Superfruits in China: Bioactive phytochemicals and their potential health benefits – A Review

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Abstract
The term "superfruit" usually refers to certain fruits, which are rich in antioxidant components, therefore, are beneficial to human health. In China, there has been the concept of health preservation and dietary therapy through food intake in a long history. However, some other superfruits growing mainly in China have not attracted extensive attention, such as Cili, Goji berry, and sea buckthorn. Many studies suggested all of these superfruits showed strong antioxidant effects and anti-inflammatory activity in common. However, there are various other advantages and functions in different fruits. This article reviewed the research findings from the existing literature published about major antioxidant bioactive compounds and the potential health benefits of these fruits. The phytochemicals from superfruits are bioaccessible and bioavailable in humans with promising health benefits. More studies are needed to validate the health benefits of these superfruits. It would provide essential information for further research and functional food development.

KEYWORDS
antioxidants, health benefits, phytochemicals, superfruits

1 | INTRODUCTION

It is widely known that nutrient intake is the most important mean of maintaining health and preventing diseases. Since the use of some synthetic antioxidants has been restricted for their possible toxic and carcinogenic effects (Yen et al., 1998), food containing natural antioxidants gained worldwide popularity. Nutritional studies paid much attention to vegetables and fruits for their roles in alleviating the risk of numerous non-communicable diseases (Shahidi & Ambigaipalan, 2015). Regular consumption of fruits and vegetables has been demonstrated to be associated with a reduced risk of certain chronic diseases due to the presence of phytochemicals with antioxidant activities (Zhu et al., 2019).

'Superfruit’ is a term for fruit with supposed health benefits or therapeutic value as a result of some parts of its nutritional analysis or its overall nutrient density. Usually, fruits that have been recognized as superfruits are antioxidant-rich. For instance, blueberry is known as a superfruit due to its powerful antioxidant property.
In recent years, some other fruits with extremely high contents of antioxidants are also called “superfruits,” such as açai, acerola, goji berry, and mangosteen (Felzenszwalb et al., 2013; Oliveira et al., 2012; Pedro et al., 2018; Prakash & Baskaran, 2018; Wittenauer et al., 2016). The health benefits and potential applications of superfruits could be better exploited if more research is available (De Souza Sant’Ana, 2011). Chang et al. (2019) reviewed the phytochemicals, antioxidant efficacies, and health effects of a list of superfruits (açai, acerola, camu-camu, goji berry, jaboticaba, jambolao, maqui, noni, and pitanga). However, due to the abundant geographical and climatic conditions, China is a place of production of several superfruits. This review discusses the bioactive ingredients and their potential health benefits of the selected superfruits in China. It is aimed to arouse researchers’ interests in various scientific fields to study superfruits as functional foods or functional food ingredients, and hence, stimulating large-scale commercial cultivation (Figure 1).

2 | THE SCIENTIFIC MECHANISM OF PHYTOCHEMICALS WITH ANTIOXIDANT ACTIVITY OF SUPERFRUITS

Oxidative stress releases free oxygen radicals in the body to induce many disorders including cardiovascular malfunction, cancers, cataracts, aging, and other immune diseases (Kaur & Kapoor, 2001; Malik et al., 2005). Antioxidant refers to a compound that can delay or inhibit the oxidation of lipids or other molecules through the initiation or spread of oxidative chain reaction that alleviates the oxidative damage in the human body (Tachakittirungrod et al., 2007). In Table 1, the structural features and antioxidant mechanisms of the major groups in fruits are presented. The antioxidants act as scavengers to neutralize the reactive oxygen species (ROS) by donating one of their own electrons retarding to the electron-stealing reaction. As the antioxidants are capable to bind metal ions such as copper and iron that catalyze oxidation, they are recognized as chelators as well. Some of the phytochemicals halt cancer by blocking enzymes that enhance cancer or preventing various carcinogens that initiate diseases. There are a number of phytochemicals that could damage cells, tissues, and organelles by producing enzymes that destroy carcinogens in the body and others that suppress the reproduction of cells exposed to carcinogens. Meanwhile, antioxidants are supposed to be beneficial in helping to delay initial episodes of general immune disorders by extending the period between infection and clinical appearance (Kaur & Kapoor, 2001).

Normally, superfruits are rich in a number of phytochemicals that are of great antioxidative capacity. The most interesting dietary constituents are carotenoids such as β-carotene, ascorbic acid, tocopherols, dietary fiber, and polyphenols including anthocyanins, flavonols, tannins, and flavonoids (Flores et al., 2012). In

FIGURE 1 Pictures of the Superfruits:
(a) Cili; (b) Goji berry; (c) Hawthorn; (d) Mangosteen; (e) Pomegranate; (f) Sea buckthorn
general, ascorbic acid is localized in the apoplast, cytosol, mitochondria, vacuole, and plastid; anthocyanins are usually found in fruit peels. Proanthocyanidins are abundant in the peel and especially seeds of berries (Soong & Barlow, 2004). However, the antioxidant activities of different superfruits vary widely based on the assay type, where different assays follow different mechanisms of action and hence may afford different antioxidant activity trends among superfruits. This suggests the need to perform more than one type of antioxidant activity measurement to consider the various mechanisms of antioxidant action and the limitations of each assay. Thus, it is difficult to compare the antioxidant efficacies between different superfruits.

### 3 | Typical Superfruits in China and Their Potential Health Benefits

Some typical superfruits in China are reviewed in this section. Tables 2 and 3 summarized the main bioactive components and potential health benefits. Various human intervention and animal studies have evaluated the potential health benefits of selected superfruits. All the selected superfruits were reported with antioxidant and anti-inflammatory activity in common, while some of them reported with unique effects such as methanotrophic pomegranate juice, radioprotective (Cili), and vision-protective (goji berry). The risk of toxicity of the mentioned superfruits as functional foods requires more investigation. Allergic reactions were reported from goji berry consumption. Further studies into the safety and toxicological properties of these superfruits are urgently needed since they might pose allergic or chemical toxicity risks, especially for people not from China or Asia.

#### 3.1 | Cili

Cili (Rosa roxburghii Tratt) is a kind of specific wild plant in Southwest China. Cili consists of several important components such as superoxide dismutase (SOD), polysaccharide, vitamin C, vitamin E, and some mineral elements (Zn and Ca). Additionally, SOD has long been regarded as a free radical scavenger and ascorbate, which is a highly potent aqueous-phase antioxidant in plasma (Frei, 1991). This fruit has been known to have a number of beneficial effects on atherosclerosis, cancer, aging, and immunity stress. A set of indices, such as the activity of natural killer (NK) cells, free radical metabolism, microcirculation parameters, cognitive function, light reaction time, and cardiovascular function were selected to evaluate the effects of Cili among 50–75 years old people (30 men and 30 women). It demonstrated that Cili was able to enhance natural killer cell activity and strengthen immune function. Furthermore, the supplementation of Cili would significantly improve the antioxidative capacity and then reduce the injury effect on the endothelium of capillary, artery, and brain with the mechanism probably due to its bioactive components such as SOD, polysaccharides, vitamin C, vitamin E, etc (Ma et al., 1997).

Zhang et al. (2001) studied the mechanism of antiatherogenic effects in cholesterol-fed animals with Cili juice and they found that the juice not only remarkably reduced low-density lipoprotein (LDL) oxidative susceptibility but also suppressed oxidized Ox-LDL-induced macrophage growth and particularly Ox-LDL-induced cholesterol ester (CE) accumulation in murine peritoneal macrophages by promoting cellular cholesterol efflux. These results indicated that the Cili juice exerted its antiatherogenic effects largely due to its ability to inhibit the oxidative modification of LDL and suppress the formation of foam cells.
| Table 2 | Major antioxidant bioactive compounds in superfruits |
|---------|------------------------------------------------------|
| **CiLi** | Ascorbate  
Tocopherols  
Vitamin B₁  
Flavonoids  
Superoxide dismutase  
Water-soluble polysaccharides  
Organic acids, triterpenes, polysaccharides  | Zhang et al. (2001)  
Wang et al. (2018)  |
| **Goji berry** | Carotenoids  
Ascorbic acid  
Tocopherols  
Syringic  
Chlorogenic  
Gallic  
Caffeic  
P-coumaric  
4-hydroxybenzoic  
Ferulic  
Trans-cinnamic  
Rutin  
Naringin  
Quercetin  
Catechin  
Kaempferol  | Fiorito et al. (2019)  
Pedro et al. (2018)  
Amagase and Farnsworth (2011)  |
| **Hawthorn** | Flavonoids  
Phenols  
Oligomeric Procyanidins  
Chlorogenic Acid  
Epicatechin  
Hyperoside  
Isoquercitrin  
Rutin  
Vitexin-4’-O-Glucoside  
Vitexin-2’-O-Rhamnoside,  
Hyperoside  
Vitexin  
Shanyenoside A  
Quercetin  | Chang et al. (2001)  
(Zhu et al., 2015)  |
| **Mangosteen** | Tricyclic isoprenylated polyphenols  
Xanthones  
Benzophenones  
Biflavonoid  
Mangostin  
Tannin  
Chrysanthemin  
Garcinone  
Gartanin  
Ascorbic acid  | Chen et al. (2019)  
Gutierrez-Orozco and Failla (2013)  
Acuña et al. (2012)  
Moongkarndi et al. (2004)  |
| **Pomegranate** | Punicalagin  
Ellagic acid  
Anthocyanins  
Gallotannins  
Hydroxybenzoic acids  
Hydroxycinnamic acids  
Dihydroflavonols  | Putnik et al. (2019)  |

(Continues)
Furthermore, the flavonoids of Cili exhibit radioprotection and anti-apoptosis properties via the Bcl-2(Ca²⁺)/Caspase-3/ PARP-1 pathway in mouse thymus (Xu et al., 2016). In addition, water-soluble polysaccharide (RTFP) from Cili has shown the potential to be a functional ingredient or hypoglycemic agent in food, pharmaceutical, and cosmetic preparations (Wang et al., 2018). Later, the same research group reported that the digestion properties of a novel polysaccharide from Cili (RTFP-3) under saliva simulated gastric, and small intestinal conditions were studied. It was proven to be a functional ingredient to improve human health and prevent diseases through regulating gut flora (Wang et al., 2019).

3.2 | Goji berry

Goji (Lycium bæbærum L.) berry has been used for centuries in traditional medicine practice in China. It contains mainly polysaccharides, polyphenols, and carotenoids with an ability to exert beneficial effects for the prevention of chronic diseases (cancer, atherosclerosis, obesity, and diabetes), and to promote weight loss and longevity in rats (Amagase & Farnsworth, 2011; Fiorito et al., 2019; Ma et al., 2019; Pedro et al., 2018). Also, there were results that showed that goji berry demonstrated significant reductions in feelings of tiredness after exercise in the human subjects tested. This indicates that goji berry may attenuate stress-related reactivity and facilitate adaptation to physical stressors during exercise (Amagase & Nance, 2011; Chang et al., 2019). The content of polysaccharides in goji berry is more than 40% (Chan et al., 2007). Polysaccharides purified from goji berry were reported to be effective in various potential health benefits. Wang et al. (2002) found that goji polysaccharides were able to protect the seminiferous epithelium from structural damage and apoptosis, in testicular tissue culture and inhibit lipid peroxidation and cytochrome C suggesting an anti-inflammatory effect. Zhao et al. (2005) tested the influence of polysaccharides on the expression of matrix-digesting enzymes as skin cancer and aging were associated with the upregulation of matrix metalloproteinase. These results showed that polysaccharides, especially LbGp5, might have visual skin-protective properties. As goji has been used for hundreds of years for protecting the eyes in Eastern World, Chan et al. (2007) investigated the therapeutic function of this fruit against neurodegeneration in the retina of the rat OH model. They represented that the fruit extract could benefit neural tissue by inhibiting the loss of retinal ganglion cells in glaucoma. Li, Zhou, et al. (2007) concluded that goji polysaccharides were efficient antioxidants that can protect rat liver mitochondria from irradiation-induced lipid peroxidation and protein oxidation by augmenting endogenous antioxidant enzymes. Zhu et al. (2007) illustrated that LBP could elicit phenotypic and functional maturation of murine bone marrow-derived dendritic cells might result in increasing the antitumor effects of dendritic cell-based vaccine therapy. Meanwhile, Li, Ma, et al. (2007) observed that the treatment with LBP significantly raised antioxidant enzymes activity and inhibited malondialdehyde formation in the mice’s heart, brain, and serum. In addition, Le et al. (2007) reported that 95% aqueous ethanol extract of the fruit contained a great amount of flavonoids, including 247 µg myricetin, 296 µg quercetin, and 135 µg kaempferol. Recently, Jeszka-Skowron et al. (2018) reported that dried fruit extract prepared from goji showed a significant antioxidant activity as well. However, beyond their beneficial properties, goji berry contains renowned allergenic proteins, and, therefore, deserves inclusion among the allergenic foods capable of inducing allergic reactions in sensitive consumers (Uasuf et al., 2020).

3.3 | Hawthorn

Hawthorn (Crataegus pinnatifida) is a genus of fruit-bearing trees or shrubs distributed in East Asia, North America, Central Asia, and Europe between 30 and 50° of north latitude, belonging to the Rosaceae family. According to the climate, the cultivation, the utilisation, and the geographical location in China, they can be roughly divided into five producing areas, with 18 species and 6 varieties planted (Deiprete, 1997; Guo et al., 2019). Hawthorns are among the most economically important plant species in China, owing to their pleasant flavor, attractive color, and nutrient-rich fruit. Also, it is considered a highly important medicinal and aromatic plant that has been used for many years for the treatment of various diseases (Arslan & Bektas, 2018). Chinese hawthorn has been widely used in the treatment of hyperlipidemia and cardiovascular diseases. In folk medicine, hawthorn has been used to treat asthma, hyperlipidemia, heart failure, and in Iran and Mexico, for pain as well (Arslan & Bektas, 2018; Cervantes-Paz et al., 2018; Kisioglu & Nergiz-Unal, 2018).

Hawthorn leaves, fruits, and seeds have various active substances such as, flavonoids, triterpenic acids, and sesquiterpenes,
| Fruiet       | Potential health benefits                                                                 | Reference                                      |
|-------------|------------------------------------------------------------------------------------------|-----------------------------------------------|
| CiLi        | Antioxidant, Anti-inflammatory, Antioxidant, Antimutagenic, Antiatherogenic, Antitumor, Radioprotective activities | Xu et al. (2018) Wang et al. (2018)             |
| Goji berry  | Antioxidant, Anti-inflammatory, Vision-Protection effect, Lipid-Lowering effect, Hypoglycaemic effect, Anticancer, Antitumour, Immunostimulatory, Neurological Protective effect, Modulatory effect, Antiaging effect, Cardiovascular Protective effect | Ma et al. (2019)                              |
| Hawthorn    | Anti-inflammatory, Gastroprotective, Antimicrobial activities, Antioxidant, Antithrombotic, Anti-atherosclerotic, Treatment of stress, nervousness, sleep disorders, and pain control (antinociceptive), hypotensive, Antihyperlipidemic, Antihyperglycemic, Anxiolytic, Immunomodulatory, Antimutagenic | Kumar et al. (2012) Arslan and Bektas (2018) Can et al. (2010) Orhan (2019) |
| Mangosteen  | Antioxidant, Antiproliferative, Pro-apoptotic, Anti-inflammatory, Maintaining cardiovascular system and gastrointestinal health, Anticarcinogenic activities, Anticancer, Antimicrobial, Antidiabetes | Chen et al. (2019) Aizat et al. (2019) Gutierrez-Orozco and Failla (2013) |
| Pomegranate | Anticancer, Antioxidant, Anti-inflammatory, Antidiabetic, Antimicrobial, Anticarcinogenic, Anti-atherosclerotic, Hepatoprotective, Neuroprotective activities | Adu-frimpong et al. (2018) Putnik et al. (2019) |
| Sea buckthorn | Anti-inflammatory, Anticancer, Antioxidant, Anti-atherosclerotic effects, Hepatoprotective | Nelson and Olas (2018)                            |
which through different mechanisms could be beneficial for humans. Various studies have shown that hawthorn can have beneficial effects on controlling and treating cardiovascular diseases, high blood sugar, dyslipidemia, obesity, and atherosclerosis (Bleske et al., 2008; Chang et al., 2005). Dehghani et al. (2019) reported that flavonoids extracted in the leaves of hawthorn can significantly reduce atherosclerotic lesion areas, the fruit extracts contain two triterpenic acids (oleanolic acid and ursolic acid), that have the ability to inhibit the acyl-CoA-cholesterol acyltransferase enzyme and as a result reduce very low-density lipoprotein (VLDL) and LDL cholesterol levels. Also, they reported a sesquiterpene found in the seeds of hawthorn, which exhibits the ability to inhibit platelet aggregation, thus showing antithrombotic activity. In addition, a series of metabolic syndrome effects of hawthorn, such as anti-diabetic and anti-obesity by lower plasma glucose and decrease in the rate of gluconeogenesis, anti-hyperlipidemia, and reduced atherosclerosis (in vivo and in vitro studies) were reported (Shahrzad Dehghani et al., 2019).

Hawthorn has a high pectin content compared with other fruits. The hawthorn pectin content in fresh fruit is as high as 6.4% and the pectin oligosaccharides from hawthorn showed potential antiguication activities (Zhu et al., 2019). Moreover, in vitro antioxidant activity assays indicated that ultrasonic treatment significantly improved the antioxidant activity of pectin ultrasonic treatment and is an effective way to enhance the antioxidant activity. (Chen et al., 2019).

### 3.4 Mangosteen

The fruit of *G. mangostana* L. is commonly known as mangosteen, which is referred to as “the queen of fruits” in Southeast Asia (Acuña et al., 2012; Chin et al., 2008; Moongkarndi et al., 2004). It has been used as a traditional medicine for the treatment of diarrhea, inflammation, ulcer, skin infection, abdominal pain, astringent, dropsy, leucorrhoea, and gonorrhea for many years (Chin et al., 2008; Matsumoto et al., 2004; Moongkarndi et al., 2004). The pericarp of mangosteen contains mangostin, tannin, xanthone, chrysanthemine, garcinone, gartanin, vitamin B₁, B₂, C, and other bioactive substances (Gutierrez-Orozco & Failla, 2013; Moongkarndi et al., 2004). In addition, the pericarp of mangosteen showed potential as antioxidant ingredients in cosmetic formulations (Wittenauer et al., 2016). Xanthones were considered to be really important for chemopreventive or therapeutic functions. Several studies represented that xanthon derivatives, as the major secondary metabolites of mangosteen, demonstrated antibacterial, antifungal, antioxidant, anticancer, antiplasmodial, and cytotoxic activities (Gopalakrishnan et al., 1997; Gutierrez-Orozco & Failla, 2013; Ji et al., 2007; Nakatani et al., 2002; Sakagami et al., 2005; Sukamrarn et al., 2006; Yu et al., 2007). So far, there are more than 68 xanthones isolated from the mangosteen fruit with the majority of them being α- and γ-mangostin (Aizat et al., 2019).

Jung et al. (2006) found that α-mangostin, one of the important xanthon derivatives, could inhibit alveolar duct formation in a mouse mammary organ culture model and alleviate the carcinogen-induced formation of aberrant crypt foci in a short-term colon carcinogenesis model. Matsumoto et al. (2004) reported a great cytotoxic activity of several xanthones against human leukemia HL60 cells, where α-mangostin presented the most dramatic activity and induced apoptosis in human leukemia cell lines HL60, K562, NB4, and U937. Sato et al. (2004) illuminated that α-mangostin-induced apoptosis through the mitochondrial is associated with the inhibition of the Ca²⁺-ATPase pathway in rat pheochromocytoma PC12 cells. γ-mangostin is a tetraoxygenated diprenylated xanthone derivative. It has been found that γ-mangostin was able to bind to cyclooxygenase and inhibit its activity resulting in reduced production of prostaglandin E₂ (PGE₂), which would affect the activities of some cell types, such as neurons, glial, and endothelial cells at a high level (Nakatani et al., 2002). The function of γ-mangostin is supposed to contribute to its anti-inflammatory activity. Moongkarndi et al. (2004) studied the antiproliferative, apoptotic, and antioxidative properties of crude methanolic extract (CME) from mangosteen. The results implied that the CME decreased the intracellular ROS production on SKBR3 human breast cancer cell lines significantly. The components in mangosteen probably serve as the potent anticancer agents and free radical scavengers. In 2013, Gutierrez-Orozco and Failla made a review of in vivo studies on the bioavailability and metabolism of mangosteen xanthones. More recently, novel xanthones have been discovered such as 1,3,6-trihydroxy-2-(3-methylbut-2-enyl)-8-(3-formylxoy-3-methylbutyl)-xanthone, 7-O-demethyl mangostin, garmanoxanthone as well as mangoxanthane III, IV, V, VI, and VII. These xanthones were also implicated in various pharmaceutical properties, but more studies are needed to verify their effectiveness in human applications (Aizat et al., 2019).

### 3.5 Pomegranate

The fruit known as pomegranate (*Punica granatum*) originated from the Middle East, then extended to Mediterranean areas, as well as in countries such as Iran, India, China, Japan, and Russia. Pomegranate has been used as a traditional medicine in Asian cultures to treat different ailments (Adu-frimpong et al., 2018). Many epidemiological studies of the potential effects of pomegranate on cancer prevention, such as lung cancer (Khan et al., 2007), skin cancer (Rout & Banerjee, 2007), prostate cancer (Malik et al., 2005), breast cancer (Toi et al., 2003), etc. suggested that pomegranate could serve as a possible chemopreventive and therapeutic agent against different cancers. This fruit comprises three parts, the seeds, about 3% of the fruit weight, the juice, about 30% of the weight, and the peels (peri-carp). Other parts of the pomegranate including roots, bark, leaves, and flowers are also useful (Lansky & Newman, 2007). Pomegranate juice is reported to have strong antioxidant and anti-atherosclerotic functions due to its high portion of polyphenols such as ellagic acid (EA) in its free and bound forms (ellagitannins and EA glycosides), gallo-tannins, anthocyanins (cyaniding, delphinidin, and pelargonidin glycosides), and flavonoids (quercetin, kaempferol, and luteolin glycosides) (Malik et al., 2005; Putnik et al., 2019). Seeram et al. (2005)
presented that punicalagin, EA, and total pomegranate tannin could reduce the cell number of human oral, prostate, and colon tumor cells. Furthermore, when concentrations of those compounds rose up to an equivalent level (w/w) with pomegranate juice, they were able to induce apoptosis in HT-29 cells. Punicalagin is supposed to be the most potent antioxidant ingredient for its antioxidant properties. The radical scavenging ability of punicalagin was because of polyphenolic hydroxyl groups that enhance the antioxidant activity through additional resonance stabilization and α-quinone or p-quinone formation (Kulkarni et al., 2004). In addition, pomegranate juice consumption resulted in antiatherogenic influence with a remarkable reduction in oxidative stress in serum and monocytes-macrophages, and macrophage uptake of oxidized LDL and then cellular cholesterol biosynthesis (Fuhrman et al., 2005; Rosenblat, Hayek, & Aviram, 2006). Some studies showed that both pomegranate flower and juice might prevent diabetic sequelae via peroxisome proliferator-activated receptor-γ binding and nitric oxide production. Antidiabetic compounds included oleanolic, ursolic, and gallic acids (Katz, Newman, & Lansky, 2007). Pomegranate juice was also reported to decrease the potent downregulation of NOSIII induced by the oxidation of LDL in human coronary endothelial cells (Nigris et al., 2007). It has been considered that this fruit juice may be useful in Alzheimer’s disease, as supplementation of mice with PJ led to significantly less accumulation of soluble Aβ42 and amyloid deposition in the hippocampus (Hartman et al., 2006).

However, the total content of anthocyanins in pomegranate juice was reported to be higher than any other fruit juice tested for antioxidative activity. Pomegranate juice increased the biological actions of NO by protecting NO against oxidative destruction but reversed proatherogenic effects induced by perturbed shear stress (de Nigris et al., 2007; Ignarro et al., 2006).

The result from Kohno et al. (2004) suggested that administration of pomegranate seed oil (PSO) that was rich in c9, t11, and c13-CLN could inhibit azoxymethane-induced colon carcinogenesis, while Yamasaki et al. (2006) found that PSO promoted Ig production by mouse splenocytes. In addition, emerging evidence has suggested that nutraceutical ingredients like PSO possessed health-promoting effects in cell and animal models. However, these health benefits (anticancer, antioxidant, anti-inflammatory, anti-diabetic, and so on) are limited by low physicochemical stability, slow intestinal absorption, and rapid metabolism of PSO (Adu-frimpong et al., 2018).

3.6 | Sea buckthorn

Sea buckthorn (Hippophae rhamnoides L.) belongs to the Elaeagnaceae family, which is naturally distributed throughout Eurasia from the Baltic Sea and the North Sea in the west to Central Asia in the east (Gülüyev et al., 2004; Negi et al., 2005; Nelson & Olas, 2018). This fruit is elliptic or oval in shape, and it is a yellowish-orange berry with silvery dust particles covered surface, and sour in taste (Gülüyev et al., 2004). Sea buckthorn consists of series of chemical compounds including vitamins, carotenoids, flavonoids, etc. It is found that the juice is rich in vitamin E, vitamin C, and flavonoids that are 13.3, 1,540, and 1,182 mg/L, respectively. More than 75% of the total vitamin E is in the form of α-tocopherol, and isorhamnetin is one of the most active flavonol glycosides in sea buckthorn juice (Eccleston et al., 2002; Teng et al., 2006). All parts of the plant have been used as a good source of bioactive substances treating diseases in traditional medicine (Geetha et al., 2003). Nowadays, scientific studies have reported pharmacological effects of sea buckthorn. In vitro studies and in vivo human and animal models, have found that the juices, jams, and oils derived from this fruit and seeds have a wide range of beneficial anti-inflammatory, anticancer, antioxidant, and anti-atherosclerotic effects. These were attributed to the presence of phenolics, vitamins, minerals, amino acids, fatty acids, and phytosterols (Nelson & Olas, 2018). Eccleston et al. (2002) demonstrated that supplementation of sea buckthorn juice showed a moderate decrease in the susceptibility of LDL to oxidation and, therefore, its rate of accumulation by macrophages. Teng et al. (2006) studied isorhamnetin, which was the metabolite of quercetin (Ader et al., 2000), and the result illustrated potent cytotoxicity against human hepatocellular carcinoma cells (BEL-7402). The antioxidant activity of leaf extract of sea buckthorn was also detected by Geetha et al. (2003) studying chromium(VI)-induced oxidative stress in albino rats. They revealed that the ethanolic leaf extract at a concentration of 100 and 250 mg/kg body weight significantly reduced the chromium-induced oxidative damage in animals. Meanwhile, methanol extract of sea buckthorn seed exhibited high antibacterial and antioxidant capacity, which is supposed to be due to its high phenolic contents (Negi et al., 2005). Oil extracted from sea buckthorn has high concentrations of lipophilic constituents, predominantly unsaturated fatty acids in triglyceride form, and phytosterols and vitamins A and E have a positive influence on human health, especially on the cardiovascular system (Olas, 2016).

4 | CONCLUSION

This review has focused on the potential human health benefits of superfruits in China. Evidently, the functional properties are due to their abundant or unique components with high nutrition and medical value. In vivo and in vitro studies have found that the bioactive phytochemicals present in superfruits have been useful in antioxidant, anti-inflammatory, and reducing the risk of various diseases, such as heart diseases, various cancers, and brain diseases. Complementary research is also needed to enhance the potential functionalities of the by-products of these superfruits in China, as such by-products contain numerous phytochemicals that may be beneficial to human health. In the future, the studies of functional food development of these superfruits could not only benefit the health of consumers but also promote the development of China’s fruit industry.

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