The Pharma Innovation Journal 2023; 12(8): 419-426

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2023; 12(8): 419-426

www.thepharmajournal.com
Received: 19-05-2023
Accepted: 22-06-2023

Prodip Mondal
Department of Food Technology And Nutrition, School of Agriculture, Lovely Professional University, Punjab, India

Corresponding Author:
Prodip Mondal
Department of Food Technology And Nutrition, School of Agriculture, Lovely Professional University, Punjab, India

Utilization of onion peel as a functional food

Prodip Mondal

Abstract
The utilization of onion peel as a functional food has gained significant attention in recent years due to its rich composition of bioactive compounds and potential health benefits. Traditionally considered as waste, onion peel contains various phytochemicals such as flavonoids, phenolic acids, and quercetin, which exhibit potent antioxidant, anti-inflammatory, and antimicrobial properties. These bioactive compounds have shown promising effects in the prevention and management of several chronic diseases, including cardiovascular diseases, diabetes, and certain types of cancer.

This abstract presents an overview of the current research on the utilization of onion peel as a functional food. It highlights the extraction methods employed to isolate the bioactive compounds from onion peel and discusses their biological activities. The antioxidant capacity of onion peel extracts has been demonstrated through various *in vitro* and *in vivo* studies, showcasing their ability to scavenge free radicals and reduce oxidative stress. Additionally, the anti-inflammatory properties of onion peel have been linked to the modulation of inflammatory pathways and the inhibition of pro-inflammatory enzymes.

Furthermore, onion peel extracts have shown potential in managing diabetes by reducing blood glucose levels, improving insulin sensitivity, and inhibiting carbohydrate-digesting enzymes. The anti-cancer properties of onion peel compounds have been investigated in numerous studies, revealing their ability to inhibit tumor growth, induce apoptosis, and prevent metastasis. These findings suggest that onion peel can be incorporated into functional foods or dietary supplements to provide health benefits beyond basic nutrition.

Keywords: Antioxidants, functional food, onion peel

Introduction

Consumption of and demand for nutraceuticals and functional foods have increased as a result of consumer education about nutrition and health. As a result, the creation of functional foods, designer foods, and nutraceuticals is a top priority for researchers and the food industry, making it a burgeoning topic of study (AlAli *et al*., 2021; Gawlik-Dziki *et al*., 2013) [1, 23,]. Researchers are investigating various novel natural plant-based ingredients, such as by-products of fruit and vegetable processing, such as skin, pomace, seeds, and trimmings, as they are densely packed with bioactive compounds, phytochemicals, antioxidants, and nutrients and are easily accessible and affordable (Chernukha *et al*., 2021; Fidelis *et al*., 2019; Katsampa *et al*., 2015) [14, 21, 28]. These ingredients are also readily available and economical.

Onion (*Allium cepa* L.) is a crop that is grown all over the world for its medicinal and functional benefits in addition to being used for basic human consumption (Aslam *et al.*, 2022) [5]. Due to behavioural changes that led to higher demand for freshly cut and prepared veggies (onion), more waste has been produced globally, which has led to a 25% increase in onion production. Onion manufacturing waste primarily consists of undersized, roots, and malformed bulbs or skin (peel) (Sagar *et al*., 2020) [43], which has two outermost leathery layers. More than 500,000 t of onion peel are produced in Europe each year, but 300–500 kg are produced daily in India. This peel decomposes in soil, harming the environment and producing odours (Das *et al*., 2015) [17]. Is still an underutilised product even though it may be a source of biologically active ingredients including phenols and flavonoids (kumar *et al*., 2022) [30]. Peel also has a variety of medicinal effects and has antioxidant, antibacterial, and antimutagenic properties (Kumari *et al*., 2022) [30]. Alkyl cysteine sulfoxides and flavonoids are two major chemical groups represented in abundance in the multilayer tissue of onion bulbs. The first category of molecules gives onions their characteristic flavour and scent, therefore the unique flavours found in the various types are due to these molecules (Celano *et al*., 2021) [13]. Although many other types of food waste are used as animal feed, it has been discovered that onions can hurt animals. Using onion waste as a component of food items may be useful due to its high fibre content and good bioactivity

(Krikin *et al*., 2021) [29]. To create health advantages or extend the shelf life of the product, onion peel has been added to a variety of food products, including gluten-free bread, wheat bread, and beef patties (Bednricek *et al*., 2020) [6]. The addition of onion to salads reduces glycemia and other satiety issues, avoids spontaneous preterm birth, and lowers LDL cholesterol (Upadhyay *et al*., 2016) [51].

Due to the presence of trace elements like zinc and its reputation as one of the top sources of vitamin B6, onions are deemed to be a nutritious food item (Yang *et al*., 2004) [56]. By inhibiting the production of fatty acids (FAs), onion extracts, which are naturally antibacterial and destroy enterotoxigenic bacteria, demonstrate suppressive effects on the growth of malignant cell lines and adipogenesis. These extracts have also been shown to enhance fat content in streptozotocin-induced diabetic mice and ameliorate insulin resistance and hyperglycemia in diet (Islam *et al*., 2008) [26].

One of the key components used in Indian cookery is onion (*Allium cepa* L). After tomatoes, it is considered to be the second-most significant horticultural crop (Celano *et al*., 2021) [13]. Onions are an important export commodity in India, contributing to foreign earnings. Global onion production is on the rise, with China and India being key players. In 2019, worldwide onion production reached 65,430,064 tonnes, as reported by FAOSTAT. The processing of onions generates a significant amount of byproducts, particularly onion peel and skin, which pose environmental challenges when disposed of. However, onion peels and skins are rich in bioactive compounds such as polyphenols and flavonoids, making them potential functional additives. The composition of onion peel and skin varies based on factors like onion variety, agricultural conditions, and extraction methods. Generally, onion waste, including peel and skin, is a valuable source of total phenolic compounds (TPCs) ranging from 19.7 to 415 mg GAE (gallic acid equivalent)/g and flavonoids ranging from 10.6 to 183.95 mg QE (quercetin equivalent)/g. Quercetin and its derivatives are the primary components contributing to their antioxidant activities. Various studies have highlighted the antioxidant properties and potential applications of onion waste (Benitez *et al*., 2011; Burri *et al*., 2017; Celano *et al*., 2021) [11, 13]. Major phenolic components from onion peel were found by Pucciarini *et al*. (2019) [41], Katsampa *et al*. (2015) [28], Lee *et al*. (2014) [32], Milea *et al*. (2019) [35], and Nile *et al*. (2021) [37] as protocatechuic acid glucoside, protocatechuic acid, vanillic acid, quercetin 7,4′-diglucoside, and quercetin 3,4′-diglucoside. Pedunculagin, casuarictin, norbergenin, 1,2,3,4,6-pentaO-galloyl-d-glucopyranoside, arecatannin, and laevigating were flavonoids found in onion peel, as well as phenolic acids, polyphenols, tellimagrandin II, and stilbenes (4,4′, 5,6-tetrahydroxystilbene) in another study (Sukor *et al*., 2021) [51] revealed the presence of flavonoids, including isorhamnetin, kaempferol, quercetin 3,4′-diglucoside, quercetin aglycone, and quercetin 4′-monoglucoside. Our earlier review work (Kumar *et al*., 2022) [30] contains comprehensive information about the chemical make-up of onion peel.

Nutritional Profile of Onion peel

8.3–15.6% dm (dry matter) of protein, 88.5–86% dm (dry matter) of carbs, and 169–750 mg/g dm (dry matter) of dietary fibre are all present in onion trash. Along with these nutrients, the peel is a good source of total phenolics (9.4-52.7 mg gallic acid equivalent (GAE)/g dm), calcium (1.8-16.5 mg/g), potassium (11.1-15.9 mg/g), magnesium (0.6-1.5 mg/g), manganese (0.0065-0.0288 g/g), iron (0.0196-0.8889 mg/g), selenium (0.00003-0.00093 g/g), and flavonoids shabir *et al*., (2022) [45].

Onion's outer scales are made up of 66.12% of carbs, 8.06% of ash, 15.13% of crude fat, 2.64% of crude protein, and 26.84% of crude fibre. The fatty acid profile is primarily composed of 0.94% of lauric acid, 1.28% of myristic acid, 9.8% of palmitic acid, 2.84% of palmitoleic acid, 17.57% of oleic acid, 8.81% of stearic acid, 2.88% of linolenic acid, 52.87% of linoleic acid, 1.23% of behenic acid, 0.59% of arachidic acid, 0.63% of erucic acid, and 0.54% of lignoceric acid, demonstrating that the total USFA was 76.79% and total SFA content was 21.42%. However, the pearl onion had the second-highest concentration of flavonoids (19.64 mg/g), followed by the red onion cultivar (20.22 mg/g), while the white onion had the lowest concentration (0.08 mg/g) Kumar *et al*., (2022) [30].

Table 1: nutritional profile of onion peel according to shabir and kumar *et al*., (2022) [30]

Sr.no	Nutrient	Dry matter(dm) Range
1	Protein	8.3-15.6% dm
2	Carbohydrates	86-88.5% dm
3	Dietary Fiber	169-750 mg/g dm
4	Total phenolics	9.4-52.7 mg GAE/g dm
5	Calcium	1.8-16.5 mg/g
6	Potassium	11.1-15.9 mg/g
7	Magnesium	0.6-1.5 mg/g
8	Manganese	0.0065-0.0288 g/g
9	Iron	0.0196- 0.889 g/g

Bioactive compounds of onion peel

Because anthocyanins are present in onion peel, it can be utilised as a natural colourant in foods ranging from orange to red and purple to blue. In comparison to synthetic colourants, the use of these natural food colorings is expanding because they are nontoxic mutagens, have a variety of therapeutic benefits, improve capillary blood vessel integrity, and inhibit thrombosis, which lowers the risk of circulatory disease (Ali *et al*., 2016) [2].

According to Celano *et al*. (2021) [13], onion bulbs are considered to be a valuable source of bioactive substances, particularly flavonoids. Additionally, the phytonutrients found in the outer layer of onions have the potential to be studied for their long-term applications in "green" pest control within agriculture, the creation of intelligent packaging, and the production of biologically active components. Consequently, the diverse applications of onion scraps have the potential to aid in the advancement of straightforward, economical, and efficient techniques for reducing food waste. Bisphenol and its derivatives, which have a variety of biological activities including anticancer, antiviral (human immunodeficiency virus), antipyretic, and antibacterial characteristics, are made from onion skin ash water extract. The use of onion peel waste in organic synthesis, which reduces the environmental impact of the waste by using it, has increased its popularity (Aslam *et al*., 2022) [5]. It has been shown that quercetin has the power to encourage L6 myotubes to eat when they are under oxidative stress. The effects on mouse uterine contractions are effectively suppressed by quercetin and naringenin (Wu *et al*., 2015) [58].

Table 2: Extraction of bioactive compounds from onion peel

Source: variety (region)	Bioactive compounds identified	Extraction Method	Conditions	Mechanisms of action/optimized conditions
Red onion skin	Total phenolic, flavonoids and anthocyanins content	Conventional method	Solvent: 20%, 40%, 60% ethanol. Time: 30, 60, 120, and 240 min. Temperature: 25 °C	Due to its polarity, 80% ethanol required a longer time to extract the bioactive chemicals. Lower ethanol concentrations (20–40%) had higher water content, which may have helped to remove contaminants such carbohydrates (Viera *et al*., 2017) [57].
Orange-colored onion peels (Korea)	Total phenolics and flavonoids	Hot water	Solvent: Distilled water Temperature: 80 °C Time: 3 h	Extraction yield: 8.31% Total phenol: 120.60 mg GAE/g extraction (Lee *et al*., 2014) [32].
Onion peel	Tannic acid	UAE using deep eutectic solvent (DES)	Solvent: Sonication: 700 W, 20 kHz, solid to solvent ratio: 1:10, DES ratio: 1:1(cholinechoride: urea), Duty cycle: 10%, Time of extraction:3 h Temperature: 60 °C	The polyalcohol DES's low viscosity allowed more of the sample matrix to dissolve, improving yield. In addition, DES's polarity was closer to the targeted onion peel extractables, further promoting extraction. UAE uses ultrasounds to disturb plant tissue through sonic cavitation, which when combined with DES improves the extraction of bioactive compounds from onion peel (Sukor *et al*., 2021) [51].
Red onion weste (Sibiu, Romania)	Anthocyanins, Flavonoids and tannins	UAE and conventional extraction	UAE: Solvent: 70% (V/V) ethanol solution Sonication: 150W power and 40 kHz frequency, and 70% ultrasonic amplitude Solid to solvent ratio: 30/1 and 20/1 ratio Time of extraction: 5, 10, 15, 20 and 25 min Temperature: 34.02-58.40 °C Conventional: Solvent: 70% (V/V) ethanol solution Temperature: 40 °C Solid to solvent ratio: 30/1 and 20/1 ratio Time: 30, 60, 90 min	UAE yielded better bioactive compounds than conventional extraction method due to the disruption of the plant cell by the ultrasounds assisting in gaining higher yields (Oancea *et al*., 2020) [20].
Onion peel	Total phenolic compound	UAE	Sonication: 25, 33, and 45 kHz Power: 500 W Time: 1h. and 16 h. Temperature: 25 °C	The disintegration of the plant tissues caused by sonication (25 kHz) increased the extraction yield of phenolic chemical by causing higher cavitation and energy transfer. Longer agitation increased quercetin output by 130% (Filho *et al*., 2021).
Organic-colored onion peels (Korea)	Total phenolics and flavonoids	SWE	Solvent: Distilled water Sample: 1:3- powdered onion peels: DE Temperature: 110 °C and 165 °C Time: 15min Pressure: < 500psi	In SWE, greater temperatures and high pressure are maintained to keep water in its liquid condition. Additionally, this extraction helps to reduce the polarity close to ethanol or methanol, which aids in more effective bioactive extraction (Lee *et al*., 2014) [32].
Organic-colored onion peel (Korea)	Total phenolic compound	Subcritical water extraction (SWE)	Solvent: Distilled water Sample: 1:3- powdered onion peels: diatomaceous earth (DE) Temperature: 110 °C and 165 °C Time: 15 min Pressure: < 500psi	Selected chemicals may be extracted depending on the temperature used. Another advantage is that it is environmentally friendly because it simply uses water as a solvent (Lee *et al*., 2011) [32].
Yellow and red onion peel	Quercetin	SFE	SFE: Pressure: 5700 psi (393bar) Temperature: 40 °C Time: 150 and 156 min	The free quercetin levels obtained were 0.024 g/kg (red onion peel) and 0.020 g/kg (yellow onion peel) (Martino & Guyer, 2004) [34].

Antioxidant Activity

Natural antioxidants abound in onions (Sidhu *et al*., 2019) [46]. With the use of humic acids in mycorrhizal inoculate at higher ambient CO_2 levels, the antioxidant capabilities and phenolic content in the onion bulb are also improved (Bettoni *et al*., 2017) [10]. It has been demonstrated that cultivating duration and density, as well as the appropriateness and bioavailability of antioxidant activity and total phenolics of the floral shoot of the second-year onion resprout, have an impact on the antioxidant components of onion seeds Amalfitano *et al*.,

(2019) [4], Zudaire *et al*., (2017) [57]. After being rinsed with a mixture of citric acid and nisin then sprouted, fresh-cut onions' TPC (total phenolic content), TFC (total flavonoid content), and antioxidant capacity all increased (Vasipalli *et al*., 2020) [53]. Investigated was how food processing techniques such freezing, drying, sautéing, heating, and high-pressure processing affected the antioxidant capacity of onions (Fernandez-Jalao *et al*., 2017) [20]. According to Socol *et al*. (2022) [49], stir-frying onions did not affect their antioxidant capacity. However, heating and freezing onions were found to impair their antioxidant capacity. The study also discovered that the inclusion of onion extract (O.E.) in the diet of African catfish and grill chickens enhanced their ability to produce antioxidant enzymes. Furthermore, a combination of onion peel powder (OPP) and pawpaw seeds also improved antioxidant enzyme production. In a separate experiment, it was observed that consuming 100 mL of onion juice daily for eight weeks resulted in a decrease in superoxide and total free radicals, while glutathione levels and overall antioxidant content increased in healthy individuals. In their study, Compaore *et al*. (2017) [15] introduced a new approach called reaction engineering to create a mechanistic model for the drying process of onions into thin layers (REA). Drying tests were conducted in a laboratory dryer to estimate the activation energy. The observed activation energy was represented by a single polynomial function, which accounted for different product moisture contents and temperatures. This function effectively captured the energy-related characteristics of the drying process, as suggested by the model. The developed model was then validated by simulating moisture content profiles and comparing them to experimental data after appropriate statistical parameter matching. This technology enables the modeling and determination of the internal properties of onions, paving the way for future research utilizing on-site solar dryers.

Application of onion peel as a functional food

Bakery products

All age groups want to consume bakery goods, yet these goods are merely high in calories and lack nutrition. These bakery goods' nutritional profiles can be improved by adding natural antioxidants. In this vein, numerous studies are attempting to incorporate plant-based antioxidants in baked goods. With an overall acceptance score of 7.7 on a 9-point hedonic scale, Gawlik-Dziki *et al*. (2013) [23] determined that substituting wheat flour with 3% crushed onion skin in bread was sensorially acceptable. Additionally, the inclusion of onion peel at a rate of 2-3% considerably boosted the antioxidant content of bread samples. Piechowiak *et al*. (2020) [40] added dried onion skin extract to bread at doses of 0.1, 0.25, and 0.5%. Additionally, they claimed that the presence of phenols in onion skin contributed to the rise in bread's antioxidant activity when onion skin extracts were added. The antioxidant activity was increased seven-fold (CUPric reducing antioxidant capacity: 200 mg Trolox/100 g) and the total phenolic content was increased by four-fold (80 mg/100 g) when onion skin extracts (at 0.5%) were added to breads in comparison to the control (total phenolics: 20 mg/100 g; CUPric reducing antioxidant capacity: 30 mg Trolox/100 g).

In a study by Elsebaie and Essa (2018) [19], the onion peel fraction was microencapsulated using different methods (maltodextrin, soy protein isolate, or a combination of both). Cakes were prepared with microencapsulated onion powder or onion peel extract. The cakes made with encapsulated powder showed higher moisture absorption (117.22-120.05%) compared to those made with onion peel extract (113.28%). Additionally, the encapsulated powder resulted in increased phenolic stability, with soy protein isolate (SPI) encapsulation showing the highest values (88.40%), followed by maltodextrin (MD) (86.30%), SPI+MD (86.10%), and onion peel extract (51.30%). The overall acceptability rating for all cakes was high (8 to 9), except for cakes made with onion peel extract, which scored below 8. The best SPI encapsulation received the highest overall acceptance rating of 8.78 out of 9. Thus, to preserve the phenolic qualities, it is recommended to encapsulate onion peel extract before using it in baked goods. Bednricek, Jirotková, *et al*. (2020) [6] reported the utilization of onion waste in gluten-free bread. Onion peel-enriched bread contained various quercetin glycosides, dimers, and trimers. The bread samples showed high amounts of quercetin-3,4′-O-diglucoside, rutin, quercetin-4′-O-glucoside, and quercetin. The bread also exhibited significant antioxidant activity with DPPH and FRAP values, along with a notable total phenolic content. On a 5-point hedonic scale, the overall acceptability of the onion peel-enriched bread was rated at 3. Moreover, when given as supplements to 14 healthy volunteers, the bread samples resulted in increased antioxidant activity in their blood samples. In multigrain bread, the inclusion of onion skin powder (14%) acted as a natural preservative. Adding 4% onion skin powder improved the antioxidant activity, measured by DPPH (53.1%), ABTS (39.4%), and FRAP (38.8 mol GAE/g). Incorporating up to 3% onion skin did not affect sensory acceptance. Shelf-life studies revealed that bread fortified with 34% onion skin powder, stored at 4 °C, remained fresh until day 11, while control loaves began to spoil at that point. After 13 days, bread enriched with 4% onion skin powder showed microbial growth of 3.3 102 cfu/g (bacterial count) and 5.2 104 cfu/g (fungal count), compared to 1.8 102 cfu/g (bacterial count) and 5.6 104 cfu/g (fungal count) after 11 days at room temperature. Consequently, bread with added onion skin powder has a shelf life of up to 11 days at room temperature and 13 days under refrigeration (Sagar & Pareek, 2021) [43].

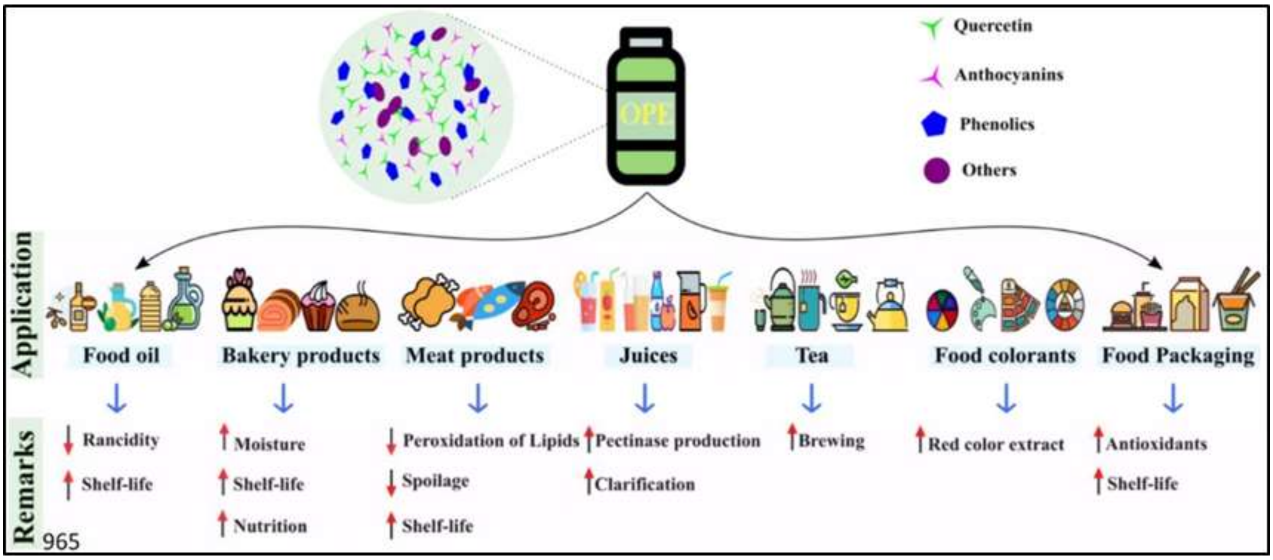

Fig 1: Application of onion peel extracts as functional ingredients in foods

Preparation of pasta and noodles

When studying wheat pasta production, Michalak-Majewska *et al*. (2020) [37] examined the effects of incorporating onion skin powder (OSP) at different levels (0%, 2.5%, 5%, and 7.5%). Both raw and cooked pasta samples were evaluated. The results revealed that adding 7.5% OSP to uncooked pasta significantly increased the total dietary fiber (TDF) content from 4.73% (control) to 10.42%. Similarly, cooked pasta exhibited higher TDF levels with increasing OSP concentrations (11.23%), while the control pasta had a lower TDF content (4.92%). Furthermore, the addition of OSP enhanced the total phenol and flavonoid contents in both raw and cooked pasta compared to the control (total phenol - raw: 0.5 mg GAE/g dm; cooked: 0.25 mg GAE/g dm and flavonoids - raw: 0.1 mg QE/g dm; cooked: 0.11 mg QE/g dm). This indicates that OSP improved the antioxidant capacity of both raw and cooked pasta. The composition of raw onion skin powder, which contained 62.07% TDF, 34.73 mg GAE/g dm total phenol, and 41.81 mg QE/g dm flavonoids, was attributed to these effects. The antioxidant activity measured using DPPH and FRAP assays was found to be 131.53 mm TE/g dm and 274.74 mm TE/g dm, respectively. In the sensory evaluation conducted by 19 trained participants using a 9-point hedonic scale, the qualities of uncooked pasta, such as color, odor, and overall acceptability, declined as the OSP concentration increased compared to the control. Similarly, sensory characteristics of cooked pasta, including color, odor, taste, hardness, adhesiveness, springiness, and overall quality, significantly decreased with higher OSP concentrations. The aftertaste and darker color associated with OSP were identified as the cause of the decline in sensory scores. Overall, the findings suggested that a 2.5% OSP inclusion level was preferable over 5% and 7.5% OSP incorporation.

A previous study conducted by Sayed *et al*. (2014) [28] investigated the fortification of dried and fried noodles using OSP (2, 4, 6%). The researchers found that the addition of OSP led to changes in the nutritional composition of the noodles. Both the protein and carbohydrate contents decreased, while the dietary fiber content increased in both dried and fried noodles after OSP fortification. Furthermore, the mineral content, including iron, calcium, zinc, magnesium, sodium, potassium, copper, and manganese, was higher in OSP-fortified noodles compared to the control. The study also observed significant improvements in total phenolic compounds (TPCs) and flavonoids with the addition of 6% OSP. The control noodles had lower levels of total phenolics and flavonoids compared to the OSP-fortified samples. The researchers attributed these enhancements in phenolics, flavonoids, minerals, and dietary fiber to the composition of OSP used in the study (Sayed *et al*., 2014) [28].

Oxidative stability of oil

During food processing and storage, lipid oxidation can occur, leading to the degradation of oils and making them unsuitable for consumption due to the development of unpleasant flavors, aromas, and tastes. Antioxidants play a crucial role in enhancing the stability of oils. The food industry is actively seeking natural alternatives to synthetic antioxidants. Several studies have investigated the antioxidant properties of extracts derived from natural sources such as seeds, peels, and agroindustrial by-products like spices (Guo *et al*., 2016; Umeda & Jorge, 2021) [24, 55].

In a study conducted by Umeda and Jorge (2021) [55], the effects of purple onion peel extract on the oxidative stability of soybean oil were evaluated during accelerated storage at 60 °C for 21 days. Two different concentrations (100 and 200 mg/kg oil) of purple onion peel extract were used. The results showed that soybean oil treated with purple onion peel extract had a lower peroxide index (7.56 meq/kg) compared to the control soybean oil (10.56 meq/kg). The peroxide index of the treated oil remained below the legal limit of 10 meq/kg, indicating a reduction in peroxide formation during the seventh day of accelerated storage. Although the effectiveness of purple onion peel extract was lower compared to synthetic tert-butylhydroquinone (TBHQ), it still exhibited the ability to prevent oxidation of the soybean oil (Umeda & Jorge, 2021) [55].

Tea from onion peel

In recent research, it has been discovered that tea can be extracted from onion peel. Conducted a study to determine the optimal brewing parameters for onion peel tea. They found that using 0.5 g of onion peel and 160.82 ml of water, the ideal brewing duration was 180 minutes. Further analysis revealed that onion peel tea contains three main ingredients: protocatechuic acid, isoquercetin, and quercetin. Matsunaga *et* *al*. (2013) [38] investigated the potential health benefits of onion peel tea. In their study, they supplemented the diets of obese male rats with 5% onion peel tea containing 1.15 mg/g of quercetin. The results showed that the rats on high-fat diets and given the onion peel tea had lower levels of serum total cholesterol, glucose, and leptin compared to the control group. This suggests that the tea exhibits anti-obesity effects. Overall, these findings demonstrate that onion peel tea, with its bioactive components such as quercetin, has the potential to offer health benefits, particularly in managing obesity-related markers.

Juice clarification

Six fungi (*Aspergillus niger*, *Penicillium loliense*, *Trichoderma harzianum*, *Trichoderma longibrachiatum*, *Trichoderma viride*, and *Ulocladium botrytis*) were examined for pectinase productivity at different culture ages (4 and 7 days) using only onion skin as the carbon source. Pectinase was produced by all *T. virides* after 4 days (0.334 U/mg culture filtrate). When the onion skins were prepared by skin milling, followed by treatments with sodium chlorite and glacial acetic acid, the productivity of pectinase was at its highest. According to the scientists (Ismail *et al*., 2016) [26], fungal pectinase can be produced using onion peel as a substrate.

Meat products

Lipid peroxidation is a significant challenge in the meat industry as it causes detrimental changes in flavor, taste, color, and texture during storage. Shim *et al*. (2012) [59] conducted a study on the antioxidant potential of onion peel extract (OPE) in inhibiting lipid peroxidation in raw ground pork. The researchers treated the pork with OPE at different concentrations (0.05%, 0.1%, and 0.2%) and compared it to a control group and pork treated with ascorbic acid (0.05%) over a 16-day refrigerated storage period (4°C). The results showed that OPE-treated pork had significantly lower TBARS (thiobarbituric acid reactive substances) values after 16 days compared to the control group. The TBARS value for OPE-treated pork ranged from 0.5 to 0.58 mg malondialdehyde/kg meat, while the control group had a TBARS value of 0.95 mg malondialdehyde/kg meat. This indicates that OPE effectively reduced lipid peroxidation and protected the pork from developing rancid flavors during storage. Additionally, the peroxide values demonstrated a retardation in lipid peroxidation with the addition of OPE, further highlighting its antioxidant properties in preserving meat quality.

The shelf-life and sensory palatability of mechanically separated fish flesh sausages were enhanced by using onion peel powder (1, 2, and 3%) for 28 days. Due to greater TPP values, it was shown that 3% onion peel powder sausages had considerably stronger antioxidant activity in terms of FRAP and DPPH compared to the control (kumar *et al*., 2022) [30]. According to Bednricek, Kadlec, *et al*. (2020) [6], after 28 days, lipid peroxidation decreased with increasing onion peel powder concentrations (1%: 0.30; 2%: 0.21; and 3%: 0.21 g MDA/g fw) in comparison to the control (0.71 g MDA/g fw). However, the addition of 1-2% onion peel powder improved the sensory palatability. Accordingly, adding up to 2% of onion peel powder can help sausages stay fresh for up to 28 days (Bednricek, Kadlec, *et al*., 2020) [6].

Uçak *et al*. (2019) [50] recommended the use of onion peel extract (OPE) to extend the shelf life of rainbow trout fish fillets. Adding OPE at levels of 2.5%, 5%, and 10% to gelatin films used to cover the fillets resulted in lower peroxide values (PV) and TBARS (thiobarbituric acid reactive substances) values after 16 days of storage at 4°C. The fish covered with gelatin films containing OPE exhibited reduced microbial growth for yeast and mould, total mesophilic, psychrophilic bacteria, and enterobacteria compared to the control group without any covering. The antioxidant qualities of OPE were attributed to its ability to prevent lipid peroxidation in meat and meat products. This suggests that onion peel can be utilized as a preservative to prevent lipid peroxidation and enhance the quality and shelf life of meat products.

Conclusion

Onion peel or skin is rich in phytochemicals, total phenolics, flavonoids, vitamins, quercetin, and other quercetin-rich compounds, which contribute to its exceptional antioxidant properties. This makes onion peel a valuable source of bioactive compounds with potential applications as functional ingredients in tea extraction and the enrichment of various food products, including pasta, noodles, and baked goods. However, further research is needed to develop fortified products incorporating onion peel powder or extracts without compromising the sensory attributes of the final products. In addition to its antioxidant properties, onion peels contain pigments that contribute to their red, yellow, brown, and white skin colors. These pigments can be extracted and utilized as natural colorants in the food industry, as well as in other sectors such as cosmetics and fabric dyes. However, extensive research efforts are necessary to explore and validate these potential applications of onion peel at an industrial scale before they can be successfully commercialized and implemented.

Conflict of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

1. Al Ali M, Alqubaisy M, Aljaafari MN, AlAli AO, Baqais L, Molouki A, *et al*. Nutraceuticals: Transformation of conventional foods into health promoters/disease preventers and safety considerations. Molecules (Basel, Switzerland). 2021;26:2540.
2. Ali Alam MS, Pandiselvam R. Aqueous ozone sanitization system for fresh produce: Design, development, and optimization of process parameters for minimally processed onion. Ozone: Science & Engineering. 2022;44(1):3-16.
3. Altemimi A, Lakhssassi N, Baharlouei A, Watson DG, Lightfoot DA. Phytochemicals: Extraction, isolation, and identification of bioactive compounds from plant extracts. Plants (Basel, Switzerland). 2017;6(4):42.
4. Amalfitano C, Golubkina NA, Del Vacchio L, Russo G, Cannoniero M, Somma S, *et al*. Yield, antioxidant components, oil content, and composition of onion seeds are influenced by planting time and density. Plants. 2019;8(8):293.
5. Aslam R, Alam MS, Pandiselvam R. Aqueous ozone sanitization system for fresh produce: Design, development, and optimization of process parameters for minimally processed onion. Ozone: Science & Engineering. 2022;44(1):3-16.
6. Bedrníček J, Jirotková D, Kadlec J, Laknerová I,

Vrchotová N, Tříska J, *et al*. Thermal stability and bioavailability of bioactive compounds after baking of bread enriched with different onion by-products. Food Chemistry; c2020. p.126562.
7. Bedrníče J, Kadlec J, Laknerová I, Mráz J, Samková E, Petrášková E. Onion peel powder as an antioxidant-rich material for sausages prepared from mechanically separated fish meat. Antioxidants. 2020;9(10):974.
8. Benítez V, Mollá E, Martín-Cabrejas MA, Aguilera Y, López-Andréu FJ, Cools K, *et al*. Characterization of industrial onion wastes (*Allium cepa* L.): dietary fibre and bioactive compounds. Plant Foods for Human Nutrition. 2011;66(1):48-57.
9. Benito-Román Ó, Blanco B, Sanz MT, Beltrán S. Subcritical water extraction of phenolic compounds from onion skin wastes (*Allium cepa* cv. Horcal): Effect of temperature and solvent properties. Antioxidants. 2020;9(12):1233.
10. Bettoni MM, Mogor ÁF, Pauletti V, Goicoechea N. The interaction between mycorrhizal inoculation, humic acids supply and elevated atmospheric CO_2 increases energetic and antioxidant properties and sweetness of yellow onion. Horticulture, Environment, and Biotechnology. 2017;58:432-440.
11. Burri SCM, Ekholm A, Håkansson Å, Eva T, Kimmo R. Antioxidant capacity and major phenol compounds of horticultural plant materials not usually used. Journal of Functional Foods. 2017;38:119-127.
12. Campone L, Celano R, Piccinelli AL, Pagano I, Carabetta S, *et al*. Response surface methodology to optimize supercritical carbon dioxide/co-solvent extraction of brown onion skin by-product as source of nutraceutical compounds. Food Chemistry. 2018;269:495-502.
13. Celano R, Docimo T, Piccinelli AL, Gazzerro P, Tucci M, *et al*. Onion peel: Turning a food waste into a resource. Antioxidants. 2021;10(2):304.
14. Chernukha I, Fedulova L, Vasilevskaya E, Kulikovskii A, Kupaeva N, Kotenkova E. Antioxidant effect of ethanolic onion (*Allium cepa*) husk extract in ageing rats. Saudi Journal of Biological Sciences. 2021;28(5):2877-2885.
15. Compaore A, Dissa AO, Rogaume Y, Putranto A, Chen, XD, *et al*. Application of the reaction engineering approach (REA) for modeling of the convective drying of onion. Drying Technology. 2017;35(4):500-508.
16. Constantin OE, Milea AS, Bolea C, Mihalcea L, Enachi E, Copolovici D, Copolovici L, *et al*. Onion (*Allium cepa* L.) peel extracts characterization by conventional and modern methods. International Journal of Food Engineering. 2020;17(6):485-493.
17. Das S, Mandal SC. Effect of process parameters of microwave assisted extraction (MAE) on natural product yield from onion peel. International Journal of Pharmaceutical Sciences and Research. 2015;6(8):3260.
18. Devani BM, Jani BL, Balani PC, Akbari SH. Optimization of supercritical Co_2 extraction process for oleoresin from rotten onion waste. Food and Bioproducts Processing, 2020;119:287-295.
19. Elsebaie EM, Essa RY. Microencapsulation of red onion peel polyphenols fractions by freeze drying technicality and its application in cake. Journal of Food Processing and Preservation. 2018;42:e13654.
20. Fernández-Jalao I, Sánchez-Moreno C, De Ancos B. Influence of food matrix and high-pressure processing on onion flavonols and antioxidant activity during gastrointestinal digestion. Journal of Food Engineering. 2017;213:60-68.
21. Fidelis M, de Moura C, Kabbas Junior T, Pap N, Mattila P, Mäkinen S, *et al*. Fruit seeds as sources of bioactive compounds: sustainable production of high value-added ingredients from by-products within circular economy. Molecules (Basel, Switzerland). 2019;24(21): 3854.
22. Gawlik-Dziki U, Świeca M, Dziki D, Baraniak B, Tomiło Czyż J. Quality and antioxidant properties of breads enriched with dry onion (*Allium cepa* L.) skin. Food Chemistry. 2013;138(2-3):1621-1628.
23. Gois Ruivo da Silva M, Skrt M, Komes D, Poklar Ulrih N, Pogačnik L. Enhanced yield of bioactivities from onion (*Allium cepa* L.) skin and their antioxidant and anti-α-amylase activities. International Journal of Molecular Sciences. 2020;21(8):2909.
24. Guo Q, Gao S, Sun Y, Gao Y, Wang X, Zhang Z. Antioxidant efficacy of rosemary ethanol extract in palm oil during frying and accelerated storage. Industrial Crops and Products. 2016;94:82-88
25. Ifesan BOT. Chemical composition of onion peel (*Allium cepa*) and its ability to serve as a preservative in cooked beef. International Journal of Science and Research Methodology; c2017.
26. Ismail AMS, Abo-Elmagd HI, Housseiny MM. A safe potential juice clarifying pectinase from i EF-8 utilizing Egyptian onion skins. Journal of Genetic Engineering and Biotechnology. 2016;14(1):153-159. https://doi.org/10.1016/j.jgeb.2016. 05.001
27. Jin EY, Lim S, Kim SO, Park YS, Jang JK, Chung MS, *et al*. Optimization of various extraction methods for quercetin from onion skin using response surface methodology. Food Science and Biotechnology. 2011;20:1727-1733.
28. Katsampa P, Valsamedou E, Grigorakis S, Makris DP. A green ultrasound-assisted extraction process for the recovery of antioxidant polyphenols and pigments from onion solid wastes using Box–Behnken experimental design and kinetics. Industrial Crops and Products. 2015;77:535-543.
29. Kirkin C, Çinar M, Derindere B, Erikman K, Onural N. Sensory Properties of Chocolate Truffles and Peanut Butter as Affected by Onion Skin Powder Addition. Journal of Tourism & Gastronomy Studies. 2021;9(3):1547-1553.
30. Kumar M, Barbhai MD, Hasan M, Punia S, Dhumal S, Rais N, *et al*. Onion (*Allium cepa* L.) peels: A review on bioactive compounds and biomedical activities. Biomedicine & Pharmacotherapy. 2022;146:112498.
31. Kumari N, Kumar M, Lorenzo JM, Sharma D, Puri S, Pundir A, *et al*. Onion and garlic polysaccharides: A review on extraction, characterization, bioactivity, and modifications. International Journal of Biological Macromolecules; c2022.
32. Lee KA, Kim KT, Kim HJ, Chung MS, Chang PS, Park H, *et al*. Antioxidant activities of onion (*Allium cepa* L.) peel extracts produced by ethanol, hot water, and subcrit-ical water extraction. Food Science and Biotechnology. 2014;23:615-621.
33. Lee KA, Kim KT, Nah SY, Chung MS, Cho SW, Paik HD. Antimicrobial and antioxidative effects of onion peel

extracted by the subcritical water. Food Science and Biotechnology. 2011;20:543-548.
34. Martino KG, Guyer D. Supercritical fluid extraction of quercetin from onion skins. Journal of Food Process Engineering. 2004;27(1):17-28.
35. Milea SA, Aprodu I, Vasile AM, Barbu V, Râpeanu G, *et al*. Widen the functionality of flavonoids from yellow onion skins through extraction and microencapsulation in whey proteins hydrolysates and different polymers. Journal of Food Engineering. 2019;251:29-35.
36. Munir MT, Kheirkhah H, Baroutian S, Quek SY, Young BR. Subcritical water extraction of bioactive compounds from waste onion skin. Journal of Cleaner Production. 2018;183:487-494.
37. Michalak-Majewska M, Teterycz D, Muszyński S, Radzki W, Sykut-Domańska E. Influence of onion skin powder on nutritional and quality attributes of wheat pasta. PLoS One. 2020;15(1):e0227942.
38. Matsunaga S, Azuma K, Watanabe M, Tsuka T, Imagawa T, Osaki T, Okamoto Y. Onion peel tea ameliorates obesity and affects blood parameters in a mouse model of high-fat-dietinduced obesity. Experimental and Therapeutic Medicine. 2013;7(2):379-382. https://doi.org/10.3892/etm.2013.1433
39. Nile A, Gansukh E, Park GS, Kim DH, Hariram Nile S. Novel insights on the multi-functional properties of flavonol glucosides from red onion (*Allium cepa* L) solid waste *In vitro* and in silico approach. Food Chemistry. 2021;335:127650.
40. OH, Al-sayed H, Yasin N, Afifi E. Effect of different extraction methods on stablity of anthocyanins extracted from red onion peels (*Allium cepa*) and its uses as food colorants. Bulletin of the National Nutrition Institute of the Arab Republic of Egypt. 2016;47(2):1-24.
41. Oancea S, Radu M, Olosutean H. Development of ultra-sonic extracts with strong antioxidant properties from red onion wastes. Romanian Biotechnological Letters. 2020;25(2):1320-132.
42. Piechowiak T, Grzelak-Błaszczyk K, Bonikowski R, Balawejder M. Optimization of extraction process of antioxidant compounds from yellow onion skin and their use in functional bread production. LWT-Food Science and Technology; c2020. p.117.
43. Pucciarini L, Ianni F, Petesse V, Pellati F, Brighenti V, Volpi C, *et al*. Onion (*Allium cepa* L.) skin: A rich resource of biomolecules for the sustainable production of colored biofunctional textiles. Molecules (Basel, Switzerland). 2019;24:634.
44. Ren F, Nian Y, Perussello CA. Effect of storage, food processing and novel extraction technologies on onions flavonoid content: A review. Food Research International. 2020;132:108953.
45. Sagar NA, Pareek S. Fortification of multigrain flour with onion skin powder as a natural preservative: Effect on quality and shelf life of the bread. Food Bioscience. 2021;41:100992.
46. Sagar NA, Pareek S, Gonzalez-Aguilar GA. Quantification of flavonoids, total phenols and antioxidant properties of onion skin: A comparative study of fifteen Indian cultivars. Journal of food science and technology. 2020;57:2423-2432.
47. Shabir I, Pandey VK, Dar AH, Pandiselvam R, Manzoor S, *et al*. Nutritional profile, phytochemical compounds, biological activities, and utilisation of onion peel for food applications: a review. Sustainability. 2022;14(19):11958.
48. Sidhu JS, Ali M, Al-Rashdan A, Ahmed N. Onion (*Allium cepa* L.) is potentially a good source of important antioxidants. Journal of food science and technology. 2019;56:1811-1819.
49. Socol CT, Chira A, Martinez-Sanchez MA, Nuñez-Sanchez MA, Maerescu CM, *et al*. Leptin signaling in obesity and colorectal cancer. International Journal of Molecular Sciences. 2022;23(9):4713.
50. Soquetta MB, De Marsillac Terra L, Bastos CP. Green technologies for the extraction of bioactive compounds in fruits and vegetables. CyTA-Journal of Food 2018;16(1):400-412.
51. Sukor NF, Selvam VP, Jusoh R, Kamarudin NS, Rahim AS. Intensified DES mediated ultrasound extraction of tannic acid from onion peel. Journal of Food Engineering. 2021;296:110437.
52. Uçak İ, Yerlikaya P, Khalıly R, Abuibaid A. Effects of gelatin edible films containing onion peel extract on the quality of rainbow trout fillets. Eurasian Journal of Food Science and Technology. 2019;3(2):40-48.
53. Upadhyay RK. Nutraceutical, pharmaceutical and therapeutic uses of *Allium cepa*: A review. International Journal of Green Pharmacy (IJGP). 2016, 10(1).
54. Uwineza PA, Waśkiewicz A. Recent Advances in supercritical fluid extraction of natural bioactive compounds from natural plant materials. Molecules (Basel, Switzerland). 2020;25(17):3847.
55. Umeda WM, Jorge N. Oxidative stability of soybean oil added of purple onion (*Allium cepa* L.) peel extract during accelerated storage conditions. Food Control. 2021;127:108130
56. Vasipalli P, Parihar P, Jain P, Mahajan KC. Study of Various Storage Conditions on the Quality Attributes of Pre-treated Onion Paste. Int. J Curr. Microbiol. App. Sci. 2020;9(4):533-539.
57. Viera VB, Piovesan N, Rodrigues JB, Mello RDO, Prestes RC, Santos RCVD, *et al*. Extraction of phenolic compounds and evaluation of the antioxidant and antimicrobial capacity of red onion skin. (*Allium cepa* L.). International Food Research Journal. 2017;24(3):990-999.
58. Wu CH, Shieh TM, Wang KL, Huang TC, Hsia SM. Quercetin, a main flavonoid in onion, inhibits the PGF2α-induced uterine contraction *in vitro* and *in vivo*. Journal of Functional Foods, 2015;19:495-504.
59. Yang J, Meyers KJ, van der Heide J, Liu RH. Varietal differences in phenolic content and antioxidant and antiproliferative activities of onions. Journal of agricultural and food chemistry. 2004;52(22):6787-6793.
60. Zudaire L, Viñas I, Abadias M, Simó J, Echeverria G, Plaza L *et al*. Quality and bioaccessibility of total phenols and antioxidant activity of calçots (*Allium cepa* L.) stored under controlled atmosphere conditions. Postharvest biology and technology. 2017;129:118-128.
61. Sayed HS, Hassa NMM, El khalek MHA. The effect of using onion skin powder as a source of dietary fiber and antioxidants on properties of dried and fried noodles. Current Science International. 2014;3:468-475.
62. Shim SY, Choi YS, Kim HY, Kim HW, Hwang KE, Song DH, *et al*. Antioxidative properties of onion peel extracts against lipid oxidation in raw ground pork. Food Science and Biotechnology. 2012;21(2):565-572.