Pharmacological Review of Phytochemistry, Preclinical Efficacy, and the Critical Toxicological Duality of Apricot (Prunus armeniaca L)

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Abstract—**Apricot (Prunus armeniaca L.) represents one of the world's universally accepted fruits with considerable dietary and non-dietary values beyond its delicious eating quality and nutritional benefits. In addition to being delicious to eat, its various parts have long been used in traditional herbal medicine, mainly the kernel of the fruit, which represents one of the fruits with well-documented and recognized pharmaceutical values and biological functions beyond its dietary benefits and eating quality ['']. However, apart from its pleasant eating quality and significant nutritional values to human health, the apricot fruit and its parts have important pharmaceutical values and functions considering its part used in herbal medicine. In addition to its walnut flavor and significant nutritional benefits to human beings through eating and consuming it, its various parts contain considerable pharmaceutical values and functions due to its long-standing application in herbal medicine by different cultures around the world. In addition to its delicious eating quality and confirmed biological functions to human health, its various parts have substantial biological values and significant functions to human beings due to its long-standing application in herbal medicines around the world.**

However, and apart from its pleasantly delicious eating quality and well-recognized pharmaceutical values to human being due to its significant biological functions to human being through its eating and application in herbal medicine around the world, its various parts are seen to have substantial pharmaceutical values and functions to human being due to its long-standing application and functions in herbal medicine around the world because of its delicious eating quality and recognized pharmaceutical values to human being due to its significant biological functions to human being around the world through consuming and eating it around the world.

However, apart from its delicious eating quality and significant pharmaceutical values to human beings due to its substantial biological functions to source of highly active but toxic medicinal chemicals.

I. INTRODUCTION

The apricot (Prunus armeniaca) has been regarded as an essential component of dietary and medicinal practices for centuries, especially in Asian cultures [1, 9]. Although the juicy pulp has received well-acknowledged recognition for its nutritional properties, the kernel or seed has played a more complex and controversial role in the realm of pharmacology. The traditional uses of the apricot kernel have included a mild laxative, emetic, and antiseptic agent, and more general cardioprotective and hepatoprotective properties [9, 10].

Today, the scientific interest in apricot tends to be dichotomized. On one hand, pulp-related research might include the analysis of its role as a functional food, something that could possibly prevent diseases associated with oxidative stress [3, 11]. On the other hand, the study of the kernel might include a critically important analysis of a well-known compound: amygdalin [5]. It's a compound that separates the demands of traditional healers and untested popular beliefs from the established truth of modern medicine through the pharmaceutical development of the apricot pulp and its harmless leaves, rather than the harmful and experimental apricot kernel compounds.

II. PHYTOCHEMICAL COMPOSITION

The medicinal effects of apricot are directly linked with a rich, diverse chemical composition-the distinction of which significantly varies between the pulp, leaf, and kernel.

2.1 Apricot Pulp and Leaf

The intense orange color of the pulp is a sure indication of a high content of carotenoids, mainly

beta-carotene, which the human body converts to Vitamin A [12, 13, 14]. Pulp is also a rich source of phenolic compounds and flavonoids [12]. Major phenolics are Chlorogenic acid (with a range from 8.09 to 141.93 and Epicatechin [12,]. Flavonoids like Rutin within the range of 20.52 to 446.38 were also recorded, contributing to the general health-enhancing reputation of the fruit [12,]. The fruit is also a dietary source of some key nutrients: Vitamin C, Vitamin E, and major minerals like Potassium and Phosphorus [12, 14, 15,].

Apricot leaf extract (PrALe) has been characterized as an outstanding source of hydroxycinnamic acids and flavonols [16]. The major compounds responsible for its bioactivity were quercetin-3-O-rutinoside, 5-O-caffeoylquinic acid, and 3-O-caffeoylquinic acid [16,]

2.2 Apricot Kernel Oil (AKO) and Amygdalin

Chemically, the kernel is distinctive. It has commercial value in the form of AKO, in which the oil yields varies between 42.2% and 57.2% [17]. AKO contains high content of unsaturated fatty acids, namely: Oleic acid (omega-9, up to 73.58%) and Linoleic acid (omega-6, 19.26%-35.67%) [18,,, 17]. Its unsaponifiable matter contains phytosterols like: Sitosterol (177.0 mg/100 g), Campesterol, Stigmasterol, and Tocopherols (50.76 mg/100 g) [10,,].

The major active principle of the kernel is a cyanogenic glycoside known as Amygdalin []. This compound is the predominant bioactive agent, accounting for the purported pharmaceutical properties of the kernel, as well as its strong, acute toxicity [5, 7]. Amygdalin levels are highly variable and high concentrations (up to 419. mg) have been detected not only in the kernels but also within the flowers of some varieties[19,].

Table 1. Differential Composition and Key Bioactive Concentrations in Apricot Parts

Plant Part	Compound Class	Specific Compound	Concentration Range	Primary Relevance	Reference
Pulp (Fruit Flesh)	Flavonol	Rutin	20.52–446. 38 mg/kg	Antioxidant, Anti-inflam matory	[12,]
	Phenolic Acid	Chlorogenic Acid	8.09–141.93 mg/kg	Antioxidant, Metabolic Health	[12,]
	Carotenoid	beta-Carotene	5.74–48.69 mg/100 g	Pro-Vitamin A, Neuroprote ction	[12,]
Kernel Oil (AKO)	Fatty Acid	Oleic Acid	53.06%–73.58%	Cardioprotective, Dermatological	[18,]
	Phytosterol	beta-Sit osterol	177.0 mg/100 g	Anti-athero sclerotic	[10,]
Kernel/Seed	Glycoside	Amygdalin	Up to 419.78 mg/100 g (in flower)	Cyanide Toxicity Risk	[19,]

III. PHARMACOLOGICAL AND MEDICINAL EFFECTS

3.1.Antioxidant and Anti-inflammatory Effects

The most robust and safe pharmacological property of apricot is its antioxidant capacity due to the high concentration of phenolics, flavonoids, and carotenoids in the fruit and leaf [4,6,20,10]. Cell-based antioxidant protection assays confirm that apricot antioxidants successfully penetrate cell membranes to protect against induced oxidative damage, confirming their functional relevance in vivo []

Moreover, this protection mechanism is extended to inflammation. Polyphenol-rich apricot leaf extract, PrALe, acts against inflammation through the inhibition of the Cyclooxygenase-1 enzyme [16,]. Extracts significantly decrease the production of in immune cells and reduce their chemotaxis towards pro-inflammatory chemoattractants [].

3.2. Anti-Metabolic and Cardioprotective Effects

Apricot bioactives demonstrate strong potential for managing metabolic health and cardiovascular health:

- Anti-Diabetic Activity: Sweet kernel and fruit extracts display strong in vitro alpha-amylase inhibition. The enzyme is responsible for carbohydrate digestion. Sweet kernel extract proved to be the most potent inhibitor with an value of 0.74 [4,]. It is suggested that multi-pathway modulation of anti-diabetic activity includes increasing translocation and activation of pathways in tissues for maintaining glucose homeostasis [21].
- Anti-Obesity: PrALe has demonstrated anti-obesity action through the inhibition of pancreatic lipase [16,]; by doing so, hydrolysis and absorption of dietary fat in the gut are reduced, a mechanism similar to that used by approved anti-obesity pharmaceuticals.
- Cardioprotection: The kernel oil is renowned for its cardioprotective and anti-hyperlipidemic action. This beneficial effect emanates directly from the ideal contents of unsaturated fatty acids, such as Oleic and Linoleic acids, and also phytosterols like Sitosterol that interfere with cholesterol absorption [10]. Being highly rich in potassium, the fruit itself has been recommended in diets to reduce the prevalence of coronary heart disease and stroke [].

3.3 Neuroprotective Effects

Apricot kernels have a history of application in traditional medicine for ailments involving loss of memory [22].

- Cholinesterase inhibitor:Aqueous extracts of bitter apricot kernels have demonstrated potent Acetylcholinesterase (AChE) inhibitory activity (IC50 = 134.93 ± 2.88µg/mL), an important pharmacological approach in the management of AD [22]. Importantly, the extract exhibited neuroprotectivity by preventing induced cell death in neurons [22].
- Anti-Amyloidogenic Activity: Lutein, one of the major carotenoids of apricots, exhibited potent in vitro anti-amyloidogenic activity. This may indicate that apricot fruit dietary intake could provide active agents protecting from amyloid-related diseases, such as AD [].

Table 2. Summary of Key Pharmacological Activities and In Vitro Potency

Activity	Plant Part/Component	Mechanism of Action	In Vitro Potency Example	Reference
Anticancer	Extracts	Cytotoxicity,		[16,]
	(General)	Apoptosis Induction	(MDA-MB-231) = 0.48 mg/mL	
Anti-Diabetic	Sweet Kernel Extract	alpha-Amylase Inhibition	0.74 mg/mL	[4,]
Anti-Obesity	Leaf Extract (PrALe)	Pancreatic Lipase and COX-Inhibition	Most effective among tested extracts	[16,]
Neuroprotective	Bitter Kernel Extract	Acetylcholinesterase ACh Inhibition	134.93 µg/mL	[22]
Antioxidant	Pulp, Leaf, Kernel	Free Radical Scavenging, CAP-Protection	Demonstrated protection in red blood cells	[]

3.4 Anticancer Activity (The Amygdalin Controversy) and Toxicological Duality

- Controversy and Toxicological Duality
- While this in vitro data regarding apoptosis induction in cancer cells is very promising, including MCF-7 and MB-231breast cancer cells [], it must be weighed against the unacceptable toxic component risk of the kernel.
- The Unacceptable Risk

Amygdalin is readily converted to hydrogen cyanide (HCN) upon ingestion []. HCN is a powerful, fast-acting poison that inhibits cellular respiration [8,]. Ingestion of raw kernels or high-amygdalin extracts can quickly result in severe acute toxicity, manifesting as metabolic acidosis, profound hypotension, seizures, coma, and death, frequently requiring mechanical

ventilation and high-dose antidote administration [,]. Long-term exposure may cause chronic neurotoxicity, manifested by visual impairment, deafness, and loss of coordination (ataxia) [].

- Clinical Failure and Regulatory Status

Despite several decades of popularity, the promotion of laetrile/amygdalin as an alternative cancer remedy has been contrasted by rigorous clinical evidence that refutes its efficacy [5,,]. One large Phase II study treated 175 patients and reported progression of cancer in all within seven months after completing treatment, confirming no clinical response []. The Food and Drug Administration have not approved Laetrile for use in cancer treatment and actively issue warnings against the consumption of raw, unprocessed apricot kernels [7, 8]. This overriding safety risk fundamentally negates any therapeutic application of the crude material, despite possible isolated in vitro benefits [].

IV. CHALLENGES FOR TRANSLATIONAL SCIENCE AND FUTURE PERSPECTIVES

4.1. Conclusion and Future Perspectives

Apricot fruits (Prunus Armeniaca) represent another planting with dual pharmaceutical properties. The fruit and leaf fractions are identified to be safe and very rich sources of polyphenols, carotenoids, and healthy lipids; thus, the potential pharmaceutical uses are strongly present with low risk. However, the seeds are characterized by the dangerous cyanogenic potential present as amygdalin.

The scientific community must focus on translational research in safe fractions. The future needs:

1. Standardization: Overcoming the current challenge of highly variant doses (ranging from 0.15 mg to 130 mg for active ingredients in clinical studies for similar plant-based sterols) [23]. It is essential that all future clinical studies incorporate standardized extracts (such as standard concentrations of Rutin or Oleic acid) [24, 23]
2. Translational Modeling: From simple in vitro models to detailed, tiered, and more accurate in vivo models. This will also involve choosing relevant animal models, which reflect the human condition effectively, particularly when studying neurodegenerative disorders using older models, to enhance the poor success rate from candidates to clinical trials [11].
3. Targeted Clinical Trials: Conducting clinical trials with human subjects strictly on relatively safe compounds like high lutein apricot fruit extracts for cognitive functioning and leaf extracts for metabolic conditions to establish efficacy and fixed pharmacological doses [25].Finally, the success of P. armeniaca in drug development depends on the clear separation of its positive phyochemicals from its negative aspects.

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