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Review

Chemical constituents and biological activities of saponin from the seed of *Camellia oleifera*

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Camellia oleifera **Abel (Theaceae) is a woody plant that is native to China. It is an important source of edible oil and is used in traditional medicine. It contains a triterpenoid saponin with high medical value that can be obtained from the seed cake residue (marc) after oil extraction. This saponin has prospects for wide applications. In this review, we summarize previous and current information regarding the chemical structure, physicochemical properties and biological activities of the saponin from the seed cake of *C. oleifera* and provide new insights for future research.**

Key words: Saponin, *C. oleifera* Abel, biological activity, chemical constituent.

INTRODUCTION

Camellia oleifera Abel (Theaceae) is an important woody plant that is native to China (Li et al., 2009; Liu et al., 2009). It is widely distributed and extensively cultivated in China for its edible seed oil and medicinal properties. It is found in forests, thickets, streambanks and foothills at altitudes of 500 - 1300 m (Figure 1). Its seed oil is rich in vitamins and is capable of enhancing human immunity (Wang et al., 2007). In southern China, *C. oleifera* oil is highly regarded as edible oil with *ca.* 80% oleic acid. The oil is effective in treating ringworm and can reduce LDL ('bad cholesterol') and prevent cardiovascular diseases. Camellia oil is also regarded as the ideal edible oil for diabetic patients. China is the largest producer of *C. oleifera* in the world, with a planting area reaching 3.5 million hectares and an annual output of 6.45 billion kg of seeds (Figure 2), accounting for 95% of the total world output.

Apart from edible oil, *C. oleifera* also contains saponins that impart anthracnose resistance to the plant (Ye, 2001). The major saponin is a triterpenoid that can be extracted from the residue (marc) of *C.oleifera* seed cake after oil extraction (Figure 3). This saponin is effective in relieving cough and treating tracheitis, cardiovascular diseases and cancer. The saponin content of the seed cake is more than 10%. However, only about 5% of the *C. oleifera* saponin are been utilized, therefore, improvement in the development and utilization of *C.oleifera* saponin is needed. In this review, we summarize previous and current information regarding the chemical structure and biological activities of saponin from the seed cake of *C. oleifera* and provide new insights for future study.

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Chemical structure of *C. oleifera* saponin

The structural sugars contained in *C. oleifera* saponin are glucuronic acid, arabinose, xylose and galactose (Figure 4). Structural acids include Tren, Cis-1, 2-dimethyl acrylic acid and acetic acid. The *C. oleifera* saponin has a similar structure to 5-7 species of sapogenins of triterpenoid saponin. The ligand of saponin is composed of 5-7 kinds of tea sapogenols (Li et al., 1994).

Physicochemical properties of *C. oleifera* Saponin

The taste of *C. oleifera* saponin is pungent and sharp, and may induce sneezing due to stimulation of the nasal mucous membranes. The saponin is a white, highly hygroscopic columnar crystal. It is insoluble in anhydrous alcohol, ethanol, cold water, ether, petroleum ether and other non-polar solvents. It is soluble in hot glacial acetic acid and alkaline aqueous solution. The chemical reaction of the saponin and higher alcohols can result in double salts. The saponin causes hemolysis of red blood cells and so, it cannot be administered by intravenous injection.

Figure 1. Fruits of *C. oleifera.*

Figure 2. Seeds of *C. oleifera.*

Figure 3. Seeds cake of *C. oleifera.*

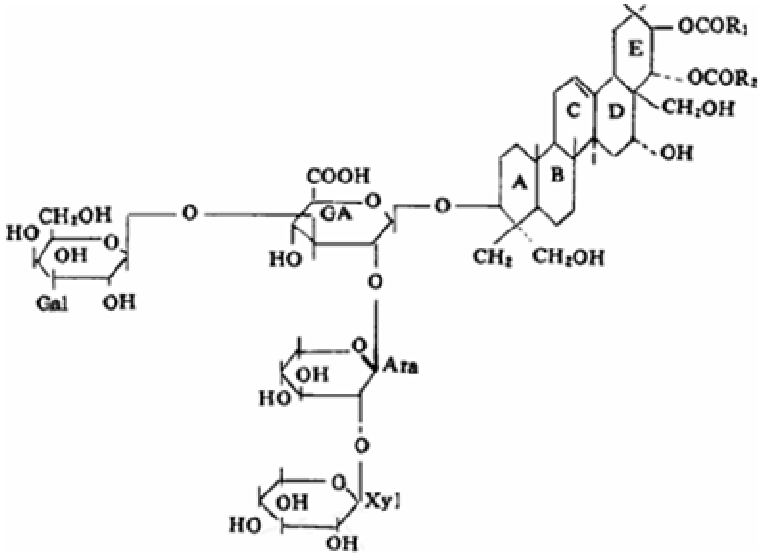

Figure 4. Molecular structural of *C. oleifera* saponin (R1R2: Lower fatty acid; GA. glucuronic acid; Ara. Arabinose; Xyl. Xylose; Gal. Galactose).

When administered orally, it is toxic for ectothermic, but not endothermic, animals.

BIOLOGICAL ACTIVITIES

Antibacterial and anti-mutagenesis effects

C. oleifera saponin shows good inhibitory action against the fungus that causes dermatosis. The *in vitro* antimicrobial tests showed that *C. oleifera* saponin had a marked antibacterial effect. Strong inhibitory effects were seen against *Trichophyton meginii* with a minimum inhibitory concentration (MIC) of 0.375%. The saponin was least effective on *Microsporum ferrugineum,* with a MIC of 5% (Zhu et al., 1989).

The saponin is an active material with anti-tumor activity. Chen et al. (1998) studied the anti-mutation effect of extracted saponins with the Ames test, using three other Chinese anti-tumor medicines; alkanet, prunella vulgaris

and pteris nervosa, as a control group for comparison. The *C. oleifera* saponin had an antimutagenic activity as strong as these three control medicines.

Inhibition of cardio-cerebral vascular diseases

Recently, Chinese scholars have studied in detail the effect of *C.oleifera* saponin on cardio-cerebrovascular diseases. Li et al. (2006) showed a protective effect and studied the mechanism of action of *C.oleifera* saponin on isolated rat myocardial anoxia/reoxygenation (A/R) injury. The saponin improved cardiac muscle contractility; caused a significiant reduction in the lipid peroxidation byproduct, malondialdehyde; increased the activity of myocardial superoxide dismutase and glutathione peroxidase; decreased creatine kinase concentration in the coronary outflow and attenuated myocardial cell Ca^{2+}accumulation.

These influences of saponin were attenuated by the K_{ATP} channel blocker, Glibenclamide. The saponin showed a clear protective action against myocardial injury following ischemia induced by A/R, with the mechanism of action involving the opening of the K_{ATP} channel. The *C. oleifera* saponins can effectively protect the myocardium against ischemia induced by isoproterenol. Huang et al. (2001) studied the protective effect and a pharmacological ischemic preconditioning effect of *C. oleifera* saponin on intact rat heart. A preconditioning intravenous (IV) injection of saponin, effectively protected the myocardium from ischemia induced by isoproterenol. The cardio protective effect was significantly attenuated when the NO synthesis inhibitor and methylene blue were injected prior to saponin.

The saponin showed a protective effect in human umbilical vein endothelial cells against hypoxia-reoxygenation injury. Huang et al. (2005) investigated the effect of *C.oleifera* saponin on injury of endothelial cells induced by hypoxia-reoxygenation and neutrophil adhesion, and explored its possible mechanisms. Hypoxia-reoxygenation resulted in human umbilical vein endothelial cell injury and enhanced neutrophil adhesion with a concomitant increase in lactate dehydrogenase activity, malondialdehyde level, and adhesion rate. Conversely, the saponin reversed the decreases in superoxide dismutase and glutathione peroxidase activities in a concentration-dependent manner.

Spermicidal effects of *C. oleifera* saponin

The *in vitro* spermicidal effect of the saponin on spermatozoa of mice and humans was compared with that of the known spermicides, methyl phenoxy-polyethanol (MPPE) and phenylmercuric acetate (PMA) (Gao et al., 1990). The spermicidal effect of the saponin (MEC=10 µg/ml) on mouse spermatozoa was more potent than that of MPPE (IMEC = 40 µg/ml) and PMA (MEC = 20 µg/ml). However, the effect on human spermatozoa was weaker (100 µg/ml) than that of MPPE (MEC = 50 µg/ml) and PMA (MEC = 50 µg/ml). The spermicidal effect of saponin on mouse spermatozoa could also be reduced significantly by human semen.

The saponin showed a substantial spermicidal effect *in vitro* and an antifertility function *in vivo* in mice. The environmentally, friendly saponin should therefore, be exploited as a spermicide or prophylactic and an antifertility medication against rodent pests in future. Chen et al. (2006) studied the antifertility function of the saponin as a sterilant against rodents. They found that the *in vitro* spermicidal effect of the saponin in male mice provided an excellent positive relationship in a dose-dependent manner. The minimum spermicidal concentration was 0.05 mg/ml in 3 min, which corresponded with the activity of nonoxynol spermicide and was lower than mandelic acid (0.1 mg/ml) and citric acid (0.25 mg/ml). Compared with the control group, after oral (i.g.) administration) of 125 mg/(kg·d) saponin sterilant for 4 weeks, reductions of 92.1% for live sperm and 52.6% for sperm motility were seen in male mice, while in female mice, a decrease of 64.0% in gravidity rate and a decrease of 67.4% in live embryos was observed.

Antioxidant and free radical scavenging activities of *C. oleifera* saponin

Lv et al. (2005) measured and analyzed the saponin content of *C. oleifera* and studied the capacity of the saponin to scavenge hydroxyl free radicals produced by the Fenton reaction and to scavenge superoxide anion. The saponin had a strong antioxidant capability, it could inhibit TBARS formation in Fe^{2+} induced liposomes, it has a strong capacity to inhibit the oxidation of 2'-deoxyribose and it could scrub active oxygen radicals produced by chemical reactions.

DISCUSSION

In addition to the effects of the *C. oleifera* saponin, other anticancer functions were discovered in other extracts of *C.oleifera*, showing the potential of this plant for wide medicinal applications. Tang et al. (2008) studied the *in vitro* anticancer activity of *C. oleifera* extracts on cell cultures. The extracts had a significant dose-dependent anticancer activity on MCF-7 and SMMC-7721 cells over a range 7.82 - 500 µg/ml. Methylaminopterin and vincristine sulfate, as positive control drugs, also inhibited the viability of these two tumor cell lines in a dose-dependent manner. The inhibition ratio was greater for 95% ethanol extracts of *C. oleifera* than for water extracts. Zhu et al. (2007) investigated the anti-free radical, anti-hyperglycemic and anti-tumor effects of C*. oleifera* fleshy fruit (EFF) and

fleshy leaf (EFY) extracts. The EFF was similar to vitamin E in its ability to scavenge free radicals and inhibit lipid peroxidation. In an alloxan-induced diabetic mouse, EFF and EFY decreased the serum glucose levels, with no effect on glucose levels in a control non-diabetic mouse.

The purpose of this review is to collect all of the available information regarding the chemical constituents and biological effects of the *C. oleifera* saponin. This will help scientists to take action for future research into the components of this important plant.

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