Review article

Technological interventions in exploration of underutilized berries for multilevel values

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Receipt: 10.10.2024 *Revised: 25.11.24* *Acceptance: 27.11.24*
DOI: 10.53552/ijmfmap.10.2.2024.1-9

ABSTRACT

Berries are associated with numerous health benefits, potentially addressing a variety of diseases. Polyphenols, particularly anthocyanins, have garnered significant attention in the literature for their health-promoting properties.In vitro studies have shown that anthocyanins and other polyphenols present in berries may have a number of potential anti-cancer and heart disease advantages, including antioxidant, anti-inflammatory, and cell regulatory actions. Berry phenolic compounds can be used as natural antibacterial agents in a variety of applications, including food and medicine. Ozone therapy stimulated a defence mechanism against oxidative damage in blueberry fruit stored at 4°C. Extracts from blueberries significantly decrease skin inflammation and too represent a promising new defence against harm from cutaneous pollution. Because of their advantages in avoiding urinary tract infections, among the berries, cranberries have long attracted attention (UTIs). The ability of those cranberry products tends to prevent UTI and act as a non-antibiotic substitute could significantly impact public health by lowering the overall amount of antibiotics administered for UTI.Such health benefits emphasize the significant potential of berries in functional food and therapeutic applications.

Keywords:Anthocyanin, berries, health benefits,ozone treatment, phenolic compounds.

INTRODUCTION

The production of berries for food processing has been steadily rising, indicating a strong demand for products with added value, especially from consumers who remain health-conscious. Blueberries, raspberries, blackberries, cranberries, and blackcurrants were chosen at a stage that been almost fully ripe in order to maintain their sweetness and appropriate flavour. After all, those berries were processed to create a range of finished or semi-finished products, including puree and juice. These fruits remain as an excellent source for blending because to their intense flavour and colour including their structure makes them simple to juice using either cold or hot pressing.

Like other fruits, berries tend to have a number of vitamins that remain essential for overall health. Ascorbic acid, vitamin C, remain abundant in many berry species, although only a small number of the fruits may meet the recommended daily allowance (RDA) of human. Berries perform good antioxidant activity, making them a clear dietary source of vitamin C which operate as a cofactor in hydroxylation processes that necessary for the production of collagen that play a part in the production of hormones, strengthening immune system, platelet aggregation, thrombus formation, iron absorption and too protect against

osteoporosis, heart disease and several categoriesof cancer. Berries are rich in folic acid, a water-soluble vitamin B, which helps reduce the risk of heart disease and cancer through mechanisms such as reducing homocysteine levels, catalyzing the synthesis of nitric oxide, and preserving DNA integrity. Additionally, folic acid been necessary to prevent malformed neural tubes in newborns (Beattie *et al.*, 2005; Golovinskaia and Wang, 2021).

Underutilized berries

Underutilized berries were those which remain neither grown commercially on large scale nor traded widely. Berries are distinguished by their tiny (5 to 25 mm) pieces with relatively soft flesh, irregular shape and absence of an inner core or peel. Seeds remain small and simple to separate while juicing. These fruits were however readily polluted when grown on or near the ground. The fragile fleshes are also more vulnerable to physical harm and insect attack. The tiny unit size also makes it challenging to identify and remove blemished or defective pieces. Underutilized berries included to bayberries, blueberries, raspberries, cranberries, blackberries, currants, wineberries, barberries, bilberries, gooseberries, cloudberries, huckleberries, and nannyberries. The best natural antioxidants were found in blueberries, which also a great source of fiber, manganese, vitamin C, vitamin K, and vitamin A. These berries can be purchased fresh or processed into dried or infused berries, puree, juice, individually fast frozen (IQF) fruit, or dried fruit. Following that, they may be added to a range of consumer items including jellies, jams, pies, muffins, snack foods, pancakes and morning cereals. Berries also tend to be observed as a potential source of phytochemicals oftenincludes antioxidants, anti-cancer agents, anti-neuro degenerative agents, anti-inflammatory agents. In chronic smokers, blueberry has decreased the oxidative stress biomarkers. For three weeks, consuming one cup of blueberries daily will lower the chance of heart disease, as well as diabetes, eye problems, Alzheimer's disease and cancers of the mouth, breast, colon and prostate as reported by Golovinskaia and Wang (2021); Paredes-López*et al.* (2010).

Reason for being underutilized berries in India

Berries were underutilized in India because they fail to thrive in our climatic conditions, and they require specific chilling hours to flower or fruit. The disease management of these berries have been also difficult since these crops were closely grown to ground which leads to many contaminations. The post-harvest management remain not that easy because they were very much delicate skinned and face lot of bruising damage during transport thatresults several post-harvest loss which ultimately leads to decline in productivity.

Nutrient Composition of underutilized berries

Berries observed to be fortified with numerous sources of essential vitamins, minerals, and dietary fibers. They are high in natural sugars but low in calories and fat. Raspberries, blackberries and blackcurrants provide vitamin C, dietary fiber, potassium and folates. Blueberries have the lowest amount of vitamin C among these berries, while strawberries have the highest ranging from 9.7 to 60 mg/100g. Strawberries, blackberries, and raspberries were theprodigious providers of potassium (Vitamin B9) and folate. Cranberries remain high in vitamin E, while blueberries and blackberries high in vitamin K. Blackberries are rich in antioxidants such as lutein, zeaxanthin, and beta-carotene. Blackcurrants contain the highest levels of calcium, iron, phosphorus, and potassium among those berries (Golovinskaia and Wang, 2021). Bayberry and yellow Himalayan raspberry-based health beverage possess high content of various antioxidants(Hare Krishna and Attri, 2016).

Phytochemicals in Berries

Conjugated anthocyanidinswere the anthocyanins responsible for distinctive and vivid colour palette of dark berries. There are six major anthocyanidins in the plant kingdom: pelargonidin, peonidin, petunidin, delphinidin, cyanidin, and malvidin. Glucose, sophorose, rutinose, rhamnose, galactose, arabinose and xylose were among the sugars with which they form conjugates. Anthocyanin profiles of tissues that recognisable were used in identification of adulteration with juices and wines. The presence of delphinidin, cyanidinrutinosides and glucosidesexpressthe way that distinguishes blackcurrants from other fruits.

The bog whortleberry of *Vacciniumuliginosum*, bilberry of*Vacciniummyrtillus* and elderberries were found to have most quercetin (15.8 mg/100 g) respectively. Myricetin (8.9-20.3 mg/100 g) remain as the most prevalent flavanol in blackcurrant cultivars, followed by quercetin and kaempferol. Different berry species, colour, flavour and potential health benefits can all be influenced by the polyphenol content of the berries. A large family of substances known as polyphenolsranges in structure and potential bioactivity. Berries have a range of colours from red to purple to blue because anthocyanins, a kind of polyphenol pigment been present as reported byKristo and Sikalidis (2022).

Anthocyanins

Natural pigments called anthocyaninsrender many fruits and vegetables their distinctive colours and have several positive health effects on humans and other living things. In addition to other disorders, these anthocyaninswere crucial for the treatment of diabetes, cancer, neurological and cardiovascular diseases. They also have antioxidant, anti-inflammatory and antibacterial characteristics. Blueberries, blackberries and black raspberries contain far greater anthocyanin concentrations than red raspberries, cranberries and blackcurrants which observed to have tremendous therapeutic value (Kristo and Sikalidis, 2022).

The most common berries that contain these compounds includescyanidin, pelargonidin, delphinidin, malvidin, peonidin, and petunidin. When sugars and anthocyanidinsremain mixed, anthocyaninswere created. Several anthocyaninsobserved to be found in urine after berries or berry extract consumption, however at extremely low levels - typically 0.1% or lessof the eaten dosage. Anthocyanin levels in human plasma peak 0.5–1 hour after ingestion and return to baseline within 6–8 hours. Thus, unlike flavanol glycosides, glycosylated anthocyanins can enter the circulation. This may be the case because human small intestine b-glucosidases do not break down quercetinglucosides or anthocyanin glucosides. Improved analytical methods now starting to show the presence of reduced amounts of methylation and sulphated metabolites in urine after consumption, even though historically only unmodified anthocyanins have been detected in urine following supplementation (Kristo and Sikalidis, 2022; Kalt, 2014).

Proanthocyanidins

The finest sources of proanthocyanidins (condensed tannins) remain with those berries such as cranberries, blackcurrants, and blueberries. As the fruit turns from red to black as it ripens, proanthocyanidin concentration fluctuates, peaking but then drastically declining in the last stage. Studies on blackberries revealed that proanthocyanidin and anthocyanin levels vary with development stage. Astringency, sourness, bitterness, sweetness, saliva viscosity, aroma, and colour composition attributed to proanthocyanidins. The PAC level of cranberries and blueberries be extremely high. Cranberries have more PACs than other berries. These remainless blueberries in PAC. PACs have anti-inflammatory,

antibacterial, antiviral, anti-inflammatory, vasodilator, antioxidant and anti-carcinogenic effects (Golovinskaia and Wang, 2021).

Flavanols

Berries include phenolic compounds called flavanols, which include kaempferol, quercetin and myricetin. These compounds have antibacterial, anticancer and antioxidant qualities and help prevent cardiovascular diseases. Quercetin and myricetin remain abundant in blueberries. The primary flavanol in cranberries and black raspberries bequercetin. These berries also contain myricetin glycosides, but in less amounts. Nine quercetin compounds and three kaempferol derivatives included in blackberries. Red raspberries have the anti-oxidants quercetin and kaempferol. Bilberries and bog whortleberries were found to have the highest levels of quercetin (Golovinskaia and Wang, 2021).

Phenolic acid

Antioxidative and anticancer characteristics possessed by the hydroxycinnamic and hydroxybenzoic acids p-coumaric, caffeic, ferulic, and p-hydroxybenzoic, gallic and ellagic. In addition to various phenolic acids, the cranberry peel includes significant amounts of ursolic acid in the aglycone form (of which phydroxycinnamic acid is the most important). Ferulic, caffeic and gallic acids have been found in blueberries. The potent antioxidant chlorogenicacid remains one of the important phenolics found in blueberries. Red raspberries include both hydroxybenzoic acids and hydroxycinnamic acids. Blackberries have a total ellagic acid concentration of 319.7 mg/100 g, according to acid hydrolysis. Ellagic acid contains a variety of biological characteristics, including the ability to neutralise free radicals, stop the development of cancer cells and have anti-inflammatory and antibacterial actions (Golovinskaia and Wang, 2021; Dou *et al*., 2022).

Ellagitannins

A growing body of studies suggests that eating foods high in ellagic acid and ellagitannins may be beneficial to human health. Ellagitanninswere the complex derivatives of ellagic acid as a member of the hydrolyzable tannin family. They have antibacterial, anti-inflammatory, anti-carcinogenic and anti-Helicobacter pylori (*H. pylori*) qualities. Ellagatannins ripe in raspberries and blackberries.Elagitannins are the main hydrolyzable tannins present in blackberries, along with sanguiin H6 and lambertianin. The two main ellagitannins identified in raspberries were C lambertiantrimer and the sanguiin H6 dimer (Golovinskaia and Wang, 2021; Lee, 2017).

Stilbenes

Berries include a particular type of phenolic, non-flavonoid chemicals called stilbenes. Resveratrol been the component in berries were most well-known. The biological and pharmacological characteristics of stilbenesremain diverse and too have positive impacts over human health. These characteristics include antioxidant, anticancer and neuroprotective effects. Berries like blueberries and cranberries contain stilbenes (Golovinskaia and Wang, 2021).

Oxidative stress suppression

High levels of free radical formation tend to oxidative stress, which has been connected to many degenerative diseases and the speeding up of ageing. Berry antioxidants interact with substances that actively scavenge oxygen radicals, including carotenoids, phenolic compounds, and vitamin C. Berries have four times the antioxidant content of other fruits and 10 times the antioxidant content of vegetables. According to studies, blueberries have powerful phenolic components and vitamin C levels were strongly associated with their antioxidant potential. Raspberries have a high level of radical scavenger activity and contain a lot of antioxidants. The primary

antioxidant in raspberries, p-coumaric acid, is present in the freeze-dried aqueous extracts of many raspberry cultivars. Additionally, polyphenols, ellagitannins and anthocyanins shown antioxidant and anti-tumour growth properties. According to studies, anthocyanins and ellagitannins account for 75% of raspberries antioxidant potential. Along with other bioactive components, the two main antioxidants in black raspberries, cyanidin 3-rutinoside and cyanidin 3-xylosylrutinoside have been connected to the prevention and treatment of numerous malignancies which shown positivity in human research (Golovinskaia and Wang, 2021; Kalt, 2014).

Neutraceutical rich fruits	**Nutraceutical factors**
Blue berries, black berries, cranberry, raspberry, black currant	*Flavonoids* (Anthocyanidins): Cyanidin 3-glycosides, Malvidin, Delphinidin, Pelargonidin
Berries and cherries	*Flavanols*: Morin, ProcyanidinsProdelphinidins, Catechin, Epicatechin and their gallates
Berries, currants, cherries	*Anthoxanthins*(Flavonols): Myricetin, Fisetin, Quercetin, Kaempferol, Isorhamnetin
Raspberry, blueberry, cranberry	*Phenolic acids*: Chlorogenic acid, Ferulic acid, p-coumaric acid Ellagic acid, Gallic acid
Raspberries, blackberry	*Tannins*: Catechin, Epicatechin polymers, Ellagitannins, Proanthocyanidins, Tannic acids

Verma*et al*.(2024)

Berries as cancer preventer

Scavenging reactive oxygen species (ROS), which cause oxidative damage to cellular macromolecules like DNA and RNA, be one of the most crucial components of antioxidant activities. Oxidative stress remains one of the primary causes of increased carcinogenicity because it promotes the accumulation of oxidative DNA damage, which aids in the development of tumors. The formation of cancer is typically seen as a microevolutionary process requiring the combined effects of several events, *viz.,* (1) creation of a somatic cell's DNA mutation; (2) encouragement of tumorigenic cell clone multiplication and (3) advancement of malignant transformation of the tumour into cancer.

Several distinct human cancer cell lines show antiproliferative activity in response to anthocyanins and ellagic acid. Ellagitannins and anthocyanins, which have chemo-preventive potential, remain abundant in black raspberries. Freeze-dried black raspberries have been demonstrated in studies to lessen the development of colon and oesophageal cancer due to toxins. The development of several tumour cell lines, including those from the colon, prostate, breast, mouth, cervix, ovary and skin that entirely inhibited by bilberry extract when tested *in vitro*. A diet rich in blueberries may help prevent breast cancer caused by oestrogen (Golovinskaia and Wang, 2021).

According to *in vitro* research, certain berry extracts limit the development and multiplication of cancer cells, cause cell death and have an impact on angiogenesis by preventing the production of the vascular endothelial growth factor (VEGF). It has been proposed that it could control these processes. Results from animal models, however, were not definitive, for instance, rats fed tumour initiator-containing diets with freeze-dried black raspberries saw a decrease in the development, occurrence and variety of oesophageal tumours. Blueberries,

however, did not have the same effects(Golovinskaia and Wang, 2021; Kostecka-Gugala*et al*., 2015).

Diabetes

By preventing the rise in blood glucose levels, the physiologically active phytochemicals anthocyanins and proanthocyanidins, which were abundant in berries tends to cure diabetes and other metabolic illnesses. When compared to other berry extracts, red raspberry extracts have the strongest amylase inhibition properties. According to fractionation experiments, the raspberry extract's active component against -glucosidasebe the unbound anthocyanin-enriched fraction. The bound fraction, however, was beginning to accumulate amylase inhibitors. This demonstrates that proanthocyanidins significantly reduces amylase activity. A slower rate of glucose absorption in the stomach has been associated with the soluble fibres polydextrose and glucan present in cranberries. Cranberry flavonoids increase glycaemic response while reducing intestinal glucose absorption. Amylase and glucoamylase activity can be inhibited by proanthocyanidins and ellagitannins found in cranberry extract. By removing reactive carbonyl radicals, cranberry procyanidins can help prevent the glycation of human hemoglobin and serum albumin (McDougall and Stewart, 2012).

Benefits in immune system

It has been demonstrated that consuming 330ml of berry juice daily for two weeks improves natural killer cell lytic activity, increases lymphocyte responsiveness to mitogen activation and causes human volunteers to release cytokines unique to T lymphocytes. It was not known if these conceivably advantageous benefits were exclusive to berries or a more widespread reaction to increasing fruit consumption. According to Beattie *et al*. (2005) and Bader *et al*. (2022), an obtrusive and persistent *Escherichia coli* was suppressed by cranberry concentrate because it reduced the bacteria's adherence and invasion. This was in accordance with the findings of Khoo*et al*. (2022).

Prevention of urinary tract infection

Numerous studies have been conducted on the impact of cranberries on the condition of the urinary system since the 1920s. It was long thought that cranberries tendency to make urine more acidic because of intake explained their capacity to cure urinary tract infections (UTI). Cranberry proanthocyanidins, on the other hand, seem to stop p-fimbriated*E. coli* from adhering to the uroepithelial cells. Similar traits may be seen in other fruit kinds, such as the blueberry, a species of *Vaccinium*. The effects of cranberry juice and tablets have been the subject of numerous published clinical investigations. Numerous studies have demonstrated that cranberry juice or pills do have some protective effects, even if there were insufficient evidence to recommend their usage in the treatment or prevention of UTIs (Liska*et al*., 2016; Raz*et al*., 2004).

The rich nutritional content of dietary fiber, vitamin C, vitamin K and the necessary mineral manganese makes blackberries unique. Fruit acid, flavonoids and tannins were found in the leaf, whereas saponins and tannins been found in the root. The U.S. Department of Agricultural Research Service observed that young blackberry leaves had a high concentration of antioxidants, or the capacity to absorb oxygen radicals, in a study published in the "Journal of Agricultural Food Chemistry" in February 2000 (Ayoub, Maha 2015). In Europe, *R. fruticosus* has been used to treat diabetes (Verma*et al*., 2014). Consuming meals high in phytonutrients on a regular basis can help prevent cardiovascular diseases. Additionally, anthocyaninsbeen used to create packaging films that serve as freshness indicators for food (Feng*et al*., 2022).

Response of antioxidative defence System to ozone treatment in stored blueberry

Ozone remains as a material with strong oxidative properties. Numerous studies suggest that ozone can be utilized to prolong the commercial life of berry fruits while ensuring their high nutritional and processing value, as well as their microbiological safety. The study examined the amounts of antioxidant enzyme activity, reactive oxygen species (ROS) and protein oxidative damage in blueberry fruit that was ozonated and that was not during storage. Over the first 21 days of storage, ozonated fruit displayed increased antioxidant enzyme activity than non-ozonated fruit, including glutathione peroxidase, superoxide dismutase, and phenylalanine ammonia-lyase. The amount of hydrogen peroxide and superoxide anion radicals in ozonated fruit was significantly lower than in untreated material because of the improved ROS detoxifying system activity. However, after 21 days of storage, ozone treatment caused proteins to undergo oxidative changes, which may be the reason why the enzymes required for cellular defence against oxidative stress remain less active. This illustrates the need for more food science research on the use of ozonation technologies in stimulating the postharvest shelf life of soft fruits (Piechowiak, *et al*., 2020).

Prevention of ozone induced cutaneous inflamassome actions with blueberry extracts

O_3 has the ability to damage tissue, but primarily because of its interaction with the stratum corneum's (SC) cutaneous lipids, which produces molecules such hydrogen peroxide (H_2O_2) and lipid peroxidation products (4-Hydroxynonenal), which tends to trigger an inflammatory reaction. Although different blueberries have been used medicinally and topically to lessen wrinkles, telangiectasias, and skin aging, the potential protective mechanisms of topical application against pollution-induced damage have never been assessed, especially for vaccinium species, according to the Traditional Ecological Knowledge of Native American pharmacopeia. Since ozone exposure has already been connected to the development and exacerbation of inflammatory skin illnesses, it was thought that using blueberry extracts would be able to avoid redox imbalance and, hence, block the ozone-induced activation of the cutaneous inflammasome. Without the aid of blueberry extract, ozone was unable to enhance the oligomerization of the components of the inflammasome, as well as the expression of genes and proteins linked to the inflammasome. Additionally, blueberry extract pre-treatment was successful in decreasing oxidative markers associated with ozone exposure and speeding up the healing of epithelial wounds (Pambianchi*et al*., 2020).

Osmotic dehydration of berries

The degree of osmotic dehydration of berries been significantly influenced by the concentration of the hypertonic solution. A drop in mass indicates that the 70°Brix solution achieved the most severe osmotic dehydration and the best dehydration time. The blackberries lost 16% and 21% of their moisture after 6 hours, 4% and 7% of their moisture in 1.5 hours, 3% and 6% of their moisture after 6 hours, and 4% and 8% of their moisture after 7 hours. As a result, the berries lose less moisture when a hypertonic sucrose solution with the target concentration of 60°Brix had beenused. Additionally, it was discovered that lengthening the time of osmotic dehydration that not recommended since it causes the berries to become mushy and distorted, which remain unacceptable. A longer period of dehydration also causes the sensory indications to change negatively (Gribova *et al*., 2021).

Conclusion

Folic acid and vitamin C, two essential vitamins were abundant in berries. They include many phytochemicals as well. These exhibit a range of *in vitro* characteristics that point to possible health

advantages. Before further information regarding berry anthocyanins and flavanols*in vivo* absorption and metabolic destiny be available, it would be prudent to refrain from attributing to berries any extra health benefits beyond those that presently recognized to exist in all fruits and vegetables. However, locally grown fresh or frozen berries were an underutilized and possibly healthy dietary option in areas where consumption of plant-based meals remains frequently low. In recent years, there has been significant research progress in understanding the bioactive compounds in berries and their practical applications. The antioxidant chemicals bioavailability in berries and similar components from other fruits in general, as well as stronger proof of their benefits on consumer health, appear to be the main areas of research which triggers the necessity of nutritional security in futuristic generations of human.

CONFLICT OF INTEREST STATEMENT

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.

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