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# CHEMICAL CHARACTERISTICS, IDENTIFICATION, AND PHARMACEUTICAL APPLICATIONS OF BIOACTIVE CONSTITUENTS IN AMARANTHUS CAUDATUS AND AESCULUS HIPPOCASTANUM

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**Abstract:** Medicinal plants are essential sources of biologically active compounds (BACs) that possess diverse therapeutic effects. Among these, Amaranthus caudatus (love-lies-bleeding) and Aesculus hippocastanum (horse chestnut) are recognized for their abundance of phenolics, flavonoids, and saponins with significant antioxidant, anti-inflammatory, and vascular-protective properties. This article reviews their major chemical constituents, presents experimental quantitative data, describes modern analytical identification methods, and discusses existing pharmaceutical dosage forms developed from these plants.

**Keywords:**Amaranthus caudatus; Aesculus hippocastanum; bioactive compounds; phenolic acids; flavonoids; saponins; escin; betalains; antioxidant activity; phytochemical analysis; HPLC; LC-MS/MS; spectroscopic identification; pharmaceutical dosage forms; herbal medicine; nutraceuticals; venotonic agents; anti-inflammatory activity; natural antioxidants; plant-based therapeutics.

## Introduction

Phytochemical and pharmacognostic research of medicinal plants provides the foundation for drug discovery and the formulation of herbal medicines. A. caudatus is a traditional pseudocereal with nutritional, antioxidant, and hepatoprotective effects, while A. hippocastanum is one of the most extensively studied medicinal trees in Europe due to its vasoprotective and anti-edematous activity. Understanding their chemical profile and pharmaceutical applications contributes to both evidence-based phytotherapy and nutraceutical innovation.

Phytochemical Profile of Amaranthus caudatus

Main Groups of Constituents

The chemical composition of A. caudatus includes phenolic acids (gallic, ferulic, and p-coumaric), flavonoids (rutin, quercetin, kaempferol), betalains, saponins, and amino acids. Betalains, which impart the characteristic red color, act as natural antioxidants.

Quantitative Data

Experimental analyses report total phenolic content (TPC) from 159.6 to 958.2 µg GAE/mg dry extract, while rutin concentration varies between 0.12 and 42.3 mg/g depending on genotype and growth stage. Flavonoid content averages 8.9 mg CE/100 g, and tannin extracts demonstrated

41% superoxide radical inhibition and up to 69% cell viability recovery in oxidative stress models.

Phytochemical Profile of Aesculus hippocastanum

Principal Compounds

The key bioactive components of horse chestnut include triterpenoid saponins (mainly escin), flavonoids, coumarins (esculin, fraxin), tannins, and sterols. Escin exhibits strong venotonic and anti-inflammatory activity, stabilizing capillary walls and reducing edema.

Experimental Findings

In vitro antioxidant assays have shown 46% hydroxyl radical inhibition at 100 µg/mL. In animal studies, escin reduced serum leptin and thyroxine ($FT_4$) by approximately 30–36%, increased HDL-cholesterol by 17%, and restored endogenous antioxidant markers such as glutathione (GSH). LC-MS/MS analysis confirmed multiple antioxidant mechanisms, including peroxynitrite scavenging (3.4–13.2 mmol AAE/g).

**Analytical Identification Techniques**

Modern analytical tools used for these species include:

HPLC-DAD, UPLC-MS/MS – for precise quantification of flavonoids, phenolics, and saponins.

TLC – for rapid phytochemical screening. GC-MS – for volatile and lipid components. UV-Vis, FTIR, NMR – for structure confirmation and total content assays (Folin–Ciocalteu, $AlCl_3$ methods). Antioxidant potential is evaluated via DPPH, ABTS, and FRAP assays, linking chemical composition with biological efficacy. Pharmaceutical Forms and Therapeutic Applications Aesculus hippocastanum–based Medicines The pharmacologically active compound escin from horse chestnut is widely used in official and over-the-counter (OTC) products worldwide. Common dosage forms include: Topical gels and creams: Venostasin® Gel, Reparil® Gel N, Lioton® with escin — used to reduce venous insufficiency, varicose veins, swelling, and bruising.

Oral tablets and capsules: Venoplant®, Aescin®, Phlebodril®, standardized to 16–20 mg escin per dose for chronic venous disease and hemorrhoidal conditions.

Injectable forms (in hospital settings): Escin sodium salts in ampoules for anti-edematous therapy. Clinical data confirm escin's ability to improve capillary tone, inhibit hyaluronidase activity, and decrease vascular permeability.

Amaranthus caudatus–derived Products

While A. caudatus is primarily cultivated as a functional food and nutraceutical, several pharmaceutical and cosmeceutical forms have been developed: Nutritional powders and capsules: rich in amaranth oil, flavonoids, and proteins; used as dietary supplements for antioxidant support, liver protection, and metabolic regulation. Topical formulations: creams and emulsions containing A. caudatus seed oil or betalain extracts — promote wound healing and provide natural UV protection. Liquid extracts and tinctures: standardized hydroalcoholic extracts used in phytotherapy for detoxification and general toning. Recent patents describe encapsulated amaranth extract nanoparticles enhancing bioavailability of phenolic compounds for cosmetic and pharmacological applications.

Pharmacological and Biological Relevance

Both plants demonstrate clear therapeutic significance. Amaranthus caudatus contributes to antioxidant defense, lipid metabolism, and tissue repair, while Aesculus hippocastanum remains a clinically supported agent for venous disorders, capillary fragility, and local inflammation. Their active compounds act synergistically by stabilizing membranes, reducing oxidative stress, and improving microcirculation.

Conclusion

The chemical diversity and biological efficacy of Amaranthus caudatus and Aesculus hippocastanum validate their long-standing use in traditional and modern medicine. Advanced chromatographic and spectroscopic methods have enabled precise identification of their active constituents. Existing pharmaceutical formulations — from oral capsules to topical gels — demonstrate the successful integration of natural bioactives into evidence-based medicine. Future research should focus on standardized extraction, bioavailability enhancement, and clinical evaluation of combined phytocomplexes derived from these species.

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