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Review Article

From environment to environmental adaptation: Environmental perspectives on the study of food and medicine homology

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Abstract: Food intake is a major way for the body to obtain materials, energy, and information from the external environment. Food and medicine homology (FMH) substances as food not only contain abundant nutrients, but also carry various bioactive components to promote human health. The special functional factors derived from FMH substances under specific environmental conditions can significantly impact the body's adaptability. Understanding the complex relationships among environment, FMH substances, and organisms, including the active components of FMH under different environments and their influence on the mechanisms of adaptation to extreme environments, is critical. In this review, the effects of environmental factors on the content and structure of the active components in FMH were comprehensively summarized and discussed, also the effects of FMH on the adaptation of the body to extreme environments. Furthermore, the insights into potential future research directions in the field of FMH and environmental adaptation were provided. This review summarizes the effects of FMH on the body from an environmental perspective and offers new references and insights for the development of FMH.

Keywords: environment; Food & Medicine Homology; active components; environmental adaptation

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1 Introduction

From the perspective of material basis, the term FMH usually refers to a natural substance that has medicinal and nutritional functions at the same time, and the medicinal ingredients should have no harmful effects on the body[1]. The idea of FMH can be traced back to the *Huang Di Nei Jing*, which refers to the dual use of food and medicine. In the book, it is mentioned that food can also be used as medicine (such as medicinal diet) to improve human immunity and achieve the effect of preventing or treating diseases[2]. Rooted in the thousand-year wisdom and medical tradition of the Chinese nation, the FMH theory regards food and medicine as the common source and advocates the concept of "food therapy". Globally, there are many concepts similar to FMH, such as functional foods and dietary supplements[3]. Since modern times, with the improvement of people's health management awareness, more and more people try to use FMH substances instead of chemical drugs for disease intervention and health management. Modern pharmacological studies have demonstrated the preventive and therapeutic effects of FMH substances on various diseases, especially chronic diseases[4, 5].

Specific dietary and functional food factors can regulate the body's physiological functions. The FMH substances encompass a diverse array of active components, including polysaccharides, polyphenols, saponins, and alkaloids, which provide significant nutritional and medicinal benefits[6-8]. Given their inherent food-grade safety, these substances can be consumed directly or incorporated into various foods. These active components can be transmitted to the body as external information to prevent and treat disease by improving antioxidant capacity *in vivo* at safe doses. For instance, crocin could alleviate hydrogen peroxide (H_2O_2)-induced oxidative stress by regulating the nuclear factor erythroid 2 -related factor 2 (Nrf2) pathway in intestinal epithelial cells[9]. The polysaccharide extracted from the Chinese medicine *Lonicera japonica* could promote NLR family pyrin domain containing protein 3 (NLRP3) inflammasome degradation and improve atopic dermatitis[10]. Alkaloids extracted from *Dendrobium huoshanense* exhibited obvious protection against oxidative neuronal damage[11]. In addition, FMH substances with a wealth of information play an important role in regulating the gut microbiota, immunoregulatory activity, anti-tumor, relieving fatigue, protecting the liver and so on[12-15]. Thus, FMH substances are receiving increasing interest for their versatile pharmacological and biological activities.

Currently, wild FMH substances, such as wild ginseng, are increasingly favored by people. This preference stems primarily

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from the belief that wild ginseng, owing to its exposure to varied environments, produces an array of secondary metabolites and possesses enhanced bioactive properties along with a richer probiotic composition[16]. As we all know, the quality of FMH plants is closely related to the ecological factors in the growing environment. The extreme climate limits the growth, distribution, and life cycles of FMH plants[17]. Moreover, the FMH plants have strong plasticity with different growth conditions, mainly including active ingredients and prebiotic information[18]. Therefore, the special environment can induce the production of special functional food components in the FMH plants, and then affect the adaptability of the body in the special environment. It is an interesting phenomenon that the FMH substances in special environment can promote the adaptability of the body in the corresponding environment.

Organisms can adapt to the environment through food intake, and food raw materials are also affected by the environment. There is a harmonious coexistence between organisms and the environment. In this review, the active components and information of FMH and the effects of adversity on them were reviewed and discussed. Meanwhile, the effects of FMH on the adaptation of the body to extreme environments, including hypoxia, radiation, cold and humid environments were discussed and elucidated. Finally, future perspectives in this field were explored. With the development of science and technology, the combination of artificial intelligence (AI) technology, fingerprint technology and FMH contribute to the environment-FMH-body's environmental adaptability interaction relationship and to provide new insights for the development of functional factors from FMH substances.

2 Environment can affect the active components of FMH

Food intake is a way for organisms to exchange material, energy, and information with the outside environment. FMH substances not only provide essential nutrients, but also have corresponding active components performing certain biological functions in the body. In addition, the active components produced by FMH substances in different environments are also different. At the same time, the environment can also affect the structure and physiological activity of FMH active components. Hence, a brief review of active components carried by FMH in different environments is presented in this section (Table 1).

2.1 The effects of natural environments on the active component contents

The environment can affect the contents of functional factors or secondary metabolites in FMH. It is well known that most FMH substances come from plants. A previous study showed that growth and development of plants could affect the production of secondary metabolites[19]. The outstanding medicinal and edible value of many alpine FMH plants may be related to the adaptation and evolution of alpine ecosystems. The most typical example is *Rhodiola rosea* growing in extremely cold and high-altitude environments, which has strong vitality and special adaptability. Many studies have suggested that salidroside extracted from *Rhodiola rosea* could improve the anti-hypoxia ability of the body and might transfer the environmental adaptability from plant to the body[20,21]. As altitude increases, the environment becomes

Table 1 The active components carried by FMH in different environments

Environment		FMH	Active component	Contents/structure	Reference
Natural environment	High altitude	*Gentiana dahurica* Fisch.	Polysaccharides	Increase the content of monosaccharide and change primary structure	[42]
	High altitude	*Rhodiola rosea*	Salidroside	-	[20]
	High altitude	*Epidium meyenii* W.	Polysaccharides and alkaloids	-	[22]
	Wild environment	American ginseng	Ginsenosides	Increase two times compared with cultivated ginseng	[23]
	Warmer, relatively humid and shady environments	*Panax ginseng*	Ginsenosides	Be suitable for the accumulation of ginsenosides	[25]
Artificially induced environment	Salt induction	*Lonicera japonica* Thunb., *Taraxacum officinale* and *Panax ginseng*	Chlorogenic acid, caffeoylquinic acids and ginsenoside triterpenoid	More accumulated leaf chlorogenic acid in *Lonicera japonica* Thunb.; Promote the accumulation of caffeoylquinic acid in *Taraxacum officinale*; Affect the metabolite profile of ginsenoside triterpenoid in *Panax ginseng*	[26-28]
	Phosphorus loss	*Dendrobium officinale*	Alkaloids	Promote the accumulation of alkaloids	[29]
	UVB radiation	*Dendrobium officinale*	Polysaccharides, alkaloids and flavonoids	Increase the contents of total polysaccharides, total alkaloids and total flavonoids	[30]
	EDTA induction	Brown mustard (*Brassica juncea*)	Anthocyanin and ascorbic acid	Promote the produce of anthocyanin and ascorbic acid	[31]
	Cold induction	*Hippophae salicifolia D. Don*	Proline	Increase 2.7 times	[32]
	Saline-alkali induction	*Alfalfa* (*Medicago sativa* L.)	Polysaccharides	Increase the content of monosaccharide and change three-dimensional structure	[40]
Geoherbalism	-	*Stellariae radix*	Mo element	In the central arid zone and the northern area of Ningxia are significantly higher than that in the south of Ningxia	[34]
	-	*Pogostemon cablin*	Patchouli alcohol and pogostone	Present in *Pogostemon cablin*, and not present in *Agastache rugosus*	[35]
	-	Zhejiang *Ophiopogon japonicas*	Methyl ophiopogon flavanone A, 4-coumaric acid and 8-aldehyde-5-*O*-methyl ophiopogon flavanone B	Significantly higher than other regions	[36]

more hostile, resulting in nutritional deficiencies and oxidative stress. The polysaccharides and alkaloids of *Lepidium meyenii* W. in high altitude environment are highly sensitive to environmental stress, which may be due to shorter vegetation period and larger rhizomes biomass than root biomass, thus increasing the content of bioactive components in high-altitude environment[22]. Exposure to a variety of natural environments can lead to stress responses of FMH plants, which may affect changes of secondary metabolites. For instance, ginsenosides in wild ginseng were twice as high as those in cultivated ginseng[23]. The reason may be that ginsenosides as defensive compounds can weaken the effects of the environment in wild ginseng[24]. Ecological factors are correlated with the active ingredient contents of FMH. Study have shown that the warm, humid and cool environment was suitable for the accumulation of ginsenosides and the environments rich in mineral elements were conducive to the accumulation of amino acids[25]. Therefore, although the price of wild and natural FMH is higher, they are still more favored by people.

2.2 The effects of artificially induced environments on the active component contents

In addition to the natural environments, artificially induced environments can also change the active component contents of FMH. Compared with the natural environments, active induction is a way to artificially and controllably change the environment, which can more conveniently control the environmental conditions and induction degree. Under moderate salt induction, *Lonicera japonica* Thunb., *Taraxacum officinale* and *Panax ginseng* could accumulate more chlorogenic acid, caffeoylquinic acids and ginsenoside triterpenoid, respectively[26,27]. In addition, salt induction could affect the metabolite profile of ginsenoside triterpenoids in *Panax ginseng*[28]. These FMH plants may maintain ion homeostasis and water balance and prevent oxidative stress by increasing the content of active substances to adapt salt-induced environment. A moderate amount of phosphorus loss or Ultraviolet B (UVB) radiation has been shown to improve the production of alkaloids and polysaccharides in *Dendrobium officinale* (*D. officinale*), and further increased the antioxidant activity and quality of *D. officinale*[29,30]. Brown mustard could produce more anthocyanin and ascorbic acid under ethylenediamine tetraacetic acid (EDTA) induction[31]. FMH plants defend themselves by enhancing the production of anthocyanins due to their antioxidant activities and regulation of the osmotic balance in the plants. Active induction is an effective strategy to improve the physiological activity of FMH. After 24 h of cold induction, the content of proline in *Hippophae salicifolia* D. Don (Seabuckthorn) was increased by 2.7 times and the specific activities of superoxide dismutase (SOD) and catalase (CAT) also were observably increased, which suggested that cold induction could improve the antioxidant activity of FMH[32]. The active ingredient contents of FMH present obvious differences in various environmental conditions.

2.3 Geoherbalism of FMH

FMH substances have different content of active components in different environments, and thus have different physiological activities, such as geoherbalism. Geoherbalism usually refers to traditional Chinese medicine (TCM) produced in a specific region, compared with those from other regions, have the batter quality. Geoherbalism of FMH is also important, and it is the result of genetic variation and environmental interaction[33]. *Stellariae radix* from different producing areas emerge a certain consistency in the types of inorganic elements, but there were some differences in the content of inorganic elements. The Mo element of *Stellariae radix* collected in the central arid zone and the northern area of Ningxia was significantly higher than those in Yuanzhou and Pengyang in the south of the central arid zone of Ningxia. So Mo element may be a potential inorganic element to distinguish the *Stellariae radix*[34]. Genetic and environmental factors contribute to the different content of active ingredients in FMH in different regions. Patchouli alcohol and pogostone are the main components of volatile oil in patchouli, which is not present in *Agastache rugosus*. It can be seen that patchouli alcohol and pogo stone can be used as the markers to distinguish patchouli from *Agastache rugosus*[35]. As an genuine FMH in Zhejiang province, Zhejiang *Ophiopogon japonicas* contains more methyl ophiopogon flavanone A, 4-coumaric acid and 8-aldehyde-5-*O*-methyl ophiopogon flavanone B than those in other areas[36]. The characteristics of genuine FMH refers to the structure type and content of the specific active substance in FMH. The unique proportion of active ingredients of different structures reflects the unique quality of genuine FMH. In recent years, fingerprint technology can be used to identify the characteristics of genuine FMH by various chromatographic and spectral techniques, such as high performance liquid chromatography (HPLC), fourier transform infrared spectroscopy (FT-IR) and gas chromatography-mass spectrometer (GC-MS), so as to distinguish the FMH in genuine and non- genuine producing areas[37]. The ecology of the genuine producing area is one of the main conditions for the survival of FMH, which directly affects the growth and development of FMH. At the same time, they will influence each other and synergically affect the growth and development of FMH, which is a very complex process[38].

2.4 The effects of environments on the composition and structure of the active FMH components

The environment not only affects the contents of FMH active components, but also affects the structure, then to influence its activities. The FMH-derived natural polysaccharide exemplifies a high-molecular-weight compound, boasting a complex structure that intricately dictates its diverse biological activities[39]. Soil salinity is the most common abiotic stress signal and can enhance plant resistance to stress by triggering the biosynthesis of intracellular components. Saline-alkali soil could increase the residue ratio of Ara and GalA in the polysaccharide of alfalfa (*Medicago sativa* L.) and change three-dimensional structure, and then improve the anti-lipid formation of alfalfa polysaccharide[40]. The increase of Ara content can promote the formation of cell walls, which in turn protects cells from environmental damage. *Gentiana dahurica* Fisch. (*G. dahurica*) is one of the legitimate sources of Qinjiao in Traditional Chinese Medicine and grows on high-altitude plateaus with the strong UV irradiation. The crude polysaccharide isolated from *G. dahurica* (GDP) contained up to 49.51% Ara, which is much higher than that of *Gentiana straminea* (3.24%)[41]. The high content of Ara may be attributed to plant biosynthesis as a response to UV stress in the regional climate on the Qinghai-Tibet Plateau. Meanwhile, GDPs exert protective effects against UVB irradiation by reducing reactive oxygen species (ROS) and attenuating S-phase cell arrest[42]. It can be seen that the environment can affect the composition and structure of FMH polysaccharides, and then make them have stronger activity.

3 FMH can regulate the body's environmental adaptability

FMH are diverse and produce a wide range of metabolites with various bioactive properties, such as resistance to plateau hypoxia, radiation, cold and moisture. The different active components carried by FMH substances as information can be transmitted to the body performing biological functions to regulate the body's adaptation to the environment. For instance, ginsenosides, puerarin and 6-gingerol can improve the body's radiation tolerance, reduce alcoholic steatohepatitis and relieve oxidative stress[43-45]. The raw materials of different environments are a great treasure house of FMH substances. The FMH substances growing in a special environment can produce special secondary metabolites or increase the content of secondary metabolites, thus influencing the environmental adaptability of the body, which is transmitting the information to the body. FMH substances can transmit their own information to the body through dietary intervention, to improve environmental adaptability of the body. In this section, the regulatory effect and possible mechanisms of FMH on the adaptability of organisms to extreme environment were summarized and emphasized (Table 2).

3.1 FMH regulates the body's adaptation to hypoxic environment

Hypoxia is a pathological condition resulting from a lack of oxygen throughout the body or in specific body organs and

Table 2 The regulatory effect of FMH on the adaptability of the body to extreme environments.

FMH	Extreme environments	Cell/animal/human	Possible mechanisms of environmental adaptability	Reference
Rhodiola crenulate (Salidroside)	Hypoxic environment	PC12 cells	Regulate the PI3K/Akt/NF-κB signaling pathway	[21]
Osmanthus fragrans Lour. Flowers	Hypoxic environment	PC12 cells	Promote cell proliferation	[84]
Polygonatum kingianum	Hypoxic environment	H9C2 cells and SD rats	Prolong survival time and regulate the targets-related biochemical parameters of rats under hypoxia	[54]
Arenaria kansuensis	Hypoxic environment	RSC96 cells and C57BL mice	Scavenge free radicals and inhibit the cell permeability and the leakage of LDH	[49]
Saussurea involucrate	Hypoxic environment	BALB/c mice	Decrease the mortality rate	[48]
Chinese *cordyceps*	Hypoxic environment	ICR mice	Modulate the VEGF signal pathway	[50]
wild mushroom *Agaricus blazei (Quél.)*	Hypoxic environment	Kunming mice	Prolong the survival time, increase GSH-Px, CAT and SOD activities and decrease MDA and NO levels.	[52]
Cantharellus cibarius	Hypoxic environment	Swiss albino mice	Prolong survival time	[53]
Codonopsis pilosula	Hypoxic environment	ICR mice	Prevent lipid peroxidation and enhance antioxidant activity	[55]
Ginseng	Hypoxic environment	BALB/C mice	Promote angiogenesis	[56]
Walnut	Hypoxic environment	BALB/C mice	Improve the blood's oxygen carrying capacity and oxygen utilization rate, reduce lipid peroxidation damage, increase the brain's ability to buffer against lactic acidosis and promote angiogenesis	[57]
Portulaca oleracea	Hypoxic environment	ICR mice	Promote the activity of the key enzymes in glycolysis and improve the level of ATP	[59]
Zingiber officinale	Hypoxic environment	Swiss albino mice and Albino Wistar rats	Reverse the weight gain of liver and adrenal gland and the atrophy of spleen induced by hypoxic stress model	[60]
Crataegus	Hypoxic environment	Swiss albino mice	Prolong survival time	[61]
Rhodiola crenulata	Hypoxic environment	Human feeding trial	Increase the level of SpO_2 and reduce heart rate	[51]
Cordyceps	Radiation environment	HaCaT cells	Perform antioxidative and anti-DNA damage effect on UVB-induced damage.	[64]
Acacia reticulata	Radiation environment	HS68 cells	Reduce the production of ROS, increase expression of antioxidant enzymes, weaken MAPK/AP-1 signaling	[65]
Lily	Radiation environment	Human umbilical Vein endothelial cells	Protect DNA double-strand breaks	[70]
Litchi chinensis	Radiation environment	L929 fibroblast cells	Reduce DNA damage	[71]
Red ginseng	Radiation environment	C57BL/6 mice	Decrease IR-induced phosphorylation of Akt and p38 MAPK and down-regulate COX-2 expression.	[66]
Lonicerae japonicae flos	Radiation environment	SD rats	Modulate the GTPCH1/BH4/eNOS pathway	[67]
Date palm (*Phoenix dactylifera*)	Radiation environment	Albino rats	Modulate oxidative damage	[68]
Angelica sinensis	Cold environment	Human umbilical vascular endothelial cells	Regulate the expression of NO and eNOS.	[73]
Ginseng	Cold environment	Wistar male rats	Inhibit cardiomyocyte apoptosis via regulating SIRT1 expression and attenuating the inflammatory responses.	[74]
Poria	Cold environment	Rats	Alleviate cold-deficiency syndrome and raise the decreased levels of glucokinas, phosphoglycerate kinase, cytochrome c reductase and triiodothyronine	[76]
Rosa canina L.	Damp heat environment	Wistar rats	Decrease the overproduction of ROS and the expression of p-PERK, p-eIF2 alpha and CHOP protein	[78]
Shengmai san	Damp heat environment	SD rats	Inhibition of iNOS-dependent NO overproduction in the brain and excessive accumulation of several inflammatory cytokines in the peripheral blood stream.	[79]

tissues[46]. It has been found that medicinal and food plants growing in the plateau area have unique characteristics such as strong resistance, a solid root system, and adaptation to low temperatures[47]. Additionally, some plants native to the plateau area have been shown to possess the ability to alleviate symptoms of hypoxia, such as *Rhodiola crenulata*, *Saussurea involucrate*, *Arenaria kansuensis* and Chinese *cordyceps*[21, 48-50]. In particular, Chinese *cordyceps*, a parasitic Thitarodes insect-Ophiocordyceps sinensis fungal complex on the Qinghai-Tibet plateau. *Cordyceps* is a traditional Chinese medicine known for its ability to treat a wide range of diseases. It was found that (9Z, 12Z)-octadeca-9,12-dienoic acid and cerevisterol in *Cordyceps* sinensis could promote angiogenesis and thus exert anti-hypoxic effects by modulating the vascular endothelial growth factor (VEGF) signal pathwa[50]. Meanwhile, *Rhodiola crenulata* extract could reverse hypoxia-induced reductions in the blood oxygen saturation (SpO_2) level and cognitive impairment by human feeding trial[51]. In addition, three water-soluble polysaccharides of wild mushroom *Agaricus blazei (Quél.)* could enhance the hypoxia resistance of mice[52]. *Cantharellus cibarius* could effectively prolong the survival time of mice under a hypoxic environment[53]. Polygonati Rhizoma (PK) is a Chinese herbal medicine that can be consumed as medicinal purposes and as a dietary supplement. PK contains gracillin (saponin) and glycyrrhizin (flavonoid) as active ingredients. It exerts anti-hypoxic effects by scavenging excess free radicals, maintaining antioxidant enzyme activities, and inhibiting oxidative stress caused by lipid peroxidation[54]. Oligosaccharides and polysaccharides from Codonopsis pilosula[55], oligopeptides from ginseng and walnut both have anti-hypoxia effect[56, 57]. At the same time, studies have shown that *Portulaca oleracea*, Zingiber officinale Roscoe, *Crataegus pentaegyn* and *Crataegus microphylla* fruits as a food and a Chinese medicine simultaneously, and its ethanol extraction had potential anti-hypoxic activity[58-61].

3.2 FMH regulates body's adaptation to radiation environments

Exposure to ionizing radiation (IR) causes a wide range of biological damage and alterations, including oxidative stress, inflammation and even cancer[62]. And UVB irradiation-induced photoaging leads to wrinkles, dryness, and skin roughness. *Cordyceps* sinensis has the beneficial effects on immune system disorders caused by IR[63]. Meanwhile, it has been shown that *Cordyceps* extracts similarly have antioxidative and anti-DNA damage effects on UVB-induced damage[64]. Studies have shown that *Acacia reticulata* extract has anti-photoaging activity on fibroblasts of UVB-treated human skin[65]. Studies have shown that the administration of red ginseng may improve defense against irradiation-induced oxidative stress[66]. It has been shown that the medicinal and food plant Lonicerae *japonicae* flos and its main component chlorogenic acid could prevent abdominal radiotherapy-induced vascular endothelial dysfunction through the GTPCH1/BH4/eNOS pathway[67]. Meanwhile, the date palm (*Phoenix dactylifera*) pit extract was found to have the ability to modulate the dose reduction factor, antioxidant status, and some biochemical changes in serum and liver tissues. It has radioprotective efficacy against γ-irradiation-induced liver injury in male albino rats[68]. Lanzhou lily (*Lilium davidii var. unicolor)* is the only lily with medicinal and food values in China[69]. Lily polysaccharides (LPs), a key bioactive component found in the bulbs, have demonstrated the ability to mitigate damage caused by radiation exposure[70]. In addition, *Litchi chinensis* as the food and medicine homologous substances, and its extracts protected the cells' DNA against UVA- and UVB-induced damage by decreasing ROS formation[71].

3.3 FMH regulates body's adaptation to cold stress and damp heat environment

Cold stress can lead to the increase of vasoconstrictors and the decrease of cell viability, and then cause damage to the body[72]. It was found that ferulic acid in the Chinese herb *Angelica sinensis* could prevent cold stress-associated cardiovascular disease by reducing the levels of vasoconstrictors such as Transient receptor potential cation channel subfamily M member 8 (TRPM8) and endothelin-1 (ET-1) and improving cell viability[73]. One of the major bioactive components of ginseng, ginsenoside, may be used as a bioactive ingredient in processed functional foods or food supplements to prevent myocardial injury caused by acute cold exposure[74]. In general, herbs considered to have cold or cool properties are thought to help clear heat and detoxify toxins, nourish yin and remove dryness, and address heat-related illnesses, such as *Anemarrhenae Rhizoma*[75]. In contrast, herbs with hot or warm properties, such as the roots of Aconiti Lateralis Radix Praeparaia and the root of *Aconitum carmichaelii* Debx, may be used to treat cold-deficiency conditions[73]. In addition, studies have shown that *Poria* could alleviate cold-deficiency syndrome and raise the decreased levels of glucokinas, phosphoglycerate kinase, cytochrome c reductase and triiodothyronine in cold-deficiency model[76]. In China, the fruit and leaves of tea of fig (*Ficus carica L.*) were used as raw materials for the treatment of damp-heat diarrhea, hemorrhoids and other diseases[77]. Overexposure to heat conditions can affect the functioning of the cardiovascular system and may promote cardiovascular disorders. Heat shock induced myocardial injury via increasing endoplasmic reticulum response-mediated apoptosis, pretreatment with the natural antioxidant *Rosa canina* L. alleviates heat stress-induced myocardial injury in rats[78]. Shengmai san (SMS) is a Chinese herb that is also used as a food. SMS could effectively inhibit cerebral ischemia and damage during heat stroke by reducing cerebral oxidative stress[79]. Huoxiang Zhengqi Dropping Pills/powder/ liquid (*Atractylodis Rhizoma, Citri Reticulatae Pericarpium, Magnoliae Officinalis Cortex, Atractylodis Macrocephalae Rhizoma, Poria, Arecae Pericarpium, Pinelliae Rhizoma, Glycyrrhizae Radix Et Rhizoma, Pogostemonis Herba, and Perillae Folium.*) has good efficacy in the treatment of acute heat stroke, which could treat acute heat stroke by regulating gastrointestinal dysfunction and anti-inflammatory intestinal function-regulating activity, and alleviate the body's damp-heat syndrome[80, 81]. In addition, it has also been reported that *Pogostemonis Herba* and *Magnoliae Officinalis Cortex*, the main active substance of Huoxiang Zhengqi Dropping Pills/powder/ liquid, have also been shown to alleviate heat stress[82, 83].

4 Future perspectives on FMH and environmental adaptation

The active components and various physiological activities of FMH have been confirmed by many studies. However, how FMH substances transmit environmental information to the body to improve the environmental adaptability of the body is not clear. During thousands of years of adaptation and evolution of extreme ecological systems, there are complex regulatory relationships among environment, FMH substances and organisms. As a medium, FMH participates in the mutual adaptation between the environment and body. The environment can affect the contents and structure of special active components in FMH. In turn, FMH, which carries special information, can transmit the signal to the body, thereby improving the body's tolerance and adaptability (Fig.1). Most existing studies have only established associations between the environment and FMH, or between FMH and human health, but have not elucidated the interaction between the environment, FMH, and the body's environmental adaptation. Exploring and elucidating the interaction relationship and the mechanism of information exchange among the environment, FMH and environmental adaptation of body are also the focus of future research. The mechanism of mutual adaptation between body and environment based on food intake is the basis of comprehensive utilization of FMH substances and is worthy of further study.

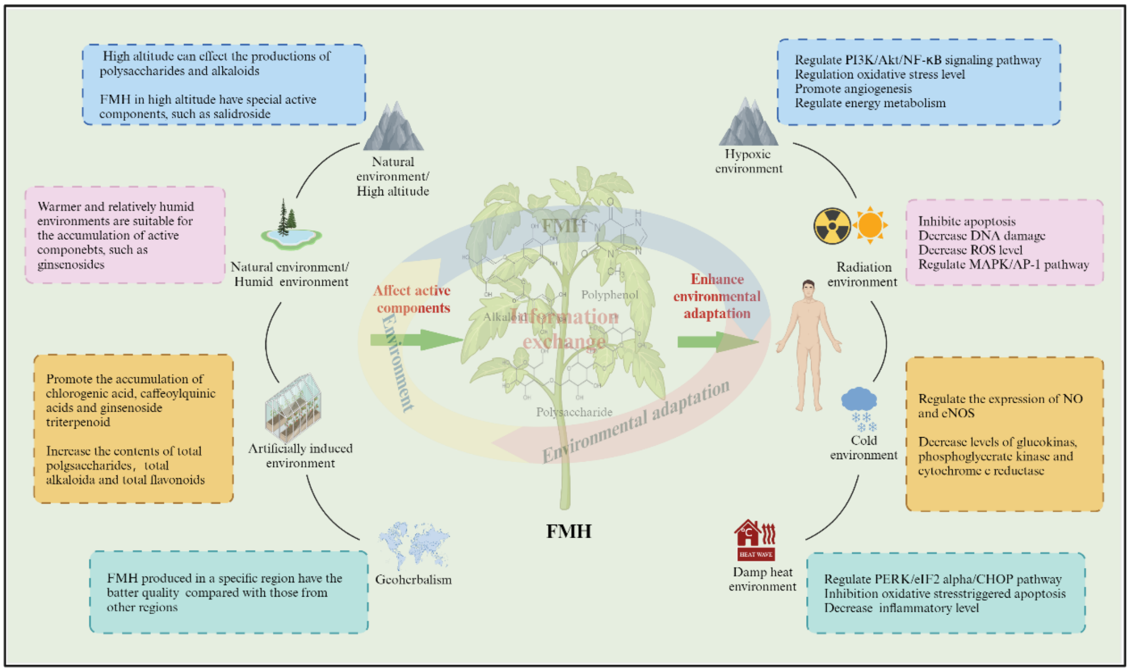

Figure 1 The interaction relation of the environment-FMH-the body's environmental adaptability.

With the continuous progress of computer technology, AI has been applied in many aspects of traditional Chinese medicine culture, such as drug discovery, identification and verification of drug targets, and the screening of active components. As one of the core concepts of TCM culture, FMH has the potential to "accurately regulate" the human body. AI can effectively search for known active components by simulating the interaction between the target and FMH active component candidate. With the development of modern science and technology, the quality evaluation technology of genuine FMH is gradually improving. The fingerprint technology based on active ingredients provides reference and technical support for the identification and quality evaluation of genuine FMH. In the future, combining AI technology, fingerprint technology, and FMH can reveal the mechanisms of FMH information transmission, how environmental factors affect the content and structure of active components, and how these substances influence the body's environmental adaptability. Active induction is an effective strategy to improve the biological activity of organisms. Simulating extreme environments to induce the production of specific active substances and secondary metabolites for biological manufacturing is an effective pathway for the industrialization of FMH in the future.

5 Conclusion

At present, there are complex regulatory relationships among the environment, FMH substances and organisms. However, the interaction between the environment, FMH, and human health has not been definitively proven. This review summarized the special functional factors, such as salidroside and ginsenoside, produced by FMH substances in specific environments. Meanwhile, the influence of FMH on the adaptability and mechanisms of organisms in extreme environments was also discussed. It is an interesting phenomenon that FMH substances from specific environments can promote the body's adaptability to those corresponding environments. Nevertheless, the environment-FMH-human health interaction still requires further research in the future.

Conflicts of interest

The authors declare that there are no conflicts of interest in this work. Jike Lu is an associate editor of Food & Medicine Homology, but was not involved in the processing, peer review or decision making of this article.

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References

[1] Cong, B. Perspectives in Food & Medicine Homology. *Food &*

Medicine Homology, **2024**, 1: 9420018. https://doi.org/10.26599/FMH.2024.9420018
[2] Ho, Z. C. Principles of diet therapy in ancient Chinese medicine: 'Huang Di Nei Jing'. *Asia Pacific journal of clinical nutrition*, **1993**, 2: 91–5. https://apjcn.nhri.org.tw/server/APJCN/2/2/91.pdf
[3] Shan, F., Huang, L., Guo, J., et al. History and development of "one root of medicine and food". *Chinese Bulletin of Life Sciences*, **2015**, 27: 1061–1069. https://doi.org/10.13376/j.cbls/2015146
[4] Ma, A. J. X., Zou, F. M., Zhang, R. W., et al. The effects and underlying mechanisms of medicine and food homologous flowers on the prevention and treatment of related diseases. *Journal of Food Biochemistry*, **2022**, 46: 14430. https://doi.org/10.1111/jfbc.14430
[5] Song, D. X., Jiang, J. G. Hypolipidemic components from medicine food homology species used in China: Pharmacological and Health Effects. *Archives of Medical Research*, **2017**, 48: 569–581. https://doi.org/10.1016/j.arcmed.2018.01.004
[6] Li, Y. C., Liu, B. G., Yang, J., et al. Characterization of polysaccharide from *Lonicera japonica* Thunb leaves and its application in nano-emulsion. *Frontiers in Nutrition*, **2023**, 10: 1248611. https://doi.org/10.3389/fnut.2023.1248611
[7] Zhang, Y., Liu, Y. Q., Zhao, C. C., et al. Polyphenols of brown (*Brassica juncea*) and white (*Sinapis alba*) mustard seeds: Extraction optimization, compositional analysis, antioxidant, and immunomodulatory activities. *Food Bioscience*, **2024**, 58: 103753. https://doi.org/10.1016/j.fbio.2024.103753
[8] Wu, H., Qu, L., Bai, X., et al. Ginsenoside Rk1 induces autophagy-dependent apoptosis in hepatocellular carcinoma by AMPK/mTOR signaling pathway. *Food and Chemical Toxicology*, **2024**, 186: 114587. https://doi.org/10.1016/j.fct.2024.114587
[9] Wang, J., Song, H. B., Huang, Y. J., et al. Protective effect of crocin on peroxidation-induced oxidative stress and apoptosis in IPEC-J2 cells. *Environmental Toxicology*, **2024**. https://doi.org/10.1002/tox.24216
[10] Bai, X. Y., Rao, X. M., Wang, Y. Q., et al. A homogeneous *Lonicera japonica* polysaccharide alleviates atopic dermatitis by promoting Nrf2 activation and NLRP3 inflammasome degradation via p62. *Journal of Ethnopharmacology*, **2023**, 309: 116344. https://doi.org/10.1016/j.jep.2023.116344
[11] Hui, A. L., Chen, J. C., Deng, S. H., et al. Phytochemical profile of alkaloid extract from Dendrobium *huoshanense* and inhibitory effects against oxidative stress in H_2O_2-induced PC12 cells. *Chemistry & Biodiversity*, **2024**, 21. https://doi.org/10.1002/cbdv.202301332
[12] Korbásová, M., Tomenendálová, J., Chloupek, J. Anti-tumour effect of combinations of three acids isolated from *Taraxacum officinale*. *Acta Veterinaria Brno*, **2022**, 91: 77–85. https://doi.org/10.2754/avb202291010077
[13] Li, N., Wang, D., Wen, X. J., et al. Effects of polysaccharides from *Gastrodia elata* on the immunomodulatory activity and gut microbiota regulation in cyclophosphamide-treated mice. *Journal of the Science of Food and Agriculture*, **2023**, 103: 3390–3401. https://doi.org/10.1002/jsfa.12491
[14] Zhou, Y. P., Wu, Q., Yu, W., et al. Gastrodin ameliorates exercise-induced fatigue via modulating Nrf2 pathway and inhibiting inflammation in mice. *Food Bioscience*, **2023**, 51: 102262. https://doi.org/10.1016/j.fbio.2022.102262
[15] Cao, W., Wu, J. P., Zhao, X. Y., et al. Structural elucidation of an active polysaccharide from *Radix Puerariae lobatae* and its protection against acute alcoholic liver disease. *Carbohydrate Polymers*, **2024**, 325: 121565. https://doi.org/10.1016/j.carbpol.2023.121565
[16] Wang, Z. P., Wang, T. T., Hu, J., et al. Comparisons of wild and cultivated American ginseng (*Panax quinquefolius* L.) genomes provide insights into changes in root growth and metabolism during domestication. *Plant Biotechnology Journal*, **2024**, 84: 310–321. https://doi.org/10.1111/pbi.14316
[17] Kumar, R., Kumari, M. Adaptive mechanisms of medicinal plants along altitude gradient: contribution of proteomics. *Biologia Plantarum*, **2018**, 62: 630–640. https://doi.org/10.1007/s10535-018-0817-0
[18] Galitsyn, G., Lomovskiy, I., Podgorbunskikh, E. Seasonal and geographic variation in serotonin content in sea buckthorn. *Plant Foods for Human Nutrition*, **2023**, 78: 186–192. https://doi.org/10.1007/s11130-022-01038-2
[19] Li, Y. Q., Kong, D. X., Fu, Y., et al. The effect of developmental and environmental factors on secondary metabolites in medicinal plants. *Plant Physiology and Biochemistry*, **2020**, 148: 80–89. https://doi.org/10.1016/j.plaphy.2020.01.006
[20] Song, D., Zhao, M., Feng, L. X., et al. Salidroside attenuates acute lung injury via inhibition of inflammatory cytokine production. *Biomedicine & Pharmacotherapy*, **2021**, 142: 111949. https://doi.org/10.1016/j.biopha.2021.111949
[21] Wu, Y., Ma, Y., Li, J., et al. The bioinformatics and metabolomics research on anti-hypoxic molecular mechanisms of Salidroside *via* regulating the PTEN mediated PI3K/Akt/NF-κB signaling pathway. *Chinese Journal of Natural Medicines*, **2021**, 19: 442–453. https://doi.org/10.1016/S1875-5364(21)60043-2
[22] Zhu, H. K., Liu, C., Qian, H. Pharmaceutical potential of high-altitude plants for fatigue-related disorders: A review. *Plants-Basel*, **2022**, 11: 2004. https://doi.org/10.3390/plants11152004
[23] Wang, J. R., Leung, C. Y., Ho, H. M., et al. Quantitative comparison of ginsenosides and polyacetylenes in wild and cultivated American ginseng. *Chemistry & Biodiversity*, **2010**, 7: 975–983. https://doi.org/10.1002/cbdv.200900264
[24] Deng, L. M., Luo, L. F., Li, Y., et al., Autotoxic ginsenoside stress induces changes in root exudates to recruit the Beneficial *Burkholderia* strain B36 as revealed by transcriptomic and metabolomic approaches. *Journal of Agricultural and Food Chemistry*, **2023**, 71: 4536–4549. https://doi.org/10.1021/acs.jafc.3c00311
[25] Zhu, L. L., Xu, L., Huang, Y., et al. Correlations between ecological factors and the chemical compositions of mountainous forest cultivated ginseng. *Journal of Food Composition and Analysis*, **2022**, 114: 104867. https://doi.org/10.1016/j.jfca.2022.104867
[26] Yan, K., Cui, J. X., Zhi, Y. B., et al. Deciphering salt tolerance in tetraploid honeysuckle (*Lonicera japonica* Thunb.) from ion homeostasis, water balance and antioxidant defense. *Plant Physiology and Biochemistry*, **2023**, 195: 266–274. https://doi.org/10.1016/j.plaphy.2023.01.013
[27] Zhu, Y., Gu, W., Tian, R., et al. Morphological, physiological, and secondary metabolic responses of *Taraxacum officinale* to salt stress. *Plant Physiology and Biochemistry*, **2022**, 189: 71–82. https://doi.org/10.1016/j.plaphy.2022.08.002
[28] Balusamy, S. R., Rahimi, S., Yang, D. C. Characterization of squalene-induced PgCYP736B involved in salt tolerance by modulating key genes of abscisic acid biosynthesis. *International Journal of Biological Macromolecules*, **2019**, 121: 796–805. https://doi.org/10.1016/j.ijbiomac.2018.10.058
[29] Liu, L., Xiang, H. X., Shen, H. M., et al. Effects of low phosphorus stress on the main active ingredients and antioxidant activities of *Dendrobium officinale*. *Industrial Crops and Products*, **2021**, 173: 114095. https://doi.org/10.1016/j.indcrop.2021.114095
[30] Feng, X. Y., Cui, D. D., Zeng, L. J., et al. Effects of UV-B irradiation alone and in combination with salicylic acid on the growth and active ingredients of *Dendrobium officinale*. *Russian Journal of Plant Physiology*, **2021**, 68: 483–490. https://doi.org/10.1134/S1021443721030043
[31] Saman, R. U., Shahbaz, M., Maqsood, M. F., et al. Foliar application of ethylenediamine tetraacetic acid (EDTA) improves the growth and yield of brown mustard (*Brassica juncea*) by modulating photosynthetic pigments, antioxidant defense, and osmolyte production under lead (Pb) stress. *Plants-Basel*, **2023**, 12: 115. https://doi.org/10.3390/plants12010115
[32] Gupta, S. M., Grover, A., Pandey, P. et al. Female plants of *Hippophae salicifolia* D. Don are more responsive to cold stress than male plants. *Physiology and Molecular Biology of Plants*, **2012**, 18:

377–80. https://doi.org/10.1007/s12298-012-0133-7
[33] Chen, X. L., Sun, S. C., Han, X. X., et al. Multiomics comparison among populations of three plant sources of Amomi Fructus. *Horticulture Research*, **2023**, 10: 128. https://doi.org/10.1093/hr/uhad128
[34] Li, Z., Song, L., Wang, H., et al. Analysis of inorganic elements characteristics of *Stellariae Radix* from different producing areas based on ICP-MS combined with multiple statistics. *Chinese Journal of Information on Traditional Chinese Medicine*, **2022**, 29: 103–109. https://doi.org/10.19879/j.cnki.1005-5304.202110406
[35] Li, C., Jing, W., Mo, X., et al. Research progress in chemical constituents and pharmacological effects of *Pogostemon cablin* and predictive analysis of quality marker. *Chinese Pharmaceutical Journal*, **2023**, 58: 954–965. https://doi.org/10.11669/cpj.2023.11.002
[36] He, J., Huang, W., Ma, X., et al. Geoherbalism and grand evaluation of Zhejiang *Ophiopogon japonicas* based on PCA and PLS-DA. *Chinese Pharmaceutical Journal*, **2021**, 56: 285–292. https://doi.org/10.11669/cpj.2021.04.005
[37] Zhao, L., Shi, M., Zhang, Q., et al. Research progress on quality characteristics and formation mechanism of genuine medicinal materials. *Chinese Traditional and Herbal Drugs*, **2022**, 53: 6931–6947. https://doi.org/10.7501/j.issn.0253-2670.2022.21.032
[38] Zhou, T., Tang, Y. D., Zhou, L. P., et al. Transcriptomic divergence of the *Rheum palmatum* complex derived from top-geoherb and non-geoherb areas provides the insights into geoherbalism properties of rhubarb. *BMC Genomics*, **2024**, 25: 212. https://doi.org/10.1186/s12864-024-10142-3
[39] Xu, J. Q., Zhang, J. L., Sang, Y. M., et al. Polysaccharides from medicine and food homology materials: A review on their extraction, purification, structure, and biological activities. *Molecules*, **2022**, 27: 3215. https://doi.org/10.3390/molecules27103215
[40] Zhang, C. Y., Kim, E., Cui, J. M. et al. Influence of the ecological environment on the structural characteristics and bioactivities of polysaccharides from alfalfa (*Medicago sativa* L.). *Food & Function*, **2022**, 13: 7942–7943. https://doi.org/10.1039/d2fo00371f
[41] Shi, S., Wang, G. C., Liu, J., et al. *Gentiana straminea* Maxim. polysaccharide decolored via high-throughput graphene-based column and its anti-inflammatory activity. *International Journal of Biological Macromolecules*, **2021**, 193: 1727–1733. https://doi.org/10.1016/j.ijbiomac.2021.11.010
[42] Ji, W., Qian, C., Su, X., et al. Structure characterization and protective effect against UVB irradiation of polysaccharides isolated from the plateau plant *Gentiana dahurica* Fisch. *International Journal of Biological Macromolecules*, **2024**, 267: 131551. https://doi.org/10.1016/j.ijbiomac.2024.131551
[43] Duan, X. Y., Cai, H. Y., Hu, T. T., et al. Ginsenoside Rg3 treats acute radiation proctitis through the TLR4/MyD88/NF-κB pathway and regulation of intestinal flora. *Frontiers in Cellular and Infection Microbiology*, **2023**, 12: 1028576. https://doi.org/10.3389/fcimb.2022.1028576
[44] Fang, X. X., Lan, X. T., Zhu, M., et al. Puerarin induces macrophage M2 polarization to exert antinonalcoholic steatohepatitis pharmacological activity via the activation of autophagy. *Journal of Agricultural and Food Chemistry*, **2024**, 72: 7187–7202. https://doi.org/10.1021/acs.jafc.3c09601
[45] Hosseini, A., Alavi, M. S., Toos, M. G. N., et al. 6-Gingerol, an ingredient of *Zingiber officinale*, abrogates lipopolysaccharide-induced cardiomyocyte injury by reducing oxidative stress and inflammation. *Journal of Agriculture and Food Research*, **2024**, 15: 101034. https://doi.org/10.1016/j.jafr.2024.101034
[46] Zhang, Q. H., Zhao, W. B., Li, S. J., et al. Intermittent hypoxia conditioning: A potential multi-organ protective therapeutic strategy. *International Journal of Medical Sciences*, **2023**, 20: 1551–1561. https://doi.org/10.7150/ijms.86622
[47] Liu, J. C., Ge, Z., Jiang, X., et al. A comprehensive review of natural products with anti-hypoxic activity. *Chinese Journal of Natural Medicines*, **2023**, 21: 499–515. https://doi.org/10.1016/S1875-5364(23)60410-8
[48] Ma, H. P., Fan, P. C., Jing, L., et al. Anti-hypoxic activity at simulated high altitude was isolated in petroleum ether extract of *Saussurea involucrata*. *Journal of Ethnopharmacology*, **2011**, 137: 1510–1515. https://doi.org/10.1016/j.jep.2011.08.037
[49] Cui, Y. L., Tao, Y. D., Jiang, L., et al. Antihypoxic activities of constituents from *Arenaria kansuensis*. *Phytomedicine*, **2018**, 38: 175–182. https://doi.org/10.1016/j.phymed.2017.12.008
[50] Long, H. L., Qiu, X. H., Cao, L., et al. Discovery of the signal pathways and major bioactive compounds responsible for the anti-hypoxia effect of Chinese cordyceps. *Journal of Ethnopharmacology*, **2021**, 277: 114215. https://doi.org/10.1016/j.jep.2021.114215
[51] Lee, S. Y., Lin, K. T., Chen, Y., et al., *Rhodiola crenulata* extract supplement significantly attenuates hypoxia-reduced oxygen saturation and cognitive function. *Journal of Herbal Medicine*, **2023**, 41: 100732. https://doi.org/10.1016/j.hermed.2023.100732
[52] Jiao, Y. C., Kuang, H., Hu, J. J., et al. Structural characterization and anti-hypoxia activities of polysaccharides from the sporocarp, fermentation broth and cultured mycelium of *Agaricus bitorquis* (Quel.) Sacc. Chaidam in mice. *Journal of Functional Foods*, **2018**, 51: 75–85. https://doi.org/10.1016/j.jff.2018.10.017
[53] Khalili, M., Ebrahimzadeh, M. A., Omrani, F., et al. Antihypoxic activities of the golden chanterelle mushroom, *Cantharellus cibarius* (Higher Basidiomycetes). *International Journal of Medicinal Mushrooms*, **2014**, 16: 339–344. https://doi.org/10.1615/IntJMedMushrooms.v16.i4.40
[54] Li, X., Mei, M. J., Pu, X. M. et al. Protective effect and mechanism of Polygonatum kingianum against hypoxia-induced injury. *Heliyon*, **2023**, 9: e14353. https://doi.org/10.1016/j.heliyon.2023.e14353
[55] Xie, Q., Sun, Y. T., Cao, L. L., et al. Antifatigue and antihypoxia activities of oligosaccharides and polysaccharides from *Codonopsis pilosula* in mice. *Food & Function*, **2020**, 11: 6352–6362. https://doi.org/10.1039/d0fo00468e
[56] Li, D., Ren, J. W., Sun, J. Q., et al. Anti-hypoxia effects of ginseng (*Panax Ginseng* C A Meyer) oligopeptides in mice. *Tropical Journal of Pharmaceutical Research*, **2021**, 20: 1447–1454. https://doi.org/10.4314/tjpr.v20i7.18
[57] Li, D., Ren, J. W., Wang, T. X., et al. Anti-hypoxia effects of walnut oligopeptides (*Juglans regia* L.) in mice. *American Journal of Translational Research*, **2021**, 13: 4581–4590. https://pmc.ncbi.nlm.nih.gov/articles/PMC8205819/pdf/ajtr0013-4581.pdf
[58] Niu, G. Progress on chemical compositions and pharmacological function of *Portulace oleracea* L. *Journal of Anhui Agricultural Sciences*, **2005**, 33: 1090–1092. https://doi.org/10.13989/j.cnki.0517-6611.2005.06.093
[59] Chen, C. J., Wang, W. Y., Wang, X. L., et al. Anti-hypoxic activity of the ethanol extract from *Portulaca oleracea* in mice. *Journal of Ethnopharmacology*, **2009**, 124: 246–250. https://doi.org/10.1016/j.jep.2009.04.028
[60] Lakshmi, B. V. S., Sudhakar M. Attenuation of acute and chronic restraint stress-induced perturbations in experimental animals by *Zingiber officinale* Roscoe. *Food and Chemical Toxicology*, **2010**, 48: 530–535. https://doi.org/10.1016/j.fct.2009.11.026
[61] Ebrahimzadeh, M. A., Khalili, M., Jafari, N., et al. Antihypoxic activities of *Crataegus pentaegyn* and *Crataegus microphylla* fruits-an *in vivo* assay. *Brazilian Journal of Pharmaceutical Sciences*, **2018**, 54: 217363. https://doi.org/10.1590/s2175-97902018000217363
[62] Maher, K. R., Bouligny, I. M., Yeager, A. M. Prevention and management of infections after exposure to ionising radiation. *Journal of Radiological Protection*, **2021**, 41: R176–R188. https://doi.org/10.1088/1361-6498/ac14d3
[63] Wei, S. N., Peng, W. B., Zhang, C. X., et al. *Cordyceps sinensis* aqueous extract regulates the adaptive immunity of mice subjected to ^{60}Co γ irradiation. *Phytotherapy Research*, **2021**, 35: 5163–5177. https://doi.org/10.1002/ptr.7186
[64] He, H. L., Tang, J., Ru, D., et al. Protective effects of *Cordyceps*

extract against UVB-induced damage and prediction of application prospects in the topical administration: An experimental validation and network pharmacology study. *Biomedicine & Pharmacotherapy*, **2020**, 121: 109600. https://doi.org/10.1016/j.biopha.2019.109600

[65] Seo, H., Kim, C., Kim, M.B., et al. Anti-Photoaging Effect of Korean Mint (Agastache rugosa Kuntze) Extract on UVB-Irradiated Human Dermal Fibroblasts. *Preventive Nutrition and Food Science*, **2019**, 24: 442–448. https://doi.org/10.3746/pnf.2019.24.4.442

[66] Koo, H. J., Jang, S. A., Yang, K. H., et al. Effects of red ginseng on the regulation of cyclooxygenase-2 of spleen cells in whole-body gamma irradiated mice. *Food and Chemical Toxicology*, **2013**, 62: 839–846. https://doi.org/10.1016/j.fct.2013.10.009

[67] Mu, W., Zhang, L. H., Jiang, W., et al. *Lonicerae japonicae* flos ameliorates radiotherapy-induced mesenteric artery endothelial dysfunction through GTPCH1/BH4/eNOS pathway. *Phytomedicine*, **2022**, 102: 154146. https://doi.org/10.1016/j.phymed.2022.154146

[68] Abdel-Magied, N., Ahmed, A. G., Zid, N. A. Possible ameliorative effect of aqueous extract of date (*Phoenix dactylifera*) pits in rats exposed to gamma radiation. *International Journal of Radiation Biology*, **2018**, 94: 815–824. https://doi.org/10.1080/09553002.2018.1492165

[69] Li, W. M., Wang, Y. J., Wei, H. L., et al. Structural characterization of Lanzhou lily (*Lilium davidii* var. *unicolor*) polysaccharides and determination of their associated antioxidant activity. *Journal of the Science of Food and Agriculture*, **2020**, 100: 5603–5616. https://doi.org/10.1002/jsfa.10613

[70] Kang, S., Guo, Z., Zhao, F., et al. Lanzhou Lily polysaccharide fragment protects human umbilical vein endothelial cells from radiation-induced DNA double-strand breaks. *Human & Experimental Toxicology*, **2022**, 41: 09603271221140110. https://doi.org/10.1177/09603271221140110

[71] Thiesen, L. C., Baccarin, T., Fischer-Muller, A. F., et al. Photochemoprotective effects against UVA and UVB irradiation and photosafety assessment of *Litchi chinensis* leaves extract. *Journal of Photochemistry and Photobiology B-Biology*, **2017**, 167: 200–207. https://doi.org/10.1016/j.jphotobiol.2016.12.033

[72] Ikaheimo, T. M. Cardiovascular diseases, cold exposure and exercise. *Temperature* (*Austin*), **2018**, 5: 123–146. https://doi.org/10.1080/23328940.2017.1414014

[73] Huang, S., Ma, S. S., Zhang, D., et al. Protective effect of ferulic acid on human umbilical vein endothelial cell model of cold stress. *Pharmacognosy Magazine*, **2020**, 16: 7–12. https://doi.org/10.4103/pm.pm_631_18

[74] Xue, Y., Yu, X. F., Zhang, X. H., et al. Protective effects of ginsenoside Rc against acute cold exposure-induced myocardial injury in rats. *Journal of Food Science*, **2021**, 86: 3252–3264. https://doi.org/10.1111/1750-3841.15757

[75] Jia, Y., Zhang, Z. Z., Wei, Y. H., et al. Metabolomics coupled with similarity analysis advances the elucidation of the cold/hot properties of traditional Chinese medicines. *Chinese Journal of Natural Medicines*, **2017**, 15: 631–640. https://doi.org/10.3724/SP.J.1009.2017.00631

[76] Han, X. Y., Wang, Y. N., Dou, D. Q. Regulatory effects of *Poria* on substance and energy metabolism in cold-deficiency syndrome compared with heat-deficiency syndrome in rats. *Chinese Journal of Natural Medicines*, **2018**, 16: 936–945. https://doi.org/10.1016/S1875-5364(18)30135-3

[77] Jiang, X. Y., Wang, C. W., Zhang, J., et al. Effects of different extraction methods on physicochemical characteristics and bioactivities of fig (*Ficus carica* L.) leaves polysaccharides. *Arabian Journal of Chemistry*, **2023**, 16: 105319. https://doi.org/10.1016/j.arabjc.2023.105319

[78] Nasrolahi, A., Hosseini, L., Farokhi-Sisakht, F., et al. Cardioprotective effect of *Rosa canina* L. methanolic extract on heat shock induced cardiomyocyte injury: An experimental study. *Journal of Cardiovascular and Thoracic Research*, **2020**, 12: 286–293. https://doi.org/10.34172/jcvtr.2020.47

[79] Wang, N. L., Chang, C. K., Liou, Y. L., et al. *Shengmai San*, a Chinese herbal medicine protects against rat heat stroke by reducing inflammatory cytokines and nitric oxide formation. *Journal of Pharmacological Sciences*, **2005**, 98: 1–7. https://doi.org/10.1254/jphs.FP0050018

[80] Li, Y. N., Tao, H., Hong, J. H., et al. The Chinese herbal formula Huoxiang Zhengqi Dropping Pills prevents acute intestinal injury induced by heatstroke by increasing the expression of claudin-3 in rats. *Evidence-Based Complementary and Alternative Medicine*, **2022**, 2022: 9230341. https://doi.org/10.1155/2022/9230341

[81] Huang, Q. F., Gong, M. J., Chen, Y. F., et al. Effects of Huoxiang Zhengqi Oral Liquid on intestinal barrier function in rats with dampness obstructing spleen-stomach syndrome. *Zhongguo Zhong yao za zhi*, **2020**, 45: 2144–2150. https://doi.org/10.19540/j.cnki.cjcmm.20200213.401

[82] Xu, Y., Ding, L. Z., Wang, Z. T., et al. Virtual screening of cablin patchouli herb as a treatment for heat stress: A study based on network pharmacology, molecular docking, and experimental verification. *Evidence-Based Complementary and Alternative Medicine*, **2021**, 2021: 8057587. https://doi.org/10.1155/2021/8057587

[83] Chang, C. P., Hsu, Y. C., Lin, M. T. Magnolol protects against cerebral ischaemic injury of rat heatstroke. *Clinical and Experimental Pharmacology and Physiology*, **2003**, 30: 387–392. https://doi.org/10.1046/j.1440-1681.2003.03847.x

[84] Zhou, F., Zhao, Y. J., Li, M. Q., et al. Degradation of phenylethanoid glycosides in *Osmanthus fragrans* Lour. flowers and its effect on anti-hypoxia activity. *Scientific Reports*, **2017**, 7: 10068. https://doi.org/10.1038/s41598-017-10411-0