even though they also inhibited fungal strains, their potency was predominantly superior against bacteria [50]. Conclusively, the various biological activities exhibited by these polysaccharides, including α-amylase inhibition, anti-inflammatory, antioxidant, and antibacterial effects, suggest a diverse range of potential applications in the fields of medicine [51,52].

Additionally, pumpkin pulp's anticancer potential was evaluated using a carotenoid-enriched extract. This extract demonstrated the ability to delay the growth of two malignant human cell lines. The possible mechanisms involve the activation of a specific form of autophagy that inhibits cell growth and the induction of cell differentiation, essentially forcing the cancer cells towards a more mature, less proliferative state. This research puts forth pumpkin pulp extract as a promising candidate for further exploration in cancer therapy [53].

Apart from these effects, Pumpkin seeds also have also shown other beneficial effects. Pumpkin seed oil (PSO) reduces the production of prostaglandin E2, malondialdehyde, tissue nitric oxide, xanthine oxidase, and enhances the production & storage of growth stimulating hormone (GSH) [54] by scavenging free radicals. PSO supports the treatment of several disorders such as irritable bladder, nocturnal enuresis [55], benign prostate hyperplasia [56], diabetes [57], microbial infection [57], cardiovascular, and cholesterol & hepatic [58]. Evidence shows that Pumpkin seeds possess anthelmintic effects on various gastrointestinal nematodes [59]. Furthermore, PSO also has cytoprotective properties—suppresses DNA disintegration, apoptosis, and oxidative stress [60,61].

Process of preparation of pumpkin pudding and the use of milk

Pumpkin halwa, a traditional Indian dessert, is a culinary delight that incorporates grated pumpkin, milk, sugar, and various supplementary ingredients such as ghee, nuts, and spices. In the process of preparing pumpkin halwa, pumpkin is peeled, cut into pieces, then grated or finely chopped and cooked in milk. As the milk simmers, a portion of its water content evaporates, and the mixture assumes a semi-solid consistency. Then it is sauteed in ghee over low flame, sugar is added, followed by further sautéing in ghee (clarified butter) until the desired halwa consistency is achieved. All through this process, the mixture is continuously stirred. Some pumpkin seeds and other cut dried fruits can also be added at the end stage.

In this process milk serves as a medium for boiling the mashed pumpkin. Boiling over low flame over a period of time serves to soften the pumpkin pulp and break down the thick plant cell walls, resulting in the release of the phytochemicals contained inside the cells. Moreover, the presence of heated milk allows covalent and non-covalent interactions between the bioactive compounds present in pumpkin pulp and the various milk components. which facilitate binding, encapsulation and stabilization of the phytochemicals. The various types of interactions are described in the next section.

Milk proteins and fats as phytochemical carriers for enhancing the nutritional profile of pumpkin halwa

Milk consists of two primary **proteins**, casein and whey, responsible for its structural integrity and functional properties. The milk proteins possess a large number of hydrophobic sites, allowing them to readily bind with various hydrophobic molecules [62]. The binding mechanisms employed by milk proteins to bind hydrophobic molecules such as fat-soluble vitamins, fatty acids and polyphenols include hydrophobic interactions, hydrogen bonds and van der Waals forces. The hydrophobic phyto-compounds in pumpkin and dry fruits can bind to the hydrophobic regions present on the surface or within the structure of milk proteins. This binding process is reversible, allowing for the delivery of polyphenols, vitamins, and fatty acids. In addition, the hydrophilic bioactive compounds can attach to reactive sites, such as amino and thiol groups located on the surface of protein molecules or within the protein structure, resulting in irreversible binding.

Distinct milk proteins, such as casein, β-lactoglobulin, α-lactalbumin, and bovine serum albumin, exhibit different binding capacities and mechanisms. Milk also contains micelles, colloidal particles composed of casein proteins, and calcium phosphate. The casein micelles possess a combination of hydrophobic and hydrophilic amino acids, providing them the unique capacity to encapsulate and stabilize hydrophobic compounds like carotenoids and tocopherol, which are lipid-soluble [5]. The hydrophilic characteristics of the micelle surface facilitate interactions with the gastrointestinal environment, promoting efficient absorption of the encapsulated compounds [63-66].

Milk fats or cream also play a vital role in the solubilization and absorption of phytoconstituents. Under the action of prolonged heat, the hydrophobic (lipophilic) phytoconstituents contained inside the thick-walled cells get released, and are then able to get bound to the lipid molecules of milk cream. Similar solubilization and bonding can take place between the hydrophobic phytochemicals and ghee molecules, creating a lipid based delivery system for the phyto-constituents [67]. This vesicular lipoidic system is stable, can protect against acid attack in the stomach, and can increase bioavailability of the phytochemicals in the intestines when acted upon by lipolytic processes [65, 68].

Milk fat globules, present naturally in milk, act as carriers for fat-soluble vitamins A and D present in milk. The membrane that surrounds these globules is known as MFGM (Milk Fat Globule Membrane), has an intricate structure and possesses unique emulsifying and biological properties. The intact structure of milk fat globules also renders them capable of resisting gastric acid digestion [69]. These distinctive properties of milk fat globules have a positive impact on the delivery process of hydrophobic phyto-active compounds, since recent studies have demonstrated the potential of milk fat globules in facilitating the encapsulation process of both hydrophilic and hydrophobic compounds. These characteristics signify the potential of milk fat globules as an innovative food ingredient for enhancing nutritional profiles [69].

The presence of **lipids** in milk makes the properties of milk similar to other **oil in water emulsions** [70]. During the initial stages of pumpkin halwa preparation, when the pumpkin pulp is boiled in milk, the milk fats are able to absorb and bind hydrophobic phytochemicals found in the pumpkin pulp. As a result, carotenes and other bioactive compounds solubilized by milk fats can be considered as components of an emulsion system. Studies have shown that emulsion-based carrier systems are efficient in transporting and releasing hydrophobic bioactives such as carotenes [71], significantly enhancing its health benefits. Hence, by boiling pumpkin in milk, milk proteins and lipids are utilized as carriers for the various phytochemicals in pumpkins. This process allows the beneficial compounds in pumpkins, including carotenoids and flavonoids, to bind with milk proteins and be absorbed by milk lipids, thereby providing a more bioavailable form of these nutrients [72]. Consequently, employing milk as a vehicle for delivering the bioactive compounds of pumpkins substantially enhances their nutritional value and health benefits.

Discussion

Milk proteins are versatile carriers of hydrophobic phytochemicals [63,69]. This capability allows for the enhanced bioavailability of otherwise insoluble phytoconstituents found in vegetables, thereby enhancing their delivery. Milk lipids also play a role in solubilizing and encapsulating certain phytochemicals [70]. Consequently, the enhanced bio-accessibility of essential phytoconstituents such as carotenes, flavonoids and polyphenols greatly enhances the spectrum of health benefits offered by the halwa.

Milk lipids, including triglycerides, phospholipids, and cholesterol, can serve as carriers for hydrophobic phytochemicals. These lipids can facilitate the transport and delivery of hydrophobic compounds, ensuring their absorption and bioavailability.

In addition to milk proteins and milk fats, the **milk fat globule membrane** (MFGM) also plays an important role in carrying phytochemicals. Together, milk proteins, milk fats and MFGM form an efficient delivery system for increasing the bioavailability of phytonutrients [69]. Thus, incorporation of milk solids into the traditional preparation of pumpkin halwa (puddings), serves as an effective modality for delivering the abundant phytoconstituents present in this vegetable to various organs in the body.

Another mechanism that aids the delivery and stability of pumpkin phytochemicals in pumpkin pudding is the formation of complexes between **pectin**, whey proteins and phenolic phytochemicals [4,66,73]. Hua et al. determined that protein could remarkably enhance encapsulation efficiency of the bioactive ingredients via hydrophobic interaction or hydrogen bond, and polysaccharide could coat the surface of protein via electrostatic interaction [74]. This protective layer acts to stabilize the protein and the encapsulated bioactive ingredients [74, 75]. During the heating process of preparing halwa, a portion of pectin (polygalacturonic acid) in pumpkin pulp becomes solubilized, and this pectin partially coats the whey protein aggregates (Figure 2).

The flavonoids and other polyphenols then bind to the pectin through covalent or non-covalent interactions. This food matrix contributes to the improved stability of the phytochemicals by protecting them against acid degradation in the stomach. Furthermore, the enhanced bioavailability of phytochemicals allows them to reach the large bowel, where they can exert beneficial effects on the existing gut flora [76]. This interaction between pectin, whey proteins, and phenolic phytochemicals in pumpkin milk pudding demonstrates the potential for developing food matrices that enhance the delivery and effects of bioactive compounds.

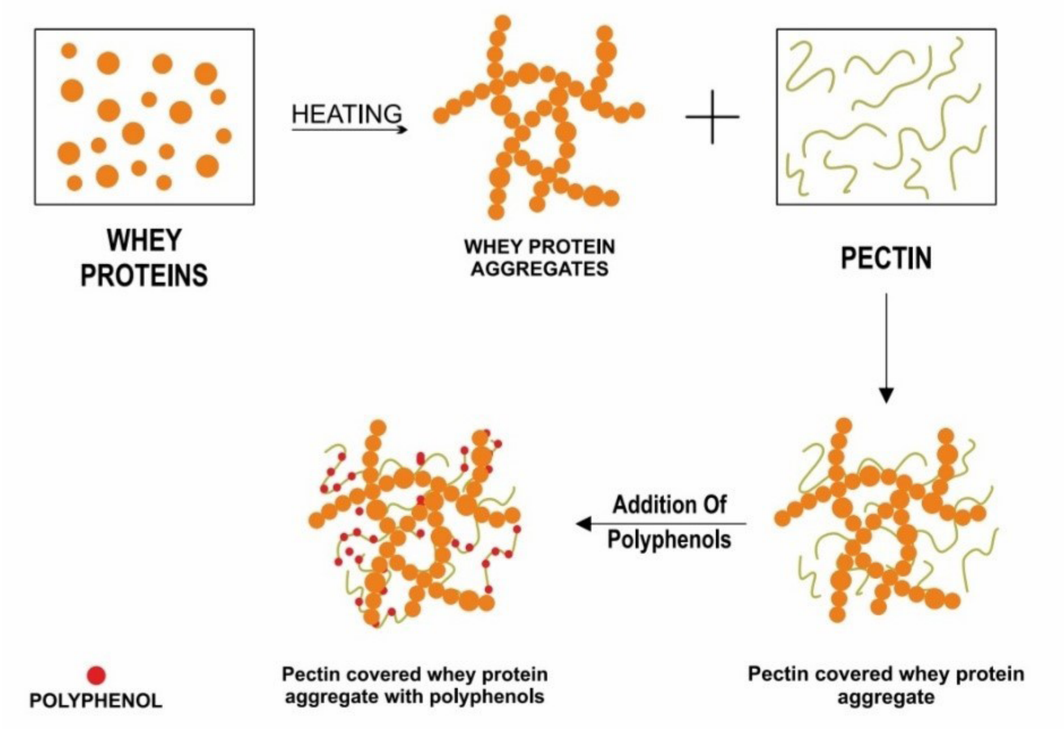

Figure 2: Whey protein aggregates are formed when the milk is added to pulped carrot and heated.

The solubilized pectin fibrils coat the whey protein aggregates, to which the poylphenols get attached. This complex is stable and helps to enhance bioavailability of phytochemical.

Conclusion

Milk components like proteins, lipids, and micelles can all contribute to delivering and stabilizing beneficial bioactive compounds. Numerous studies have demonstrated that milk proteins and lipids can act as carriers for phytochemicals found in plant parts, leading to the improved solubility, absorption, and release properties of phytochemicals [62,63,72,77,78]. While milk proteins can bind to both hydrophobic and hydrophilic phytochemicals by means of covalent and non-covalent interactions, the milk cream fats can also bind with phytoconstituents, forming lipid vesicles and emulsions [70]. Combining milk and pumpkin pulp under the action of heat, thus augments the delivery and bio accessibility of pumpkin phytochemicals such as Protocatechuic acid, Chlorogenic acid, Sinapic acid, Quercetin, Astragalin, Rutin, lignans and isoflavones. Therefore, incorporating milk as a base for pumpkin pudding presents an effective strategy for optimizing the health benefits of this nutrient-rich vegetable. This approach of incorporating milk as phytochemical carrier can also be applied while preparing other *halwas,* such as beetroot,cereal and moong pulse halwa, offering similar benefits in terms of improved bioavailability and enhanced nutritional profiles.

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