Antioxidative Activities of Medicinal Plants from TCM

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Abstract: As a natural antioxidant resource, traditional Chinese medicine (TCM) has been paid much more attentions than before. The studies on its antioxidative activity have also increased dramatically in recent years. Abundant studies on TCM show that some TCM can increase body's activity of antioxidant enzymes, enhance body's ability of scavenging free radicals and decrease the generation of lipid peroxide (LPO) and malondialdehyde (MDA) in the body etc. The action mechanism of TCM is closely related to its active constituents, including polysaccharides, quinines, flavonoids, saponins, alkaloids, terpenes, phenolic acids compounds and tannins etc. Through referring to related reports on TCM, in the last 20 years, this paper reviews literatures involved in antioxidation research on TCM. Antioxidative mechanism, functional property and application prospect of some active constituents with antioxidation in TCM are discussed.

Keywords: Traditional Chinese medicine (TCM), antioxidative effect, antioxidative mechanism, active constituents.

1. INTRODUCTION

Although the pharmacology function of traditional Chinese medicine (TCM) and western medicine treads different paths, they reach the same destination in some aspects. The mechanism of TCM is continuously elucidated with its extended and further researches. As chemical synthetic antioxidants often have side effects, e.g. butylated hydroxytoluene (BHT) and butylated hydroxyanisole (BHA), commonly used as food preservatives, but use of such compounds has been related to health risks resulting in strict regulations over their use in foods [1], finding nontoxic antioxidants from natural medicine has become the focus in recent years. Current studies have shown that some efficacies of TCM have close relationship with their antioxidative effects. Some tonics from TCM have prominent functions of anti-aging and anti-fatigue, and making body strong, all of which are attributed to their antioxidation [2].

Studies on antioxidative activity of TCM have increased dramatically in recent years because people pay more attentions on the potential applications of TCM (rich and natural derived antioxidant compounds). Some studies have shown that a group of "clearing heat" TCMs have more powerful antioxidative activity than common edible plants, as they have great pharmaceutical activities including antiinflammatory, antitumor, antiallergic, antivirus and antibacterial effects. Their pharmaceutical activities are partly related to their ability of antioxidation and scavenging free radicals.

Besides hereditary factor, the aging process is still related to some unfavorable factors that can damage the body, such as damage to DNA, proteins and lipids in the body. If free radicals produced during normal metabolism process are quickly scavenged by body’s defense system, they will not damage human body. However, if not completely scavenged, they can destroy biological macromolecules and cause human body aging [3, 4]. This defense system is divided into two kinds: one is the function of antioxidase, the other is the function of antioxidant [5]. In recent years, the utility of antioxidant therapies to many diseases is well recognized. Cellular damage arising from an imbalance between free radical generating and scavenging systems has been implicated in the pathogenesis of a wide range of disorders, including cardiovascular disease, cancer and aging [6]. Many kinds of TCM can improve the activity of body’s antioxidase, reduce damage to the body caused by free radicals, decrease the generation of lipid peroxide (LPO) and malondialdehyde (MDA) [7].

At present it has been found that antioxidative constituents of the plant drugs include polysaccharides, quinones, flavonoids, saponins, alkaloids, terpene, phenolic acids compounds, tannin, etc. Through scavenging free radicals and reducing oxidative substances in the body, the herb constituents play an important role in protecting the body from suffering oxidative injury. However, a kind of TCM often contains one or more active constituents, the antioxidation of TCM is the synergy of a variety of active constituents [8]. This article reviews the research progress on antioxidation of TCM in the past 20 years.

2. THE ANTIOXIDATIVE MECHANISM OF TCM

2.1. Scavenge Reactive Oxygen Free Radicals

Free radicals are mainly generated in the body by various endogenous systems, exposure to different physicochemical conditions or pathophysiological states. Free radicals can adversely alter lipids, proteins and DNA and have been implicated in aging and a number of human diseases [9].

Reactive oxygen free radicals are directly or indirectly transformed by oxygen. They include single electron

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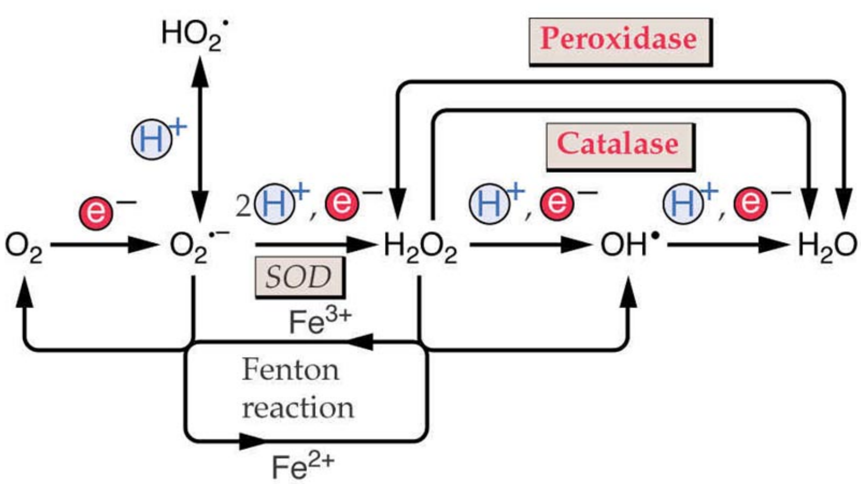
reaction products of oxygen, such as $O_2^{-}\cdot$, H_2O_2 and their derivatives, such as ·OH, $^1O_2$ and also include lipid peroxidation intermediate products, such as LO, LO_2^-, LOOH. These substances are more active than oxygen [7]. The mutual transformation process is shown roughly in Fig. (**1**).

Reactive oxygen species (ROS) are constantly formed in the human body and removed by antioxidant defenses. They will damage the body when their concentrations are over physiological limits. Damaged sulfhydryl group can make enzyme protein deactivation**;** damaged DNA can cause cell mutation**;** damaged nucleotide coenzyme can interfere with certain biochemical metabolism; attacked polyunsaturated fatty acid can cause lipid peroxidation [10-12]. ·OH is the most active oxygen free radical containing an unpaired electron. It can quickly react with any molecular in living cells and damage it. So it is the most toxic free radical to human body. $O_2^{-}\cdot$ is the leading cause of body poisoning that can make nucleic acid chain ruptured, polysaccharide depolymerized and unsaturated fatty acid peroxided, then cause the membrane injury, mitochondria oxidative phosphorylation and so on. An antioxidant is a substance that, when present at low concentrations compared to that of an oxidizable substrate, significantly delays or prevents oxidation of that substrate. Antioxidants can act by scavenging biologically important ROS, by preventing their formation, or by repairing the damage that they do [13-15].

DPPH (α, α-diphenye-β-picryl hydrazyl) radical analysis is a simple and convenient method of screening free radical scavenging agent. The experiment principle is based on the property of DPPH· with single electron having a strong absorption (deep purple) at 517 nm [16]. The degree of scavenging free radicals is determined by spectrophotometer for quantitative analysis. The antioxidative activities of 23 kinds of extracts from TCM compared by DPPH analysis are shown in Table **1**, which provides some basis materials for further research on the mechanism of TCM's antioxidation and provides some experiment basis for screening antioxidative TCM and their applications. Samples' ability of scavenging DPPH· can be expressed as formula: $SA (\%) = [A_0-(A_1-A_2)]/ A_0\times100\%$. A_0 means the absorbance of the mixture of DPPH· and solvent; A_1 means the absorbance of the mixture of samples and DPPH· after reacting; A_2 means the absorbance of the mixture of samples and solvent [17]. From up to down, the scavenging DPPH· ability of all sorts of TCM extracts is from strong to weak. When the concentration of samples is 20 ppm, the scavenging rate of the extract of grape seed has reached 100%. However, *in vitro* antioxidant assays are the simplest and easiest ones and can be considered as relevant tools for primary evaluation of large batches of test substances to select those compounds with interesting antioxidant properties. As is the case for most pharmacological activities studied *in vitro*, extrapolation to *in vivo* remains dangerous, since bioavailability and metabolism issues become involved. Consequently, supplementation studies with antioxidants *in vivo* are the best approach to assess antioxidant potential.

As indicated in Table **2**, the research for determination of the ability of inhibiting free radicals by chemical reaction shows that *P. lactiflora*, *D. morifolium*, *E. ulmoides*, *S. scandens*, *P. suffruticosa* and *E. brevicornum* all have obvious activity of scavenging free radicals [18]. Use the chemiluminescence system of xanthine-xanthine oxidase-luminol producing $O_2^{-}\cdot$ to conduct determination of some TCM's ability of scavenging $O_2^{-}\cdot$. The result shows that the ethanol extracts of *N. forbesii*, *L.chuangxiong*, *B. falcatum*, *A. pubescens*, *C. monnieri*, *F. Vulgare* and *A. Sinensis* all have the ability of scavenging $O_2^{-}\cdot$ and this ability of the ethanol extracts of *N. forbesii*, *L. chuanxiong* and *B. falcatum* are stronger than vitamin C [19]. Eight kinds of TCMs' water extracts are determined by pyrogallol autooxidation for their ability of scavenging $O_2^{-}\cdot$, and Fonten reaction is used to determine their ability of scavenging ·OH. The result shows the water extracts of *R. glutinosa*, *L. chuanxiong*, *S. chinensis*, *A. membranaceus*, *C. pilosula*, *G. uralensis*, *S. miltiorrhiza* and green tea have the abilty of scavenging both $O_2^{-}\cdot$ and ·OH [20].



$$Fe^{2+} + H_2O_2 \rightarrow Fe^{3+} + OH^- + {}^{\bullet}OH$$

Fig. (1). The mutual transformation process of free radicals in the body.

Table 1. The Comparison of Scavenging DPPH· to the Extracts of TCM

The Extracts of TCM	Main Ingredients	The Capacity of Scavenging DPPH• in Different Concentration (ppm) Samples SA %		
		200ppm	100 ppm	20 ppm
VitC	——	100	100	100
Grape seed extracts	Proanthocyanidins, catechin etc.	100	100	100
Hovenia dulcis thunb extracts	Saponins, glycosides, alkaloids and flavonoids	89.9	90.5	37.1
Ginkgo biloba extracts	Flavonoids	89.6	90.1	57.2
Carthamus tinctorius L. extracts	Yellow pigment and saponins	89.9	64.8	15.2
Salvia miltiorrhiza bunge extracts	Salvia miltiorrhiza acid	88.7	86.8	21.3
Rhodiola rosea L. extracts	Salidroside	87.4	83.2	45.3
Ginkgo biloba L. extracts	Flavonoids, ginkgetin, terpene lactone	86.9	62.7	21
Glycyrrhiza uralensis fisch. extracts	Glycyrrhetic acid	79.5	54.3	17.8
Shorthorned epimedium extracts	Lcariin	78.4	76.7	17.8
Siberian ginseng extracts	Acanthopanax senticosides	71.7	43.8	21.1
Hawthorn P.E	*Hawthorn* flavonoids	69.5	50.6	19
Rehmanniae radix preparata extracts	Reducing sugar	58.2	33	12.6
Dendrobium extracts	Fluorenone，diterpene	51.2	30.6	7.5
Common reed rhizome extracts	Polysaccharide	39.3	26.9	2.9
Astragalus root extracts	Polysaccharide	37.6	15.3	3.9
Fructus lycii extracts	Polysaccharide	25.9	13.3	——
Bupleuri extracts	Saikoside	16.7	9.4	4.7
Pueraria root extracts	Puerarin	17.3	2.8	4
Angelica sinensis extracts	Polysaccharide	15	7.5	2.3
Donkey-hide glue extracts	Pro, 18 kinds of amino acid	12.9	6.5	——
Radix asparagi extracts	Aspartate	9	3	4.3
Radix ginseng rubra extracts	Polysaccharide	8.6	8.4	8.2
Panax ginseng C. A. Mey. extracts	Ginsenoside，polysaccharid	5.5	——	——

Note: —The capacity of scavenging is zero.

Table 2. Related Research on the Mechanism of Antioxidation of Chinese TCM Medicine in Different Ways

TCM	Experimental Methods	Experimental Results	Conclusions	References
Paeonia lactiflora Pall., *Dendranthema morifolium*(Ramat.) Tzvel., *Eucommia ulmoides* Oliver., *Senecio scandens* Buch.-Ham. Ex D. Don, *Paeonia suffruticosa* Andr. *and Epimedium brevicornum* Maxim.	Respectively use bioassay method of inhibiting RBC hemolysis, brain homogenate lipid peroxidation and DNA damage and chemical method of inhibiting free radicals produced by chemical reaction.	All of these TCMs have antioxidant effect and obvious activity of scavenging free radicals. The adverse reaction is small.	These TCMs contain high antioxidative and scavenging free radicals Ingredients.	[18]

(Table 2) contd….

TCM	Experimental Methods	Experimental Results	Conclusions	References
The ethanol extracts of *Notopterygium forbesii* bois, *Ligusticum chuangxiong* Hort, *Bupleurum falcatum* L., *Angclica pubescens* maxim., *Cnidium monnieri* (Li) Cusson, *Foeniculum Vulgare* Mill and *Angelica Sinensis* diels	Adopt the chemiluminescence system of xanthine-xanthine oxidase-luminol producing $O_2^-\cdot$ to conduct determination of some TCMs' ability of scavenging $O_2^-\cdot$.	The ethanol extracts of these TCMs all have the ability of scavenging $O_2^-\cdot$, and the ability of the ethanol extracts of *N. forbesii*, *L. chuanxiong* and *B. falcatum* is stronger than vitamin C.	The ethanol extracts of these TCMs all have antioxidant effect.	[19]
The water extracts of *Rehmannia glutinosa* Libosch., *Ligusticum chuanxiong* Hort., *Schisandra chinensis*(Turcz.) Baill., *Astragalus membranaceus*(Fisch.) Bunge, *Codonopsis pilosula* (Franch.) Nannf., *Glycyrrhiza uralensis* Fisch., *Salvia miltiorrhiza* Bunge and green tea	Their abilities of scavenging $O_2^-\cdot$ were determined by pyrogallol auto-oxidation and the ability of scavenging ·OH were determined by Fonten reaction	The abilty of scavenging $O_2^-\cdot$ for eight kinds of TCMs' water extracts is, *R. glutinosa* > *L. chuanxiong* > *S. chinensis* > *A. membranaceus* > *C. pilosula* > *G. uralensis* > *S. miltiorrhiza* > green tea and the abilty of scavenging ·OH is, *S. miltiorrhiza* > green tea> *A. membranaceus* > *S. chinensis* > *L. chuanxiong* > *R. glutinosa* > *C. pilosula*> *G. uralensis*. Have significance difference ($P<0.05$).	Eight kinds of TCMs' water extracts have the abilty of scavenging both $O_2^-\cdot$ and ·OH.	[20]
AESG of *Hovenia dulcis* Thunb. and *Alpinia officinarum* Hance; the ethyl acetate extracts of *Pueraria lobata* (Willd.) Ohwi	Use UV spectrophotometer with enzyme kinetics analysis software determination of inhibitory activity to XOD for variety of TCMs' extracts.	Three kinds of extracts all show strong inhibitory activity to XOD.	Three kinds of extracts are active sites of inhibiting XOD, further can reduce the generation of peroxide free radicals.	[34]
Ginkgo biloba L. P.E	The expression of C6 glioma induced by LPS and PMA *in vitro* can produce iNOS and abundant NO. With laser confocal imaging systems and NO fluorescence probe, conduct determination of concentration change of NO and with reerse transcriptase gene amplification technology and protein imprinting technique, detect the effect of *G. biloba* P.E for C6 glioma iNOS gene expression.	*G. biloba* P.E can obviously decrease the expressions of iNOS, mRNA and protein and reduce the generation of NO.	Through NF-κB signal pathways, *G. biloba* P.E regulates the expression of iNOS gene in C6 gliomas cell and the formation of NO.	[38]
TGP (Total glucosides of paeony)	Different concentrations of TGP together with rats' abdominal macrophage incubate in advance, then add LPS to stimulate cells. Determination the generation of NO in cells nutrient solution, the expression of iNOS and inhibition of NF-κB to IκBα albumen determined by Westernblot method, meanwhile, testing the combining activity of NF-κB and DNA.	TGP can obviously inhibit the generation of NO induced by LPS and the expression of iNOS in rats' abdominal macrophage, meanwhile it also increases the content of IκBα albumen in cells and inhibit the combining activity of NF-κB and DNA.	The functions of anti-inflammatory and antioxidation for TGP are closely related to its inhibition for the activity of macrophages NF-κB, thereby reduce the expression of macrophages iNOS and the generation of NO.	[39]

(Table 2) contd….

TCM	Experimental Methods	Experimental Results	Conclusions	References
The combination of *Ligusticum chuanxiong* Hort. and *Paeonia lactiflora* Pall.	Establish blank group and high-lipid model group, continuously feeding rats, finally take blood. Determination of MDA by enzymatic method, SOD by trace rapid determination method and NO by nitrate reductase method.	When *L. chuanxiong* and *P. lactiflora* are single used, there is no influence on MDA and NO, but when used together, they can reduce the activity of serum MDA and increase the release of NO. Compared with high-lipid model group, the difference is significant.	Two drugs have synergy in aspects of antioxidant effect and protection to vascular endothelial cells.	[45]
The synergy of *Polygonum multiflorum* Thunb. polysaccharides and LBP (Lycium barbarum polysaccharides)	Make mice aging model by D-galactose and aging mice are given intragastric injection in different concentration rates of *P. multiflorum* polysaccharides and LBP.	Different concentration rates of *P. multiflorum* polysaccharides and LBP can make aging model mice thymus index and spleen index rise in different degree; the content of MDA in liver and kidney tissues decrease and the vigor of SOD and GSH-PX improves; the content of LF in brain declines. Statistical analysis shows that *P. multiflorum* polysaccharides and LBP have significant or very significant synergistic action for each experimental indicator.	*P. multiflorum* polysaccharides and LBP have significant synergistic antiaging action and the best combination for two drugs is 200mg/50mg. The mechanism of action may be related to their improving body's immune system, scanvenging ROS and inhibiting lipid peroxidation.	[46]
The petroleum ether extracts of *Lysimachia christinae* Hance	According to the system's chemiluminescence suppressed degree, evaluate the ability of inhibiting ROS for *L. christinae,* with three kinds of chemiluminescence system	*L. christinae* extracts have good effects of scavenging $O_2^{-}\cdot$, ·OH and H_2O_2 and show the dose-effect relationship. The scavenging ability for three free radicals: H_2O_2>·OH> $O_2^{-}\cdot$	*L. christinae* can be used as a potential natural medicine with antioxidant activity.	[47]
The water extracts of *Mahonia bealei* (Fort) Carr.	By means of pyrogallol oxidation producing $O_2^{-}\cdot$ and through Fenton reaction producing ·OH in H_2O_2/Fe^{2+} system, determination of the scavenging effects on $O_2^{-}\cdot$ and ·OH for different concentrations of drugs by spectrophotometry.	*M. bealei* can inhibit the speed of pyrogallol oxidation and scavenge ·OH produced by Fenton reaction. In certain scope, this ability enhances with the drug concentration increasing.	*M. bealei* has the ability of scavenge $O_2^{-}\cdot$ and ·OH.	[48]
The water extracts of *Polygonum multiflorum* Thunb., *Ligustrum lucidum* Ait., *Crataegus pinnatifida* Bunge, *Glycyrrhiza uralensis* Fisch., *Acanthopanax gracilistylus* W. W. Smith *and Leonurus japonicas* Houtt.	By means of the system of pyrogallol oxidation and Fenton reaction, determine the ability of scavenging $O_2^{-}\cdot$ and ·OH and the effect of inhibiting LPO for 6 kinds of TCMs' water extracts.	6 kinds of TCM all have some scavenging functions for two free radicals. The effect to ·OH is *P. multiflorum>L. lucidum > C. pinnatifida > G. uralensis > A. gracilistylus > L. japonicas* while the effect to $O_2^{-}\cdot$ is *P. multiflorum > G. uralensis > A. gracilistylus > L. japonicas > L. lucidum > G. uralensis*. And the inhibition effect to LPO induced by $O_2^{-}\cdot$ is accordance with that of $O_2^{-}\cdot$.	6 kinds of TCMs' water extracts all can scavenge $O_2^{-}\cdot$ and ·OH that can damage cells and can inhibit membrane LPO reaction induced by $O_2^{-}\cdot$. Their antiaging effects are relevant to antioxidative mechanism.	[49]

(Table 2) contd….

TCM	**Experimental Methods**	**Experimental Results**	**Conclusions**	**References**
Rhodiola rosea L. extracts	Mice are randomly divided into normal control group, model group, Rhodiola rosea extracts 1, 2, 4 g/kg three doses groups, vitamin E positive control group, the intervention: model group, Rhodiola rosea extracts groups and vitamin E positive control group are daily injected 150mg/kg D-galactose normal saline from subcutaneous in the back the neck, meanwhile, give Rhodiola rosea extracts groups and vitamin E positive control group intragastric injection with drugs.	*R. rosea* extracts 1, 2, 4 g/kg three doses groups can all reduce the content of LPO and MDA in brain tissue and obviously enhance the activity of LDH and SOD, compared with model group, differences are significant; observation with electron microscope shows Rhodiola rosea extracts 2, 4 g/kg groups have apparently protective effects on hippocampus' neurons mitochondria degeneration caused by galactose.	Rhodiola rosea has obvious antiaging function that is related to its antioxidant damage and protectionto neuron.	[50]
The water extracts of *Ligusticum chuanxiong* Hort. and *Trichosanthes kirilowii* Maxim.	Make rats' liver microsomal using rats' liver and observe the effect of different concentrations' TCM on microsomal lipid peroxidation model aroused by cumene hydroperoxide, vitamin C/Fe^{2+}, CCl_4/coenzyme II	In this microsomal lipid peroxidation model, both *L. chuanxiong* and *T. kirilowii* can inhibit the generation of MDA.	*L. chuanxiong* and *T. kirilowii* can inhibit lipid peroxidation and have the antioxidative effects.	[51]
Plantago asiatica L.	Rats are divided into four groups: normal control group, model group, *P. asiatica* group. Use relevant kit to determine SOD content, catalase vigor and MDA level in serum; SOD vigor and MDA level in cardiac muscular tissue; the vigor of catalase and GSH-Px in the hepatic tissue.	The SOD vigor in rats' serum and cardiac muscular tissue for model group is obviously lower than that of normal control group and *P. asiatica* group($P<0.05$) but the content of MDA in serum and cardiac muscular tissue is obviously higher than that of normal control group and *P. asiatica* group ($P<0.05$). The vigor of GSH-Px in serum, cardiac muscular tissue and hepatic tissue for model group is obviously lower than that of normal control group and *P. asiatica* group ($P<0.05$).	*P. asiatica* can obviously reduce blood lipid for hyperlipidemia rats and increase body's antioxidative ability.	[52]
Aloe barbadensis Miller. extracts	Make aging model by letting mouse inhale O_3 and give aging mouse treatment with different concentrations of *A. barbadensis* extract. By means of the Comet Assay, detect oxidative damage degree of DNA in liver and lienal tissue cells.	Compared with model group, after *A. barbadensis* treatment the trailing tail length of DNA in liver and spleen cells becomes shorter. So *A. barbadensis* effectively alleviates DNA damage degree in liver and spleen cells.	*A. barbadensis* can improve the body's ability of inhibiting free radicals oxidative damage and alleviate DNA damage degree in liver and spleen cells, thus achieve the purpose of anti-aging.	[53]

2.2. Enhance the Activity of Antioxidase

In the process of life activities, cells constantly generate free radicals which are also constantly scavenged, maintaining a dynamic balance. Antioxidase in the body can make them transform into O_2 and H_2O through a series of catalytic reaction [5]. The detailed process is shown in Fig. (**2**). There are two classes of substances that can scavenge free radicals in the body, non-enzyme components and enzymes. The defense enzyme substances in cells mostly are various antioxidases, including superoxide dismutase (SOD), catalase (CAT), peroxidase and glutathione peroxdase (GSH-Px). SOD is the main substance of scavenging $O_2^{-}\cdot$ in the body, which is catalytic decomposed into H_2O_2. H_2O_2 also has oxidative damage effect that is transformed into O_2 and H_2O by catalase. Meanwhile, with catalysis of GSH-Px, it can also react with reduced glutathione (GSH) and generate H_2O and GSH [21].

Some TCM can enhance the activity of antioxidase. For example, quercetin can not only reduce oxidative damage of pancreatic island β cell, but also can restore the activity of SOD, GSH-Px and CAT in animal's renal cell damaged by Fe^{2+} [22]. *Alpinia katsumadai* contains significant antioxidative activity. The total extract of *Alpinia katsumadai* (Zingiberaceae) can enhance the viability of Chinese hamster lung fibroblast (V79-4) cells and inhibited H_2O_2-induced apoptosis. And it also dose-dependently enhanced the activities of SOD, CAT and GPX in V79-4 cells, and these effects were comparable to other antioxidant compounds such as EGCG and resveratrol [23]. Biochemical pharmacology experiments have found that many TCM (single herb or compounds) can increase the activity of antioxidase.

2.3. Lower Lipid Peroxide (LPO)

By lowering the content of LPO, TCM can maintain the stability of the cell membrane. Direct damage to cells by free radicals is mainly to attack lipid on the cell membrane. First, free radicals react with the unsaturated fatty acid of phospholipids or low-density lipoprotein (LDL) on the cell membrane and this reaction products attack the unsaturated fatty acid nearby, eventually causing a chain reaction [24]. Its final product MDA is often regarded as an evaluation index for peroxide level [25, 26]. Many studies have shown that parts of flavonoid compounds combining with cell membrane in the form of hydrogen bond protect unsaturated double bond in cell membrane from contacting with free radicals and have the effect of anti-lipid peroxidation [27].

It is reported that *Angelica sinensis* (Oliv.) Diels injection can resist lipid peroxidation and lower the MDA level [28]. After clinical application of *Salvia miltiorrhiza* Bunge for treatment, the content of LPO in blood decreases obviously [29]. Through inhibiting the generation of MDA in RBC and observing its shape changing with electron microscope, studies have pointed out fresh fruit, dried fruit, polysaccharide, fresh leaves and slag of *Lycium barbarum* L. have antioxidation property, respectively.

2.4. Reduce the Damage of DNA

The theory of free radicals persists that excess free radicals can attack DNA and thus lead to a variety of diseases [30]. At present, the research on the antioxidation of TCM has already deeply reached the DNA molecular level in some respects [31]. As indicated in Table **2**, *A. barbadensis* can effectively reduce the DNA damage degree to mice liver and spleen cells in ozone aging model. In addition, rutin, baicalin and tea polyphenol have strongly inhibitory action and delay action to DNA chemiluminescence caused by ·OH. Judging from suppression intensity, their IC_{50} are 4.5×10^{-6} M, 7.9×10^{-5} M and 2.4×10^{-5} M, respectively. They also have protective effect to plasmid DNA damage caused by ·OH and the performance on electrophoresis pattern is supercoiled DNA increase but open circular DNA reduction [7].

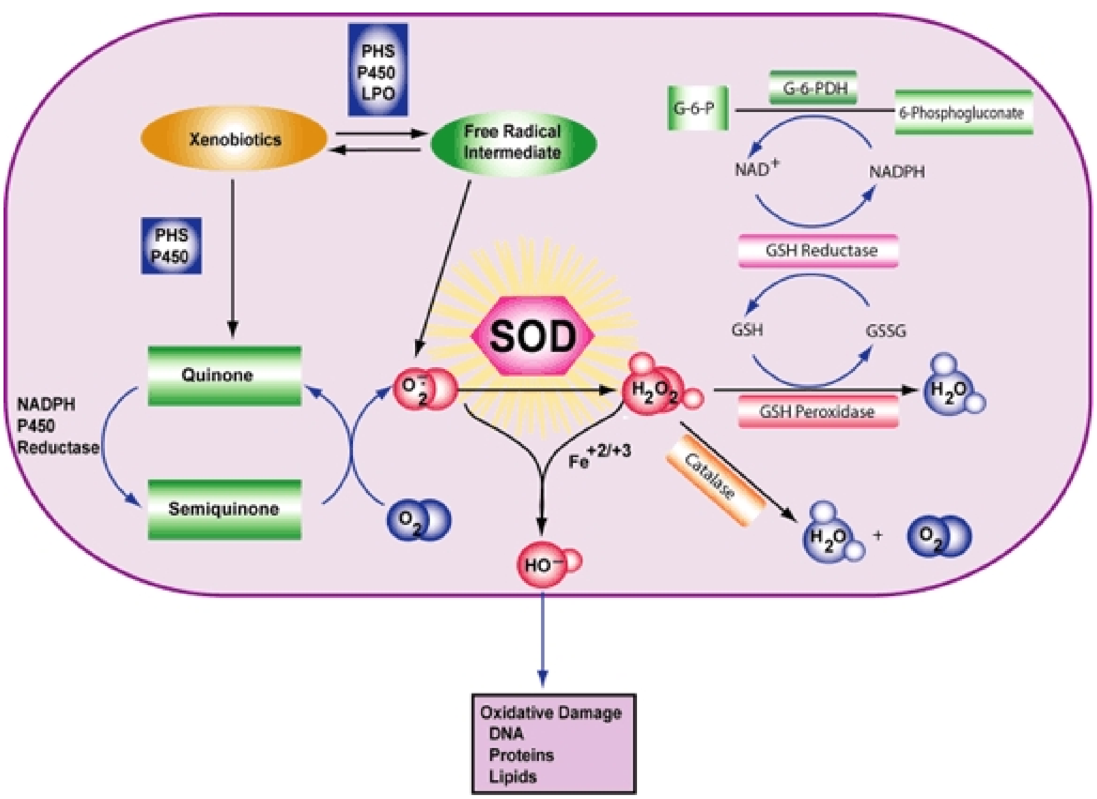


Fig. (2). The generation of reactive oxygen species (ROS) and the defense mechanism to them.

2.5. Effects of Vitality and Expression to the System of Oxidase

As to the effect of xanthine oxidase (XOD) that is an important enzyme for metabolization of nucleic acids in the body. It can catalyze xanthine and hypoxanthine oxidation to generate uric acid and peroxide free radicals [32]. High concentration of blood uric acid will lead to hyperuricemia [33]. This is a very important process for ischemia and reperfusion injury. In normal physiological condition, this enzyme exists in the form of xanthine dehydrogenases, while in ischemia condition, xanthine dehydrogenases transform into XOD and when ischemia tissue reperfusion, $O_2^{-}\cdot$ is produced in the catalysis of XOD, further leading to oxidative damage. Therefore, the content of XOD can be used as index component of antioxidant research. Some studies on *Forsythia suspense* (Thunb.) Vahl inhibition to XOD activity *in vitro* found that *F. suspense* could significantly inhibit XOD activity. As listed in Table **2**, Li *et al.* [34] have a determination of XOD inhibitory activity given by variety of TCM extracts using UV spectrophotometer with analysis software of enzyme kinetics, and screen some TCM extracts that can inhibit XOD activity *in vitro*. The result indicates that *H. dulcis* ethanol extract, *A. officinarum* ethanol extract and *P. lobata* ethyl acetate extract show strong inhibitory activity to XOD.

Besides, TCM also has effect on Nitric Oxide (NO) and Nitric Oxide Synthase (NOS). Under normal physiological circumstances, NO plays an important role in endothelia vasodilatation and balancing blood pressure in the body. But high concentration would lead to react with ROS and produce nitroso free radical with higher oxidation capacity. Besides, NO can also be regarded as a kind of free radical that causing cell oxidative damage. In the process of ischemia and reperfusion injury, the main synthetase of NO can increase the activity of inducible nitric oxide synthase (iNOS), which promote to produce more NO. Finally, too much NO causes oxidative damage [35]. (Through NF-κB and p38MAPK reducing iNOS and further lowering the generation of NO, TCM treats inflammation) [36]. When reperfusion, ligustrazine can reduce the expression of NF-κB in kidney tissue and restrain the activity of iNOS to relieve renal ischemia injury [37]. As listed in Table **2**, through NF-κB signal pathways, *G. biloba* extracts can regulate the expression of iNOS gene in C6 gliomas cell and the formation of NO [38]. The anti-inflammatory effect of total glucosides of paeony closely relates to inhibiting the activity of macrophages NF-κB, reducing the expression of macrophages iNOS and lowering the production of NO [39]. Studies have found that many flavonoid compounds including quercetin, curcumin can inhibit the activity of iNOS in ischemia-reperfusion injury. So these compounds have the effect of antioxidative [40].

2.6. The Synergy Effect of the Antioxidative Functions of TCM

In recent years, the longstanding, successful of herbal drug combinations in TCM makes it necessary to find a rationale for the pharmacological and therapeutic superiority of many of them in comparison to isolated single constituents. i.e. as the synergy among different TCM, the effects of compound TCM treatment and prevention of disease will require overall evaluation. The experiment results have been reported showing that using complex TCM have bright prospect for treatment cell damage caused by oxidatie stress [41].

Ichikawa *et al*. [42] have studied complex TCM sheng-mai-san composed of *Panax ginseng* C. A. Mey., *Schisandra chinensis* (Turcz.) Baill. and *Ophiopogon japonicas* (L. f.) Ker-Gawl. *in vitro* for its ability of scavenging free radicals and inhibitory effects to rats' brain oxidative damage. The results show that when three components pairing used, their antioxidant activity has combination effects, in general, the activity of complex TCM is significantly better than single TCM. Hras *et al.* [43] have studied the antioxidative activities of four natural antioxidants: rosemary extract, α-tocopherol, ascorbyl palmitate and citric acid. Among them, rosemary extract exhibited the best antioxidative activity, as determined by peroxide and anisidine value measurements. α-tocopherol showed a prooxidative effect on stability of sunflower oil at tested conditions. When combined with citric acid and especially ascorbyl palmitate, the rosemary extract showed an additive antioxidative effect.

The experiment of Jiang *et al.* [44] shows that pills of six ingredients with *Rehmannia glutinosa* Libosch. can significantly reduce the content of LPO in older mice serum to younger mice level, but when divided into "three tonics" and "three laxatives", the effect is far less than full prescriptions. *Epimedium brevicornum* Maxim. matched with *Panax ginseng* C. A. Mey. has significantly synergistic action in reducing the content of MDA in plasma and tissue and increasing the activity of SOD in erythrocyte. Table **2** has listed: *L. chuanxiong* matched with *P. lactiflora* can lower MDA activity of hyperlipidemia rats and significantly improve rats' antioxidative ability, but this effect is not observed when separately used [45]. The *P. multiflorum* polysaccharides when used in conjunction with LBP have significant or extremely significant synergistic effect to immune organs of aging model mice and antioxidant system [46].

Recently, many researches have been conducted in order to elucidate the mechanisms of antioxidation of TCM and the related progresses are listed in Table **2**.

3. THE ACTIVE CONSTITUENTS WITH ANTIOXIDATION IN TCM

3.1. Polysaccharides

Polysaccharides are a kind of macromolecule substance polymerized by more than 10 monosacchavides. Active polysaccharides mainly exist in fungi, algae and rhizome crude medicines [54]. Studies have found that there are functions of immunological enhancement for *Panax ginseng* C. A. Mey. polysaccharides and *Astragalus membranaceus* (Fisch) Bunge polysaccharides, antitumor function for champignon polysaccharides and polyporusum bellatus, protection to hepatocyte for tremellan and anti-hyperglycemic activity for *Dendrobium chrysotoxum* Lindl polysaccharides, all which are closely related to their antioxidant effects [55]. So polysaccharides play an important role in TCM pharmacology. They can scavenge ROS by physical, chemical and biological method, reduce the generation of MDA and increase the activities of SOD and GSH-Px etc.

The protein-bound polysaccharide of Coriolus versicolor QUEL (PS-K) has been found to express antioxidant activity as an "ion-radical scavenger" in diamine oxidation reactions [56]. As indicated in Table **3**, Hui *et al*. [57] have studied the scavenging effects of HPS-3 polysaccharide on O_2^- ·, · OH, DPPH and H_2O_2 *in vitro* and the result shows when the concentration is in 0.05-5.00 mg/ml, the maximum scavenging rate to O_2^- ·, · OH, DPPH and H_2O_2 is respectively 55.92%, 59.32%, 53.69% and 87.66%. By promoting the production of SOD and GSH–Px in epithelial cells to scavenge MDA, *Ganoderma lucidum* (Leyss.ex Fr.) Karst. polysaccharide shows the antioxidant activity [59]. Irrigated Coriolus versicolor polysaccharides 10 mg/kg for 3~15d that can not only increase the activity of SOD for normal mice, but also effectively relieve or inhibit decreasing of SOD activity caused by tumor or radiation as indicated in Table **3** [60].

3.2. Quinones

The dry root of *Lithospermum erythrorhizon* Sieb.et Zucc. is rich in shikonin Fig. (**3**) that is a class of naphthoquinone pigment. With good antioxidative activity, shikonin can significantly inhibit lipid peroxidation of micro neuron membrane in mice liver and have good ability of scavenging ·OH [67]. Its naphthalene quinone skeleton plays an important role in this characteristic while the change of side chains affects little. It also has little influence on the activity of scavenging free radicals when hydroxyl in side chains changes into ester [68]. Further studies prove that the antioxidative activity of β-shikonin not only relates to double benzene structure, but also relates to hydrogen atoms in phenolichydroxyl [69].

Rhein (RH), 4.5-dihydroxyanthraquinone Fig. (**3**), a compound extracted from *Rheum palmatum* L., *Polygonum multiflorum* Thunb., *Polygonum cuspidatum* Sieb. et Zucc. etc., has the fuctions of scavenging ROS and anti-lipid peroxidation. Using chemiluminescence analysis, the study shows extremely weak chemiluminescence induced by brain homogenate lipid peroxidation or Maillard reaction in rats can be quenched by RH. The intensity of this effect has linear relationship with MDA inhibition rate. Some studies have shown that in animal models of acute liver injury caused by CCl_4, D- GalN and hepatic fibrosis caused by CCl_4, ethanol, RH could significantly reduce the content of MDA and improve SOD level [70].

3.3. Flavonoids

Flavonoids are a class of secondary plant phenolics with significant antioxidant properties. The antioxidative mechanism of flavonoid compounds is studied more clearly than other antioxidants at present. That is, mainly through direct capturing and scavenging free radicals such as, O_2^- · and H_2O_2 etc, flavonoid compounds can provide hydrogen to free radicals, so through hydrogen abstraction reaction to generate free radical intermediates which can block or terminate free radicals chain reaction, further prevent or inhibit oxygen free radicals reaction and lipid peroxidation and restrain the formation of toxic substance, such as, LPO and its metabolite MDA and conjugated diene etc. Meanwhile, flavonoid compounds Fig. (**3**), a class of low molecular and diphenylene chromone as its mother nuclear, is a natural ingredient contained in plants and its family with various biological activity mainly include procyanidins, anthocyanins, flavonols, flavanone, flavanonol, new flavonoid, biflavone, isoflavone etc. that have attractive colors and widely exist in medicinal plants [71].

Many TCMs contain flavonoid compounds that have been confirmed to have antioxidative activity in certain TCM. For example, in Table **4** with Fenton system and Xan/XO system both of which can produce oxygen free radicals, study the effect of scavenging free radicals for flavonoids extracted in *L. chinense* leaf. And the result shows that the concentration of *L. chinense* flavonoids is 7.5-200mg/L, the scavenging rate of ·OH is 20%-72%; when the concentration is 0-217mg/L in Xan/XO system, the maximum scavenging rate of O_2^-· is 51% and it exists dose effect relation [72]. Table **4** lists some functions of flavonoids in TCM on antioxidation.

3.4. Saponins

Saponins are composed of sterides or tetraterpene connecting with glycosyl and its molecule contains many hydroxyls Fig. (**3**). So it has greater polarity. It is an important kind of active substance in TCM. Studies have shown that most saponins have obvious antioxidative effect in recent years. Saponin itself has little influence on oxygen free radicals, but it can improve the activity of antioxidase in the body, such as, SOD, CAT and so on, thereby enhance the function of antioxidative system in the body. For ginseng and astragalus etc. "supplementing qi" medicine, saponins are their common important constituents. Whether the antioxidation of saponins can reveal essence of "supplementing qi" for ginseng and astragalus etc. it needs further discussion.

Saponins in TCM with antioxidative property include araliceae saponins and leguminosae. The total saponins of *Gynostemma pentaphyllum*, *Paeonia lactiflora* Pall., *Panaxnotoginseng* (Burk.)F. H. Chen leaves, *Bupleurum falcatum* L., bitter gourd etc. also have strong functions of scavenging free radicals, antioxidation and protecting heart health. Readers can get that from Table **5**, through determination of the effect on the mice serum GSH-Px, SOD and MDA of total saponins of *Panax japonicus* (TSPJ) and testing their antioxidation, the result shows different doses of TSPJ can significantly enhance the activity of serum GSH-PX, SOD and reduce the content of serum MDA [81]. Using D-galactose to make mice subacute aging model, meanwhile mice are given *D. opoosita* saponins, six weeks later determination of the content of MDA in serum, liver homogenate and brain homogenate and the activity of SOD and GSH-Px. the result shows *D. opoosita* saponins can significantly improve the activity of SOD and GSH-Px in mice serum, liver and brain tissue, reduce the content of MDA in aging mice serum, liver and brain tissue [82].

Table 3. The Functions of Polysaccharide in TCM on Antioxidation

TCM Names and their Active Components	Experimental Methods	Experimental Results	Conclusions	References
Radix hedysari polysaccharide-3 (HPS-3)	*In vitro* chemical simulation conditions, study the scavenging effect of HPS-3 on $O_2^{-}\cdot$, · OH, DPPH and H_2O_2.	When the concentrations range is 0.05~5.00 mg/ml, the maximum scavenging rates to $O_2^{-}\cdot$, ·OH, DPPH and H_2O_2 are respectively 55.92%, 59.32%, 53.69% and 87.66% and have certain concentration-response dependency.	HPS-3 has direct antioxidant capacity *in vitro*.	[57]
Ganoderma lucidum polysaccharide (GLPS)	Add different concentrations of GLPS to ECV304 cells caused oxidative damage model by tert butyl hydroperoxide, determination of cell survival rate with MTT method and cell morphology change and mitochondrial damage with light microscope and electron microscopy.	GLPS can lower oxidative damage of ECV304 cells and in GLPS groups, ECV304 cell survival rate increases. It can reduce organelles' oxidative damage and apoptosis observed from electron microscopy.	GLPS can reduce oxygen free radicals' damage to organelles and also have good inhibitory effect on apoptosis and cell necrosis, improve cell survival rate all which prove GLPS have the functions of antioxidation and protecting cells.	[58]
Coriolus versicolor polysaccharides (CVP)	Normal, tumor-bearing, and radiated ICR mice are injected with CVP daily for 3-15 d. The SOD activity is assayed by epinephrine autoxidation test.	The SOD activities in lymphocytes and thymus are increased by CVP in both the normal mice with or without delayed hypersensitivity (DH). In tumor-bearing mice, CVP exerts not only inhibitory effects on tumor, growth and SOD activity in tumor tissue but also complete or partial restorative effects on the suppressed DH and on the declined SOD activities in lymphocytes, spleen, and thymus.	CVP exerts the favorable effects on SOD activities in mice.	[60]
Morinda officinalis How polysaccharide	Make aging model through D-galactose and determination of the activity of SOD and the content of MDA in mouse' s plasma, liver, heart and brain.	*M. officinalis* polysaccharide can enhance the activity of SOD and the content of MDA in aging rats' plasma, liver, heart and brain.	*M. officinalis* polysaccharide has anti-oxidant activity.	[61]
Lycium barbarum polysaccharides (LBP)	Determination of SOD by autoxidation of pyrogallol, GSH-Px by DTNB method, lactic acid by p-hydroxybiphenol colorimetry method and MDA by TBA colorimetry.	Mice with LBP group swim significantly longer than mice model group ($P < 0.01$); blood lactic acid index is obviously lower than that of model group ($P < 0.05$). The activity of SOD in mice' whole blood, liver tissue, muscle tissue and the activity of GSH - Px in liver tissue are obviously higher than that of model group ($P < 0.05$)	LBP has the functions of improving mice's athletic stamina and enhancing antioxidant enzymes vigor in bodies.	[62]
Cistanche deserticola Y. C. Ma polysaccharide	Make aging mouse model using D-galactose, and determination of the contents of SOD, GSH-Px, Vit E and MDA.	The SOD and GSH-Px vigor of aging mouse in the lung tissue and erythocytes improves and the content of MDA in the lung and plasma reduces, when aging mouse are irrigated *C. deserticola*. Meanwhile the content of collagen in lung decreases and elastin increases.	*C. deserticola* polysaccharide have the function of resisting oxidation damage and lung aging.	[63]

(Table 3) contd….

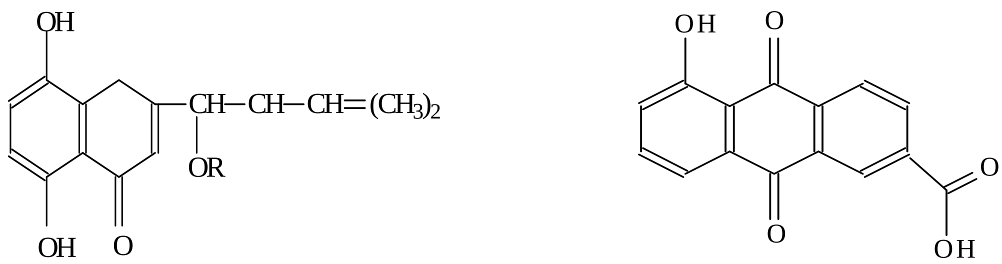
TCM Names and their Active Components	Experimental Methods	Experimental Results	Conclusions	References
Spirulina polysaccharide	Establish diabetic mouse model induced by alloxan, and determination of the activity of serum SOD by xanthine oxidase method, the content of MDA by TBA colorimetric method and the content of GSH-Px and GSH in whole blood by kits.	The activity of serum SOD decreases and the content of MDA dramatically increases for diabetic mouse in model group, compared with that of in normal control group ($P<0.01$). Spirulina polysaccharide can remarkably against alloxan effect. So it can make the activity of serum SOD enhance and the content of MDA decrease, compared with diabetes model control group ($P<0.01$). PSP can also obviously increase the content of GSH-Px and GSH in whole blood compared with diabetes model control group ($P<0.01$).	Spirulina polysaccharide can promote the biosynthesis of body's antioxidant enzymes, such as, SOD, GSH-Px and GSH etc.	[64]
Angelica sinensis (Oliv.) Diels polysaccharide	Rats are randomly divided into quiet control group, quiet in treatment group, exercise control group, exercise false feeding group and exercise in treatment group. After 30 days, all rats conduct treadmill and acute exhaustive exercise**,** then take rats' blood determination of the contents of superoxide SOD, MDA, GSH – PX and CAT.	*A. sinensis* polysaccharide can obviously improve rats' exercise ability, The activities of SOD, GSH-Px and CAT for the rats in exercise in treatment group are enhanced and the content of MDA is significantly reduced.	*A. sinensis* polysaccharide can improve rats' exercise ability and the mechanism may be related to its antioxidant effect.	[65]
Polygonatum sibiricum Red. polysaccharide	Establish diabetic mouse model induced by alloxan. Determination of the contents of T-SOD, GSH-Px and MDA in serum and liver using chemical colorimetry.	Compared with model group, *P. sibiricum* polysaccharide group could obviously decrease blood sugar of diabetic mouse ($P<0.05$) and significantly increase the index of thymus, spleen and liver and can improve the contents of T-SOD, GSH-Px and MDA in serum and liver.	*P. sibiricum* polysaccharide has certain protective effect to diabetic mouse induced by alloxan and the mechanism may be related to its antioxidant effect.	[66]

Table 4. The Functions of Flavonoids in TCM on Antioxidation

TCM Names and their Active Components	Experimental Methods	Experimental Results	Conclusions	References
Lycium chinense Mill. flavonoids	By means of the system of Xan/XO and Fenton reaction, determine the ability of scavenging $O_2^-\cdot$ and ·OH.	In Fenton system, when the concentrations of *L. chinense* flavonoids are 7.5-200mg/L, the scavenging rate for ·OH is 20%-72%; in Xan/XO system, when the concentrations of *L. chinense* flavonoids are 0-217mg/L, the scavenging rate for $O_2^-\cdot$ are 0% -51%. There is dose effect relation.	*L. chinense* flavonoids have strong ability of scavenging ·OH and $O_2^-\cdot$ and the scavenging rate for ·OH is stronger than that of for $O_2^-\cdot$	[72]
TFFC	Establish rats' peroxidation damage model induced by adriamycin (ADR). Determination of SOD with VB2-Met-NBT method, GSH-PX with DTNB method, MDA with TBA method, CAT with ammonium molybdate method and the hemoglobin with $K_3Fe(CN)_6$ method.	After rats take TFFC, the activities of SOD, GSH-Px and CAT in erythrocyte gradually rise and the content of MDA gradually declines, meanwhile existing dose dependent.	TFFC has the functions of scavenging free radicals and restraining peroxidation damage.	[73]

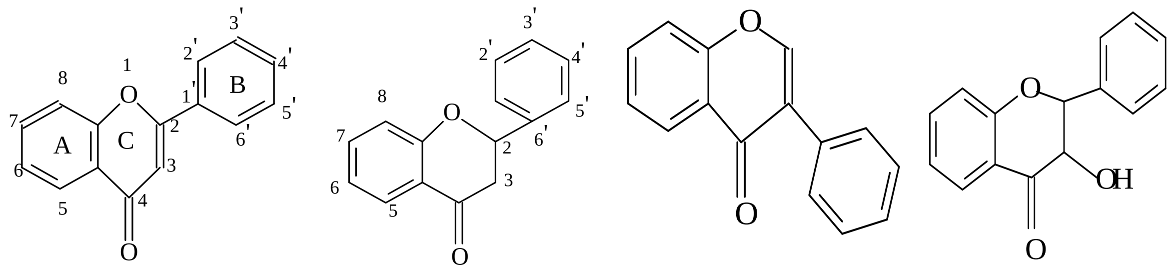
(Table 4) contd….

TCM Names and their Active Components	Experimental Methods	Experimental Results	Conclusions	References
Glycyrrhiza uralensis Fisch. flavonoids	Establish artery ischemia-reperfusion model by suture method in rats' brain and determination of the activities of MDA, SOD, NO and NOS in serum and brain tissue, then rats are irrigated with *G. uralensis* flavonoids.	*G. uralensis* flavonoids can promote the recovery of rats' neurological function for ischemia-reperfusion model and obviously decrease the content of MDA and NO in serum and brain tissue and enhance the activity of SOD.	*G. uralensis* flavonoids have antioxidation activity.	[74]
Cuscuta chinensis Lam. flavonoids	Determination of the index of MDA, total antioxidant capacity (T-AOC) and ROS, further detect testicular apoptosis by TdT-mediated dUDP-Xnick end labeling (TUNEL) method.	Different doses of *C. chinensis* flavonoids can restrain rats' oxidative damage and apoptosis of testicular cells induced by serum-free culture and its role has dose dependent. The effect is the most obvious, when the concentration of dodder flavonoids is 500 $mg \cdot L^{-1}$.	As an effective antioxidant, *C. chinensis* flavonoid can resist oxidation, and apoptosis.	[75]
Tanshinone	Establish hepatic stress injury in mice. Determination of the activity of ALT in plasma by Reitman, the content of MDA in plasma and hepatic tissue by TBARS method, oxygen radical absorbance capacity by ORAC method and the content of vitamin C and GSH in plasma and liver tissue homogenate by HPLC method.	Compared with restraint model group, The ALT level in stress injury mouse plasma is obviously reduced; the antioxidant capacity index in liver tissue homogenate and the content of vitamin C and GSH are improved; the content of MDA is reduced after irrigated tanshinone for stress injury mouse.	Tanshinone has certain protective effect on hepatic stress injury in mouse and the mechanism may be partially from its antioxidant activity.	[76]
Pueraria lobata (Willd.) Ohwi isoflavones	Health menopausal female SD rats are divided into blank control group and high, medium and low doses groups. Rats' in the experimental groups are irrigated *P. lobata* isoflavones in different concentrations. Determination of learning and memory capacity by experimental platform method and the vigor of MDA, SOD and GSH-Px by kits.	Compared with blank control group, the contents of serum MDA for rats in medium and high doses groups significantly lower; the vigor of SOD in high, medium and low dose groups all significantly increases and the serum GSH-Px vigor improves in medium and high doses groups.	*P. lobata* isoflavone has obvious antioxidant effect and can effectively improve learning and memory capacity of menopausal female SD rats.	[77]
The total flavonoids of *Epimedium brevicornum* Maxim.	Culture rats' liver tissue *in vitro* and establish peroxide model of vitro tissue. Determination of scavenging effect of the total flavonoids of *E. brevicornum* on free radicals.	The total flavonoids of *E. brevicornum* have good inhibitory function for hepatic homogenate autoxidation and inductive oxidation and for mitochondrial inductive oxidation. It also has certain scavenging effect to DPPH·, ·OH and $O_2^- \cdot$.	The total flavonoids of *E. brevicornum* have good antioxidant function.	[78]
Portulaca oleracea L. flavonoids	Respectively by the Fenton system and pyrogallol autoxidation and $Na_2S_2O_3$ titration for determination of the scavenging ability of *P. oleracea* flavonoids to · OH and $O_2^- \cdot$.	In the range of selected concentrations, when *P. oleracea* flavonoids concentration is 0.56 mg/ml, the maximum scavenging rate to·OH reachs 68.33% and the scavenging rate to O_2^- ·also reaches maximum, that is 82.26%.	*P. oleracea* flavonoids have good scavenging effect on ·OH and $O_2^- \cdot$.	[79]
Ligusticum chuanxiong Hort. flavonoids	Determination of the effect of flavonoids on serum ROS, the influence of generation of MDA for mice liver homogenate, the effect on the activity of lipoxygenase and the effect on mice oxidation hemolysis induced by H_2O_2.	When the concentration of *L. chuanxiong* flavonoids is 2.00 $g \cdot L^{-1}$, the inhibition rate to the activity of lipoxygenase is over 50%; when the concentrations of flavonoids at 0.5-10.0 $g \cdot L^{-1}$, it has strong ability of scavenging ROS *in vitro* and can reduce the generation of MDA in mouse liver homogenate and inhibit erythocytes oxidation hemolysis.	*L. chuanxiong* flavonoids have strong antioxidant ability.	[80]

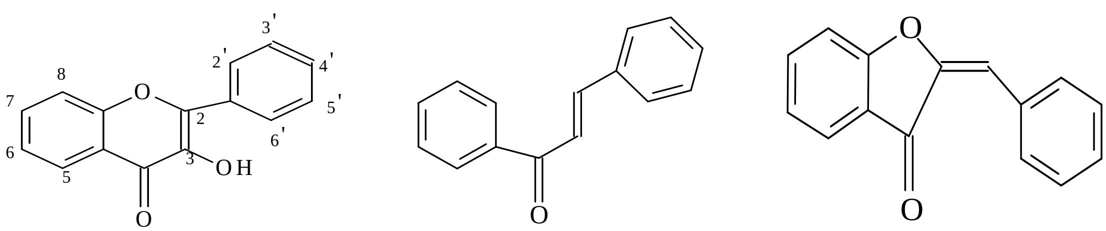


shikonin rhein

Quinones

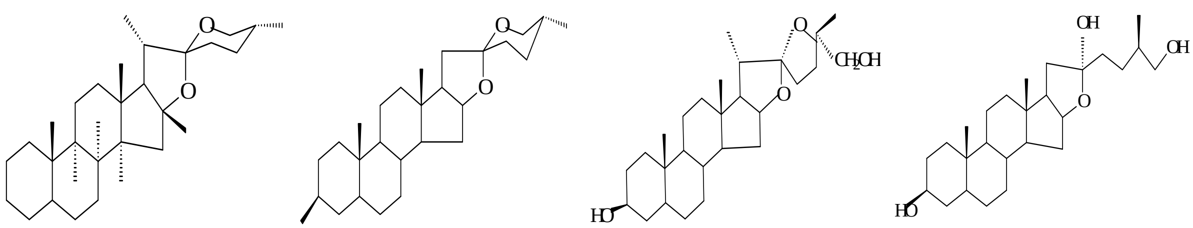


2-phenyl chromone flavanones isoflavone flavanonol



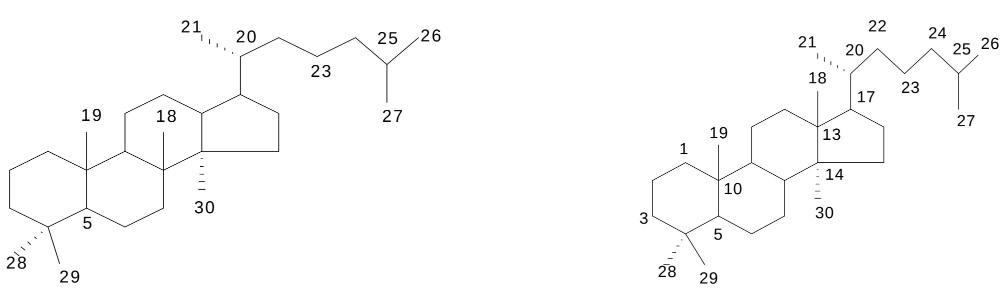
flavonol chalcone benzal-coumaranon

Flavonoids



spirostanes isospirostanols pseudo-spirostanols furostanols

Steroid saponin



dammarane lanostane

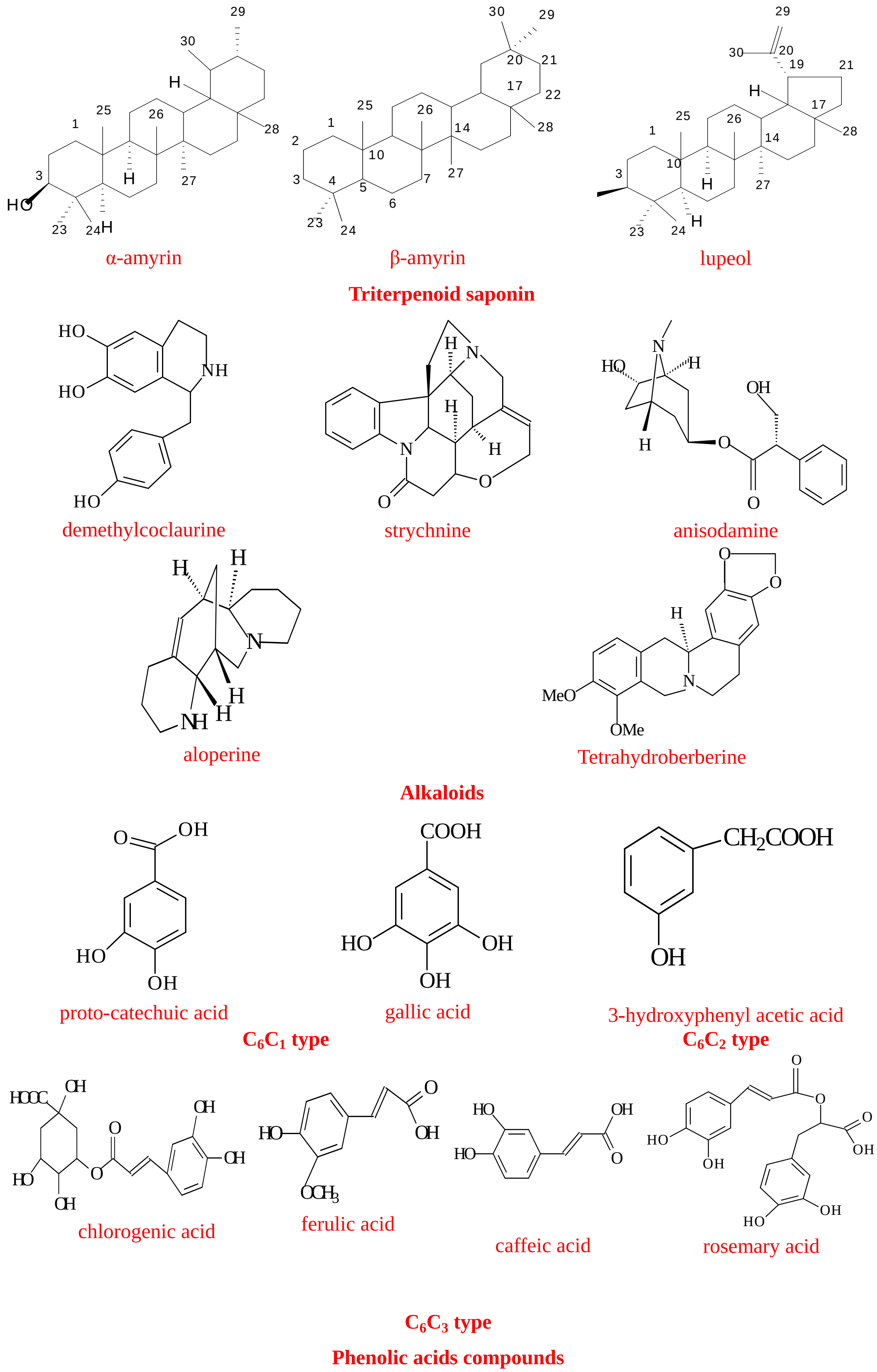


Fig. (3). The structures of some representative types of antioxidant compounds in TCM.

Table 5. The Functions of Saponins in TCM on Antioxidation

TCM Names and their Active Components	Experimental Methods	Experimental Results	Conclusions	References
Total saponins of Panax japonicus (TSPJ)	Determination of the activity of GSH-PX, SOD and MDA in mouse serum.	TSPJ in the concentrations of 75, 150, 300 $mg \cdot kg^{-1}$ all can significantly increase the content of GSH-PX and SOD and reduce the content of MDA in serum.	TSPJ has obvious antioxidation and differences are remarkable compared with blank control group.	[81]
Bitter gourd saponin	Establish subacute aging mouse model by D-galactose and give two different doses of bitter gourd saponin to mouse. Six weeks later, determination of the content of MDA and the activity of SOD and GSH-Px in serum, liver and brain.	Bitter gourd saponin can obviously improve the activity of SOD and GSH-Px and reduce the content of MDA in serum, liver and brain for aging mouse.	Bitter gourd saponin can improve the activity of body's antioxidant enzymes, scavenge free radicals and reduce the generation of lipid peroxide.	[82]
Ginsenoside Rg-1	Male SD rats are randomly divided into ginsenoside Rg-1group, model group and blank group. Rats in ginsenoside Rg-1 group and model group will run with medium workload after gastric irrigation 1h. Then test the content of MDA in serum and skeletal muscle and the activity of SOD in erythrocyte, skeletal muscle and liver for exercise-induced fatigue rat model.	Compared with model group, the contents of MDA in serum and skeletal muscle significantly lower ($P < 0.01$); the activity of SOD in erythrocyte, skeletal muscle and liver significantly increases for rats in ginsenoside Rg-1group ($P < 0.01$).	The resistance effect of exercise-induced fatigue for ginsenoside Rg-1 is probably related to its functions of increasing fatigue rats' antioxidant ability, scavenging excessive free radicals and lipid peroxide.	[83]
Codonopsis pilosula (Franch.) Nannf. saponin	Establish hyperlipidemia rats model induced by high fat emulsion and rats are given *C. pilosula* saponin in different concentrations. Then determination of the content of NO and lipid in rats' serum.	*C. pilosula* saponin can reduce the content of TC, TG and LDL-C and it also can enhance the content of NO and HDL-C.	*C. pilosula* saponin has the functions of regulating blood lipid and antioxidation.	[84]
Acanthopanax senticosu saponins (ASS)	Establish oxidative damage model of myocardium cells for suckling rats induced by H_2O_2. Give rats ASS 600, 300 $mg \cdot L^{-1}$, determination of cell survival rate, the activity of LDH and the content of MDA, SOD, CAT, GSH-Px and GSH in cells.	ASS 600 $mg \cdot L^{-1}$ can reduce oxidative damage of myocardium cells induced by H_2O_2 and also can increase the content of GSH and the activity of GSH-Px, SOD and CAT in cells.	ASS takes a protective role in oxidative damage of myocardium cells induced by H_2O_2 and can increase antioxidant ability for cells.	[85]
Panax notoginseng saponins PNS	Establish acute lung injury induced by oleic acid for rats. Rats are injected by different concentrations of PNS after oleic acid injection15 minutes. Then determination of lung wet dry (W/D) ratio and the content of NO and MDA and the activity of MPO, NOS and SOD by biochemistry method.	PNS can alleviate lung inflammation, decrease the W/D, MPO, MD, NO, NOS and increase SOD and exist a dose-response relationship.	PNS can decrease the degree of acute lung injury in rats and that may be involved in increasing lung antioxidant action.	[86]
SQDG	Establish acute liver injury mouse model induced by CCl_4. Determination of the activity of ALT, AST, SOD and GSH-Px in serum and the content of MDA in liver homogenate by spectrophotometry.	SQDG can significantly reduce the content of ALT, AST and MDA in mouse serum, increase the activity of SOD and GSH-Px and alleviate hepatocyte damage.	SQDG has protective function for acute liver injury mouse model and the mechanism is probably related to its antioxidant effect.	[87]

(Table 5) contd….

TCM Names and their active Components	Experimental Methods	Experimental Results	Conclusions	References
Saikosaponin-D(SS-D)	Cultivate rats' liver cells and ethanol induces hepatocyte injury *in vitro*. With different concentrations of SS-D protecting them, determination of the activity of ALT and GSH-Px and the content of MDA in culture solution, meanwhile test hepatocyte surviva rate by MTT method.	SS-D can evidently improve hepatocyte survival rate and inhibit the activity of ALT, the reduction of GSH-Px activity and the generation of MDA.	SS-D has obvious protective effect to hepatocyte damaged by ethanol and the mechanism is probably related to its antioxidant effect.	[88]
Alligator alternanthera saponin	Determination of the scavenging ability of alligator alternanthera saponin for ABTS, ·OH and O_2^-·respectively in ABTS system, Fe^{2+}-H_20_2 system and pyrogallol autoxidation system.	The scavenging ability to ABTS increases with the concentrations of saponin increasing; low concentrations of alligator alternanthera saponin have stimulative effect to ·OH, but with concentrations of saponins increasing, it begins to have some scavenging ability and its scavenging ability and saponins concentration have dose effect relationship; but for O_2^-·, scavenging ability first increases and then decreases along with the concentrations increasing.	Alligator alternanthera saponin has certain antioxidant effect.	[89]
Dioscorea opoosita Thunb. saponin	Establish mouse subacute aging model by D-galactose, meanwhile give them *D. opoosita*. Six weeks later, determination of the content of MDA and the activity of SOD and GSH-Px in serum, liver homogenate and brain homogenate.	*D. opoosita* can obviously improve the activity of SOD and GSH-Px and reduce the content of MDA in serum, liver homogenate and brain homogenate for aging mouse.	The antiaging function of *D. opoosita* may involve that it can improve the activity of antioxidant enzymes, scavenge free radicals and reduce lipid peroxide.	[90]

3.5. Alkaloids

Some TCM contain alkaloids, such as strychnine in *Strychnos nux-vomica* L., demethylcoclaurine in *Aconitum carmichaeli* Debx., tetrahydroberberine in *Coptis chinensis* Franch. and aloperine in *Sophora alopecuroides* L. etc. with antioxidative activity similar to BHA and BHT in linoleic acid air oxidation [91]. Pharmacology experiments show that anisodamine can obviously inhibit RBC hemolysis caused by H_2O_2 or oxidation hemolysis and restrain the formation of MDA caused by liver, brain homogenate spontaneity or induced by Fe^{2+}-VC for mice [92]. The structures of these substances are shown in Fig. (**3**).

3.6. Terpenes

Laurencia extracts (LET) are rich in natural terpenoids. Appropriate dosage of LET can obviously inhibit blood lymphocyte DNA oxidative damage induced by H_2O_2. In addition, LET can also reduce the content of MDA in blood [93].

3.7. Phenolic Acids Compounds

Phenolic acid compounds are a class of compounds that have several phenol hydroxyl in the same benzene ring. Some phenolic acid compounds and their derivatives have good function of scavenging free radicals, so they are a kind of good natural antioxidants [94]. For example, the molecular structure of ferulic acid drugs contains conjugate big π bond that can increase electronegativity of center atom, carboxyl groups that can increase water solubility and hydroxyl that can provide hydrogen proton. It can scavenge free radicals, restrain lipid peroxidation induced by ·OH and protect the structure and function of biological membrane due to its strong oxidative stability [95]. There are mainly 3 kinds of phenolic acids compounds Fig. (**3**) found in the nature plants with oxidative ability: (1) C_6C_1 type, such as proto-catechuic acid, gallic acid (*Macrocarpium officinale* (Sieb. Et Zucc.) Nakai); (2) C_6C_2 type, such as 3 - hydroxyphenyl acetic acid, (3) C_6C_3 type, such as chlorogenic acid (*Lonicera japonica* Thunb.), ferulic acid (*Angelica sinensis* (Oliv.) Diels, *Ligusticum chuanxiong* Hort.), caffeic acid, rosemary acid (*Perilla frutescens* (L.) Britt. Var. arguta (Benth.) Hand.-Mazz.) and meson acid (Propolis) etc [96].

Catechin is a kind of polyphenol riched in Camellia sinensis, which has antioxidative activity. Its antioxidative activity is better than α-tocopherol with the same concentration and is also 4-6 times as active as synthetic antioxidants like butylated hydroxytoluene (BHT), butylated hydroxyanisole (BHA). If used together with the vitamin C and vitamin E, their antioxidative activity has the synergy [97]. The polyphenols such as resveratrol [98], gallic acid and proanthocyanidins that extracted from grape seeds and pine bark have also been proved to have strong oxidative stability [99]. A water-soluble ingredient contained in *Salvia miltiorrhiza* Bunge is salvianolic acid that has strong inhibitory effect on lipid peroxidation of brain, liver and liver microsomal. It also has been reported that determined by FRAP and TEAC reagent for the antioxidative ability of 23 kinds of TCM, the result shows *Sargentodoxa cuneata* (Oliv.) Rehd. et Wils., *Fraxinus szaboana* Lingelsh., *Paeonia lactiflora* Pall., *Paeonia suffruticosa* Andr. and *Scutellaria baicalensis* Georgi have strong antioxidant capacity. So they are important sources of nature antioxidant [100].

3.8. Tannins

Tannins generally have antioxidative activity. 25 kinds of tannins and its related compounds were studied and found that 23 kinds of tannins among them had antioxidant effect in different degree. It has been reported that the inhibition rates of *Polygonum cuspidatum* Sieb. et Zucc. Tannins with 0.05, 0.1, 0.5 mg/ml to MDA are 75.0%, 82.6% and 85.0%, respectively [101].

4. FUTURE TRENDS

Over the last decade many scientific researches have focused on antioxidants in delaying or preventing oxidative stress and many compounds have already been evaluated for their antioxidant profile. However, a wide range of *in vitro* and *in vivo* assays do exist to characterize antioxidant activity, which requires a profound knowledge of the limitations and pitfalls of each of these methods, including appropriate corrective measures [102].

So far, the researches about antioxidation of TCM have made a lot of exciting achievements and many research findings among them are related to anti-aging studies. Many scholars agree that the function of free radicals lipid peroxidation and the activity of free radical scavenging agents are closely related to the degree of body aging. Furthermore, the function of free radicals is not only related to physiological aging but also linked with some pathological processes. At present, people think the reaction of free radicals may be one of intrinsic mechanisms for body aging. So inhibiting the peroxidation of free radicals and strengthenning body's antioxidative ability may be an important way for antiaging [103].

With the merits of wide source, strong antioxidative activity, good body affinity and high safety, etc., plant antioxidant will still be the focus in the future research. For TCM containing abundant constituents of scavenging free radicals, convenient method of screening free radical scavenging agents is in favour of quickly finding effective TCM and reasonable formula. With the progress of science and technology and the deepening research of TCM, believe that more TCM with antioxidation will be found. The antioxidation property of TCM will be got good development and utilization in mang aspects, such as senescence delay, radioresistance, beauty supplies and health protection and so on. In the future, people should broaden their minds and make single TCM combined with complex medicines, which makes the research on the antioxidation of TCM up to a new step. Further let large system of TCM make better service for people.

CONFLICT OF INTEREST

The author(s) confirm that this article content has no conflicts of interest.

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REFERENCES

[1] McCarthy, T.L.; Kerry, J.P.; Kerry, J.F.; Lynch, P.B.; Buckley, D.J. Evaluation of the antioxidant potential of natural food/plant extracts as compared with synthetic antioxidants and vitamin E in raw and cooked pork patties. *Meat Sci.*, **2001**, *57*, 45-52.

[2] Zhao, M.Y. A brief talk about the anti-oxidantive functions of TCM. *Shaanxi J. Trad. Chin. Med.*, **2005**, 26(6), 578-579.

[3] Freeman, B.A.; Crapo, J.D. Biology of disease: free radicals and tissue injury. *Lab. Invest.*, **1982**, *47*, 412-438.

[4] Southorn, P.A.; Powis, G. Free radicals in medicine. I. Chemical nature and biologic reactions. *Mayo Clin. Proc.*, **1988**, *63*, 381-390.

[5] Mates, J.M.; Perez-Gomez, C.; Castro, I.N.D. Antioxidant enzymes and human diseases. *Clin. Biochem.*, **1999**, *32*(8), 595-603.

[6] Hui, L.; Banbury, L.K.; Leach, D.N. Antioxidant activity of 45 Chinese herbs and the relationship with their TCM characteristics. *Adv. Access Publication*, **2008,** *5*(4), 429-434.

[7] Wang, X.; Hai, C.X.; Liang, X.; Yu, S.X.; Zhang, W.; Li, Y.L. The protective effects of *Acanthopanax senticosus* Harms aqueous extracts against oxidative stress: Role of Nrf2 and antioxidant enzymes. *J. Ethnopharmacol.*, **2010**, *127*, 424-432.

[8] Wang, H.Y.; Zhao, X.F.; Yin, S.A. The antioxidant synergistic function between TCM and food ingredients. *Chin. J. Preventive Med.*, **2006**, 40(3), 212-214.

[9] Devasagayam, T.P.A.; Tilak, J.C.; Boloor, K.K.; Sane, K.S.; Ghaskadbi, S.S.; Lele, R.D. Free radicals and antioxidants in human health: current status and future prospects. *J. Assoc. Phys. India*, **2004**, *52*, 794-803.

[10] Hagihara, M.; Nishigaki, I.; Maseki, M.; Yagi, K. Age-dependent changes in lipid peroxide levels in the lipoprotein fractions of human serum. *J. Gerontol.*, **1984**, *39*(3), 269-272.

[11] Sun, C.P.; Zhang, J.Z.; Duan, S.J. Introduction to free radical biology. Press of University of Science and Technology of China: Hefei, **1999**.

[12] Fang, Y.Z.; Zheng, R.L. The Theory and Application of Free Radical Biology. Science Press: Beijing, **2002**.

[13] Miyachi, Y. Reactive oxygen species in phot odermatology; Hayaishi, O.; Imamura, S: Tokyo, **1987**; pp. 37-41.

[14] Desai, K.M.; Wu, L.Y. Free radical generation by methlglyoxal in tissues. *Drug Metab. Drug In.*, **2008**, *23*, 151-155.

[15] Halliwell, B.D.S. Reactive oxygen species in living systems: Source, biochemistry, and role in human disease. *Am. J. Med.*, **1991**, *91*(3), 14-22.

[16] Xu, S.H.; Hang, H. A simple method of screening free radical scavenging agents. *Chin. Trad. Herb. Drugs*, **2000**, *31*(2), 96-97.

[17] Tang, L.Y.; Jiang, B. Research on the antioxidation of TCM extracts often used in ancient health promotion kampo. *China Health Ind. Forum*, **2007**, *4*, 1-6.

[18] Liu, F.; Wu, Z.B.; Niu, S.M.; He, J.S.; Xing, L.J. Studies on antioxidative and free radical scavenging activities of Chinese herbs. *Chin. Pharm. J.*, **2001**, *36*(7), 442-445.

[19] Pan, H.Y.; Han, G.; Jiang, H.; Wang, C.M. Study on antioxidation of umbelliferae Chinese herbs. *Lishizhen Med. Mater. Med. Res.*, **2006**, *17*(8), 1480-1481.

[20] Zhao, Y.H. Study of the ability of inhibition of two free radicals on extraction water from eight kinds of TCM. *China Mod. Doctor*, **2008**, *46*(17), 33-37.

[21] Pignatelli, P.; Pulcinelli, F.M.; Celestini, A.; Lenti, L.; Ghiselli, A.; Gazzaniga, P.P.; Violi, F. The flavonoids quercetin and catechin synergistically inhibit platelet function by antagonizing the intracellular production of hydrogen peroxide. *Am. J. Clinl. Nutri.,* **2000**, *72*, 1150-1155.

[22] Toyokuni, S.; Tanaka, T.; Kawaguchi, W.; Laifang, N.R.; Ozeki, M.; Akatsuka, S.; Hiai, H.; Aruoma, O.I.; Bahorun, T. Effects of the phenolic contents of mauritianendemic plant extracts on promoter activities of antioxidant enzymes. *Free Radic. Res.*, **2003**, *37*, 1215-1224.

[23] Lee, S.E.; Shin, H.-T.; Hwang, H.J.; Kim, J.H. Antioxidant activity of extracts from Alpinia katsumadai seed. Pharmacol. & Pharm. Med., **2003**, *17*(9), 1041-1047.

[24] Girotti, A.W. Lipid hydroperoxide generation, turnover, and effector action in biological systems. *J. Lipid Res*., **1998**, *39*,1529 -1542.

[25] Miao, M.S. Oxygen free radicals, disease and antioxidative TCM. *Henan J. TCM Pharm*., **2002**, 17 (4), 1-4.

[26] Cheng, J.; Wang, F.; Yu, D.F.; Wu, P.F.; Chen, J.G. The cytotoxic mechanism of malondialdehyde and protective effect of carnosine via proteincross-linking/mitochondrial dysfunction/reactive oxygen species/MAPK pathway in neurons. *Eur. J. Pharmacol.,* **2011**, *650*, 184-194.

[27] Reitman, S.; Frankel, S. A colorimetric method for the deter minati on of serum glutamic oxalacetic and glutamic pyruvic transaminases. *Am. J. Clin. Pathol.*, **1957**, *28*, 56-63.

[28] Li, Z.C.; Song, C.E.; Cao, M.Y.; Yin, D.D.; Yang, X.H.; Zhang, C.R. Effects of angellica injection on blood superoxide dismutase activity and lipid peroxide in patients with CHD. *Acta Acad. Med. Hubei*, **1997**, *18*, 132-133.

[29] Xin, Z.Q.; Zeng, X.C.; Yi, C.T.; Yuan, F.; Zhun, Z.X. Effect of salvia miltiorrhiza on serum lipid peroxide, superoxide dismutase of the patients with coronary heart disease. *Chin. J. Integr. Trad. West. Med*., **1996**, *16*, 287-288.

[30] Boyce, N.W.; Holdsworty, S.R. Hydrowyl Radical Mediation of Immune Renal Injury by Desferrioxamine. *Kidney Intl.,* **1986**, *30*, 813-891.

[31] Cao, P.; Cai, X.T.; Lu, W.G.; Huo, J.G. Growth Inhibition and Induction of Apoptosis in SHG-44 Glioma Cells by Chinese Medicine Formula "Pingliu Keli". Evid. Based *Complement Alternat. Med*., **2011**, *10*, 1155-1164.

[32] Wu, X.S.; Li, L.G. Colorimetric method for determination of xanthineoxidase. *Prog. Biochem. Biophys*., **1986**, *5*, 65-67.

[33] Ribeiro, R.C.; Pui, C.-H. Recombinant urate oxidase for prevention of hyperuricemia and tumor lysis syndrome in lymphoid malignancies. *Clin. Lymphoma*, **2003**, *3*(4), 225-232.

[34] Li, L.; Dai, L.Z.; Yang, J.; Fang, J.D. Study on xanthine oxidase inhibitory activity of the extracts from Chinese herbal medicines. *J.Wuhan Inst. Technol.*, **2010**, *32*(3), 44-46.

[35] Berry, M.N.; Grivell, A.R.; Grivell, M.B.; Phillips, J.W. Isolated hepatocytes-past, present and future. *Cell Biol. Toxicol.,* **1997**, *13*, 223-233.

[36] Pan, H.J.; Tang, N.; Hua, X.D.; Bian, K. Regulation of NOS-NO system by Chinese medicinal herbs. *Chin. J. Exp. Trad. Med. Formul.*, **2010**, *16*(12), 202-204.

[37] Wang, Y.; Ma, C.R.; He, G.F.; Fang, J.G.; Du, G.; Jiang, H.Y. Impact of tertramethylpyrazine on the expression of nuclear factor-κB and the activity of NOS after situ renal ischemia-reperfusion in rats. *Herald Med.*, **2008**, *27*(2), 128-129.

[38] Zhang, S.; Li, X.Y.; Wei, T.T. Regulatory effect of ginkgo biboba extract on the expression of NF-κB and nitroxide production in glioma cells. *Cancer Prevention Res.*, **2006**, *33*(6), 397-400.

[39] Chen, G.; Guo, L.X.; Deng, X.H.; Yin, Z.Y.; Jing, J.J. Effects of total glucosides of paeony on nitric oxide and inducible nitric oxide synthase production in macrophages and its mechanism. *Chin. J. Immunol.*, **2008**(4), *24*, 345.

[40] Groneberg, D.A.; Christian, G.–S.; Fischer, A. *In vitro* models to study hepatotoxicity. *Toxicol. Palhol.,* **2002**, *30*, 394-399.

[41] Wagner, H.; Ulrich-Merzenich, G. Synergy research: Approaching a new generation of phytopharmaceuticals. *Phytomed.,* **2009**, *16*, 97-110.

[42] Ichikawa, H.; Wang, X.; Konishi, T. Role of component herbs in antioxidant activity of shengmai san 2 a traditional Chinese medicine formula preventing cerebral oxidative damage in rat. *Am. J. Chin. Med.*, **2003**, *31*(4), 509-540.

[43] Hras, A.R.; Hadolin, M.; Knez, Z.; Bauman, D. Comparion of antioxidative and synergistic effects of rosemary extract with α-tocopherol, ascorbyl palmitate and citric acid in sunflower oil. *Food Chem.*, **2000**, *71*(2), 229-233.

[44] Jiang, Y.; Zhao, L.H.; Yan, Y.Q.; Xu, L.; Ji, Y.P. Effect of liuwei dihuang decoction and its compatible prescriptions on lipid peroxide and lipofuscin. *China J. Chin. Mater. Medica*, **1991**, *16*, 1752 -1761.

[45] Liang, R.X.; Huang, L.Q.; Liu, J.F.; Wu, Z.G.; He, X.R. The experimental observation szechuan lovage rhizome and red paeony root to lipid-lowering, antioxidation and vascular endothelium function for hyperlipidemia rats. *Chin. J. Exp. Trad. Med. Formul.*, **2002**, *8*, 432-451.

[46] Xu, A.X.; Wang, C.Q.; Yang, S.H.; Ge, B.; Zhang, Z.M. The synergistic effect on antisenility and its mechanism of PFR and PB WF. *J. Lanzhou Univ.*, **2005**, *31*, 132 -161.

[47] Liu, C.H.; Zhang, Y.; Li, Y.Q.; Qi, Y.X. Determination of antioxidant activity of *Lysimachia christinae* Hance by flow injection chemiluminescence method. *Lishizhen Med. Mater.*, **2010**, *21*, 1267-1268.

[48] Yu, Q.G.; Xiong, Z.Q. Study on antioxidation of mahonia. *Pract. Preventive Med.*, **2007**, *14*(3), 695-696.

[49] Bian, X.L.; Wang, X.L.; Li, J.N.; Pan, Q. Determination of the Scanvenging ROS Ability and Anti-lipid Peroxidation Effects of 6 Kinds of Anti-aging TCM. *North. Pharm. J.*, **2001**, *16*(2), 68-69.

[50] Zhang, Z.J.; Jiang, W.; Wan, Q. Effect of rhodiola on lipidperoxides and ultrastructure of mitochondria in the brain of senile mice. *Chin. J. Clin. Rehab.*, **2005**, (9), 235-237.

[51] Cai, C.; Zhou, Y.; Liu, W.H.; Li, J.L. Effect of Szechuan Lovage Rhizome, Trichosanthis Semen and Mulberry Leaves Extract on Models of Hepatic Microsomal Lipid Peroxidation. *Chin. J. Clin. Rehab.*, **2006**, *10*(11), 90-93.

[52] Wang, S.M.; Yang, G.L.; Dai, H.Y.; Pei, T.M.; Wang, Y.L. Effect of plantain seed on the lipid peroxidation in rats with hyperlipidemia. *Chin. J. Clin. Rehab.*, **2006**, *10*(19), 184-186.

[53] Lv, M.Z.; Chen, B.; Zhang, Z.Z.; He, Z.G. Experimental research of action of aloe extracts on anti-free radical oxidation damage DNA in senile model rats. *China J. Trad. Chin. Med. Pharm.*, **2003**, *18*(3), 136-138.

[54] Wang, Y.J. Research progress on TCM polysaccharide. *J. Med. Theor. Pract.*, **2009**, *22*(3), 279-281.

[55] Zhao, Y.P.; Son, Y.-O.; Kim, S.-S.; Jang, Y.S.; Lee, J.-C. Antioxidant and anti-hyperglycemic activity of polysaccharide isolated from *Dendrobium chrysotoxum* Lindl. *J. Biochem. Mol. Biol.*, **2007**, *40*(5), 670-677.

[56] Kariya, K.; Nakamura, K.; Nomoto, K.; Matama, S.; Saigenji, K. Mimicking of superoxide dismutase acivity byprotein-bound polysaccharide of Coriolus versicolor QUEL.and oxidative stress relief for cancer patients. *Mol. Biother.*, **1992**, *4*(1), 40-46.

[57] Hui, H.P.; Feng, S.L.; Hu, F.D.; Cui, F.; Wu, Y.Q. Study on antioxidative activity of polysaccharide from radix hedysari *in vitro*. *J. Anhui Agri. Sci.*, **2010**, *38*(8), 4056-4057.

[58] You, Y.H.; Lin, Z.B. Ganoderma lucidum polysaccharides peptide (GLPP) protects ECV304 cells from oxidative injury. *Chin. Pharm. Bull.*, **2007**, *23*(11), 1510-1512.

[59] Xie, S.Q.; Liao, W.Q. Ganoderma polysaccharides and H_2O_2-induced kerotinocytes oxidative stress. *Chin. J. Dermatovenereology*, **2006**, *20*(2), 77-79.

[60] Wei, W.S.; Tan, J.Q.; Guo, F.; Chen, H.S.; Zhou, Z.Y.; Zhang, Z.H.; Gui, L. Effects of Coriolus versicolor polysaccharides on superoxide dismutase activities in mice. *Acta. Pharmacol. Sin.*, **1996**, *17*(2), 174-182.

[61] Liu, X. The research on antidiabetics and antioxidation of morinda officinalis polysaccharides. *J. Chin. Med. Mater.,* **2009**, *32*(6), 949-951.

[62] Li, G.L.; Huang, Y.Q.; Yang, W.D.; Ren, B.B.; Shen, Y. The effect of lycium barbarum polysaccharide on endurance and antioxidative status in trained mice. *Chin. J. Sports Med*., **1998**, *17*(1), 56-57.

[63] Sun, F.X.; Yang, M.X.; Na, R.H.; Bao, B.Q.; Li, B.S. Inhibition of total flavonoid of fructus choerospondiatis on erythrocyte peroxidation induced by adriamycin. *Chin. Trad. Pat. Med.*, **2001**, *23*, 606-607.

[64] Zuo, S.Y.; Luo, H.J.; Zhu, Z.Y. Effect of polysaccharide from spirulina platensis on anti-oxidation in experimental diabetic mice. *Pharm. Biotechnol.*, **2001**, *8*(1), 36-38.

[65] Zheng, H.F.; Guo, C.C.; Yang, J.W. The effect on antioxidant ability of angelica polysaccharide to exhaustion sports rats. *J. Phys. Educ. Inst. Shanxi Normal Univ.*, **2009**, *24*(3), 126-128.

[66] Gong, H.L.; Yin, Y.Y.; Li, W.P.; Li, W.Z.; Zhang, Y.L.; Wu, G.C.; Zhu, F.F. Effects of polygona-polysaccharose on blood glucose level and antioxidant activity in diabetic mice induced by alloxan. *Acta Univ. Med. Anhui*, **2008**, *43*(5), 538-540.

[67] Kourounakis, A.P.; Assimopoulou, A.N.; Papageorgiou, V.P.; Gavalas, A.; Kourounakis, P.N. Alkannin and shikonin: effect on free radical processes and on inflammation-a preliminary pharmacochemical investigation. *Arch. Pharm.*, **2002**, *335*(6), 262-268.

[68] Assimopoulou, A.N.; Papageorgiou, V.P. Radical scavenging activity of *Alkanna tinctoria* root extracts and their main constituents, hydroxynaphthoquinones. *Phytother. Res.*, **2005**, *19*(2), 141-148.

[69] Gao, D.Y.; Kakuma, M.; Oka, S.; Sugino, K.; Sakurai, H. Reaction of beta-alkannin (shikonin) with reactive oxygen species: detection of beta-alkannin free radicals. *Bioorg. Med. Chem.*, **2000**, *8*(11), 2561-2569.

[70] Liu, K.; Zheng, H.S.; Li, Y.D. The review on rhein pharmacological effects. *Chin. Arch. Trad. Chin. Med.*, **2004**, *22*(9), 1732-1734.

[71] Heim, K.E.; Tagliaferro, A.R.; Bobilya, D.J. Flavonoid antioxidants: chemistry, metabolism and structure-activity relationships. *J. Nutritional Biochem.*, **2002**, *13*(10), 572-584.

[72] Huang, Y.Q.; Wang, J.; Shen, Y.; Su, L.M.; Lu, J.W. Extraction total flavonolid from *Lycium Barbarum L.*(TEL) and its scaveging effect on hydroxyl and super oxygen radicals. *Chin. J. Public Health*, **1996**, (9), 795-796.

[73] Sun, Y.; Wang, D.J.; Zhu, J.; Zhang, H.Q. The influence on lung protein content and antioxidation of *C. Deserticola* polysaccharide to aging mice. *Chin. Pharm. Bull.*, **2001**, *17*, 101-104.

[74] Wu, B.H.; Hu, C.L.; Wu, W.B.; Long, C.G.; Li, Q.R.; Zhang, X.D. Protective effect of flavononids from glycyrrhiza (FG) on focal cerebral ischemia reperfusion. *Henan J. Pract. Nervous Diseases*, **2003**, *6*, 6-8.

[75] Wang, C.; Qin, D.N. Semen cuscutae flavonoids protect cells of rat seminiferous tubule from apoptosis induced by serum withdraw. *Chin. Pharm. Bull.*, **2006**, *22*(8), 984-986.

[76] Xu, J.K.; Li, Y.B.; Zheng, J.J.; Jiang, T.; Yao, X.S. Protective effect of tanshinones against liver injury in mice loaded with restraint stress. *Acta Pharm. Sinica*, **2006**, *41*(7), 631-635.

[77] Wang, A.M. The research on effect of puerarin isoflavone to climacteric rats learning and memory and antioxidation. *Chin. J. Mod. Drug Appl.*, **2009**, 3(24), 68-69.

[78] Zhao, W.H.; Deng, Z.Y.; Fan, Q.S.; Zhang, W.M. Anti-oxidation on total flavones of epimedium *in vitro*. *J. Nanchang Univ.*, **2009**, *33*(1), 53-55.

[79] Su, R.; Zhang, H. Study on Antioxidant Activity of Flavonoids from *Portulaca oleracea L.*. *J. Anhui Agri. Sci.*, **2010**, *38*(8), 4068-4070.

[80] Xu, L.X.; Li, W.B.; Cai, J.X. Study on the optimization of extraction technology and the *in vitro* antioxidative effect of total flavonoids from Ligusticum chuanxiong Hort. *Chin. J. Hosp. Pharm.*, **2010**, *30*(18), 1524-1528.

[81] Min, J.; Ao, M.Z.; Hu, J.; Wang, Z.B.; Huang, S.Y. Experimental research on anti-oxidation effect of total saponins of panax japonicus. *J. Hubei Polytechnic Inst.*, **2007**, *11*(1), 110-112.

[82] Cao, Y.J.; Yang, G.; Li, L.Y. Research on Antioxidant Effect of Balsam Pear Saponins to Subacute Aging Mice. *Chin. J. Gerontology*, **2007**, 27, 947-948.

[83] Zhao, Z.M.; Pan, H.S.; Feng, Y.C. Experimental studies on the antioxidant capacity of ginsenoside Rg1. *J. Jiangxi Univ. TCM*, **2009**, *21*(1), 36-38.

[84] Nie, S.L.; Xu, X.X.; Xia, L.Z. Effect of total saponins of codonpsis on blood lipid and nitric oxide level in experimental hyperlipemia rats. *J. Anhui TCM Coll.*, **2002**, *21*(4), 40-42.

[85] Liang, Q.M.; Qu, S.C.; Yu, X.F.; Xu, H.I.; Sui, D.Y. Acanthopanax senticosus saponins ameliorates oxidative damage induced by hydrogen peroxide in neonatal rat cardiomyocytes. *China J.Chin. Mater. Med.*, **2009**, *34*(19), 2489-2492.

[86] Wang, L.; Li, J.W.; Sun, Q.H.; Liang, X.; Liu, Y.; Wang, D.H. Antioxidative effects of panax notoginseng saponins on rats with acute lung injury induced by oleic acid. *J.Kunming Med. Univ.*, **2009**, (12), 48-51.

[87] Wu, L.; Wei, W.; Gui, S.Y.; Sun, W.Y. Effects and mechanisms of Shaoqiduogan on mice with chemical liver injury. *China J. Chin. Mater. Med.*, **2006**, *31*(21), 1807-1810.

[88] Li, S.T.; Zhou, X.H.; Yang, H.M. Protective effects of Saikosaponin-D on primary cultured rats hepatocytes injured by ethanol. *J. Chengde Med. Coll.*, **2007**, *24*(4), 352-354.

[89] Cheng, C.; Qin, E.H.; Mo, K.J. Research on Functional Characteristic of Alternanthera Philoxeroides Griseb Saponin. *Food Fermn. Ind.*, **2007**, *33*(12), 60-62.

[90] Cao, Y.J.; Chen, H.; Yang, G.; Li, L.Y. Study on antioxidation of dioscin in the subacute aging mice. *Pharm. Clin. Chin.Mater. Med.*, **2008**, *24*(3), 19-20.

[91] Ye, Y. Natural plant antioxidative components and their effects. *China Food Addit.*, **2000**, *4*(4), 45-48.

[92] Huo, Z.Y.; Liu, X.L.; Zhang, J.L. Antioxidation activity of anisodamine *in vitro*. *J. Qiqihar Med. Coll.*, **2002**, *23*(7), 721-722.

[93] He, J.; Liang, H.; Shi, D.Y.; Dong, C.J.; Zhang, X.Z. Effects of laurencia extract on antioxidant activities in mice. *Chin. J. Public Health*, **2005**, *21*(9), 1082-1083.

[94] Cai, Y.Z.; Luo, Q.; Sun, M. Antioxidant Activity and Phenolic compounds of 112 Traditional Chinese Medicinal Plants Associated with Anticancer. *Life Sci.*, **2004**, *74*, 2157 -2184.

[95] Catherine, R.-E.; Miller, N.; Paganga, G. Antioxidant properties of phenolic compounds. *Trends Plant Sci.*, **1997**, *2*(4), 152-159.

[96] Huang, M.; Wang, X.J.; Yang, K. Antioxidants of Chinese materia medica and *in vitro* methods for assessment of antioxidant activities. *J. Chongqing Univ. Sci. Technol.*, **2006**, *8*(3), 109-112.

[97] Zhao, B.L. Antioxidant effects of green tea polyphenols. *Chin. Sci. Bull.*, **2003**, *48*(4), 315- 319.

[98] Filipa, V.; Plockova, M.; Midrkal, J.S. Resveratrol and its antioxidant and antimicrobial effectiveness. *Food Chem.*, **2003**, *83*, 585-593.

[99] Carmen, R.T.; Φyvind, M.A.; Gardner, P.T.; Philip, C.M.; Sharon, G.W.; Susan, J.D.; Andrew, R.C. Anthocyanin-rich Extract Decreases Indices of Lipid Peroxidation and DNA Damage in Vitamin E- depleted rats. *Free Rad. Bio. Med.*, **2001**, *31*(9), 1033-1037.

[100] Li, H.B.; Jiang, Y.; Wang, C.C.; Cheng, K.W.; Chen, F.; Li, S.X. The antioxidant property and total polyphenol content of TCM extract *in vitro*. *Forum Chin. Culture*, **2008**, *1*, 256-259.

[101] Zeng, W.C.; Cai, Q,R.; Yang, H.; Luo, Y.H.; Huang, Y.Q. Research on antioxidative activity of polygoni cuspidati tannic acid. *Pharm. Clin. Chin. Mater. Med.*, **2002**, *18*(6), 18-20.

[102] Hermans, N.; Cos, P.; Maes, L.; Bruyne, T.D.; Berghe, D.V.; Vlietinck, A.J.; Pieters, L. Challenges and pitfalls in antioxidant research. *Curr. Med. Chem.*, **2007**, *14*, 417-430.

[103] Lei, H.; Wang, B.; Li, W.P.; Yang, Y.; Zhou, A.W.; Chen, M.Z. Anti-aging effect of astragalosides and its mechanism of action. *Acta. Pharmacol. Sin.*, **2003**, *24*(3), 230-234.

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