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Review

Multipurpose Research from a Native Woody Oil Plant *Xanthoceras sorbifolia* in China

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Abstract: *Xanthoceras sorbifolia* Bunge, an indigenous oilseed tree from China, is a major woody energy plant that has been used for biodiesel production for a long time. In the past decade, *X. sorbifolia* has become a hot research topic due to its diverse bioactivities, which include improving learning and memory deficits, killing sperm, stabilizing capillaries, lowering cholesterol, and rheumatism. This review aims to analyze a comprehensive appraisal of *X. sorbifolia*, including its history, traditional uses, biological activities, food value, economic value, and current applications, and provide instruction for promoting the multipurpose utilization of *X. sorbifolia*.

Keywords: economic value; food value; pharmacological activity; *Xanthoceras sorbifolia* Bunge

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Citation: Xiao, J.; Sun, L.; Pan, Y.; Bai, X.; Chen, G.; Zhang, X.; Chen, X.; Li, N. Multipurpose Research from a Native Woody Oil Plant *Xanthoceras sorbifolia* in China. *Forests* **2023**, *14*, 86. https://doi.org/10.3390/f14010086

Academic Editor: Mathias Neumann

Received: 25 November 2022
Revised: 19 December 2022
Accepted: 30 December 2022
Published: 3 January 2023

1. Introduction

As the lifeblood of modern civilizations, energy plays important roles in industries, agriculture, transport, and other human needs. The use of fossil diesel fuels, which are nonrenewable resources, has increased with the expansion of industrialization [1]. For this reason, woody oil plants, as renewable, natural, healthy, high-quality edible oils and clean energy sources for fuel, have gained much attention from academic communities, companies, and governments [2].

Woody oil plants are very abundant in China. *Xanthoceras sorbifolia* Bunge, from the Sapindaceae family, is an indigenous shrub mainly distributed in the north of China. It is planted as a valuable woody oil crop to produce biofuels, smokeless illuminating oil, and edible oil [3]. From the 1970s to 2007, it was widely cultivated in China for wind prevention and sand fixation due to its capacity to survive in saline and alkaline land [4] and for landscaping because of its varicolored flowers [5]. The wood of *X. sorbifolia* is used as a traditional folk medicine in Inner Mongolia for the treatment of rheumatism [6]. Its seed oil, which is a qualified edible oil with high unsaturated fatty acids content, can also be prepared as biofuel oil [7,8]. Moreover, the extracts and some ingredients of *X. sorbifolia* show anti-inflammatory, anti-HIV, and antitumor activities and function to improve intelligence [6,9]. Additionally, the flowers of *X. sorbifolia*, which are high in polyphenols, have been commonly used to produce a beverage called Wenguan Tea [10]. Recently, *X. sorbifolia* has attracted global attention as an important economic crop with low investment and high income potential.

In spite of these aforementioned functions, there are still some critical issues that limit the practical application of *X. sorbifolia*. Therefore, this paper discusses the research progress on *X. sorbifolia*'s traits, history, current culture, pharmaceutical uses, bioactive compounds, and multi-functionalities comprehensively. Overall, the findings summarized in this study exemplify solid guidance for further study, utilization, and promotion of *X. sorbifolia*.

2. Morphological Characteristics

X. sorbifolia is an indigenous shrub species mainly distributed in the northwestern and northeastern regions of China, especially in Inner Mongolia, Liaoning, Shaanxi, and Hebei Provinces [11,12]. It is the monotypic genus *Xanthoceras*, belonging to the family of Sapindaceae, known by various names in local folklore, such as yellowhorn, shiny leaf, yellowhorn, golden horn, and Chinese flowering chestnut [9,10]. This plant grows well in cold, salty, and dry soil, even at temperatures below −40 °C, and has a life span of more than 200 years [7,13]. It is about 2–5 m in height, has a diameter of 90 cm at breast height, and a crown width of 9 m [3]. Its leaves have a morphology of sharply serrated margins. The inflorescence of *X. sorbifolia*, which belongs to a raceme with 20 to 50 flowers, emerges at the beginning of March. Its flower comprises five petals, and blooms last 25 to 30 days, with a peak in mid and late April [14]. Their upper part is white, and the bottom develops stripes of yellow and purplish red with age [3]. *X. sorbifolia* fruits in early autumn, with oval, leathery capsules, 5–6 cm in diameter with 3–6 loculicidal dehiscence in each fruit, and each dehiscence possesses 4–6 seeds [15]. In general, this shrub takes two to three years to ripen after sowing seeds.

3. History and Current Status

More than 1200 years ago, *X. sorbifolia* was sporadically cultivated around temples and houses to provide smokeless illuminating kerosene and edible oil [16]. Its large-scale commercial plantation history dates to the 1950s [3]. In 2007, its popularity increased again due to *X. sorbifolia* being recognized as a woody biomass plant. Studies have proven that *X. sorbifolia* has unselective soil demands and grows well in deserted mountains, barren gullies, and even sandy land. Hence, it has been cultivated to tolerate drought, cold, salinity, alkalinity, and poor soil conditions [17]. Despite its poor adaptability to shade conditions, adequate rainfall and/or irrigation in the initial growth phase will ensure its survival in farmland [3]. Currently, its plantation area reaches about 140 million acres for wind prevention, sand fixation, providing renewable energy sources, and ornamental gardens.

4. The Multi-Functionality of *X. sorbifolia*

Due to the Chinese government's encouragement and support for planting *X. sorbifolia*, its composition, pharmacology, food, and economic values have received much attention from researchers. In total, 1663 relevant pieces of literature have been recorded in databases, including Scifinder, Web of Science, and CNKI, shown in Figure 1.

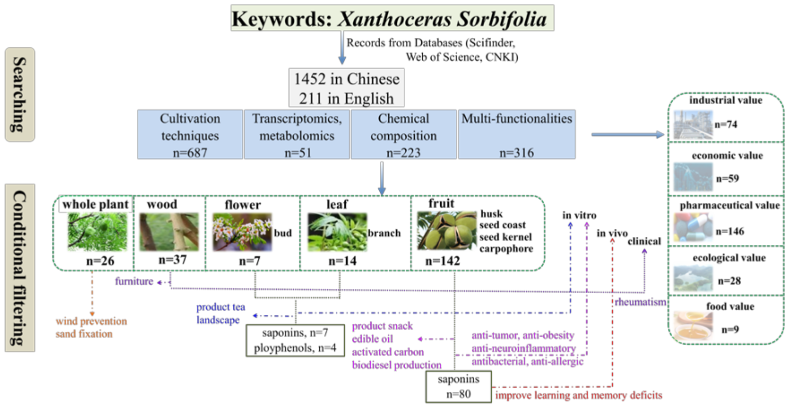

Figure 1. Flow diagram showing the search strategy, the number of records identified, and the main compositions and uses in different parts of *X. sorbifolia*.

4.1. Whole Plant

4.1.1. Economic Value

Over its long history, the whole plant has been used as material to produce carbon sinks, conserve soil and water, and for land reclamation.

4.1.2. Ecological Value

Because of its exquisite gesture, gorgeous leaves, colorful flowers, and long flowering period (more than 40 days), it can be used for landscaping [3].

4.2. Wood (Figure 2)

4.2.1. Pharmaceutical Value

The dried wood, which commonly consists of branches or stems of *X. sorbifolia*, is used as a traditional folk medicine in Inner Mongolia. In Mongolian medicine, its name is "Xiari-Sendeng", and it is used for the treatment of rheumatism [18]. Its wood was recorded in the Chinese National Pharmacopeia in 1977 [19]. Fan et al. clarified that the ultra-micro powder of *X. sorbifolia* exhibited stronger antagonistic action on adjuvant arthritis in rats than the fine powder [20]. Its 70% ethanol-H_2O extracts inhibited the accumulation of amboceptor remarkably [21]. Moreover, the n-butanol extract of the wood showed significant anti-inflammatory activities in models of adrenalectomized mice in the early, middle, and late stages [22] and demonstrated obvious anti-rheumatic effects [23].

Furthermore, a series of studies on its chemical constituents suggested that the wood of *X. sorbifolia* is rich in phenolic compounds, steroids, terpenoids, and saponins, which could be the key chemical basis representing their biological activities. For example, Yu et al. reported that the terpenoid bunkankasaponins B/F showed significant activity against ten cancer cell lines (including Hela, BGC-823, MCF-7, HepG2, etc.) with IC_{50} < 10 μM [5]. Two steroids (xanthocerasic acid, 3-oxotirucalla-7, 24-dien-21-oic acid) were found to be inhibitory components against HIV-1 protease [24]. Additionally, some flavones, such as epicatechin, myricetin, and quercetin, exhibited inhibition activities on platelet aggregation [25]. Moreover, Zhang et al. reported that the phenolic constituents dihydromyricetin, catechin, epicatechin, and myricetin showed strong DPPH scavengers and could remarkably protect peroxyl radical-induced DNA strand scission [26].

4.2.2. Economic Value

In addition to pharmaceutical uses, *X. sorbifolia* wood can also be used to produce top-grade furniture due to its hard texture and dark maroon color with a beautiful vein pattern [3].

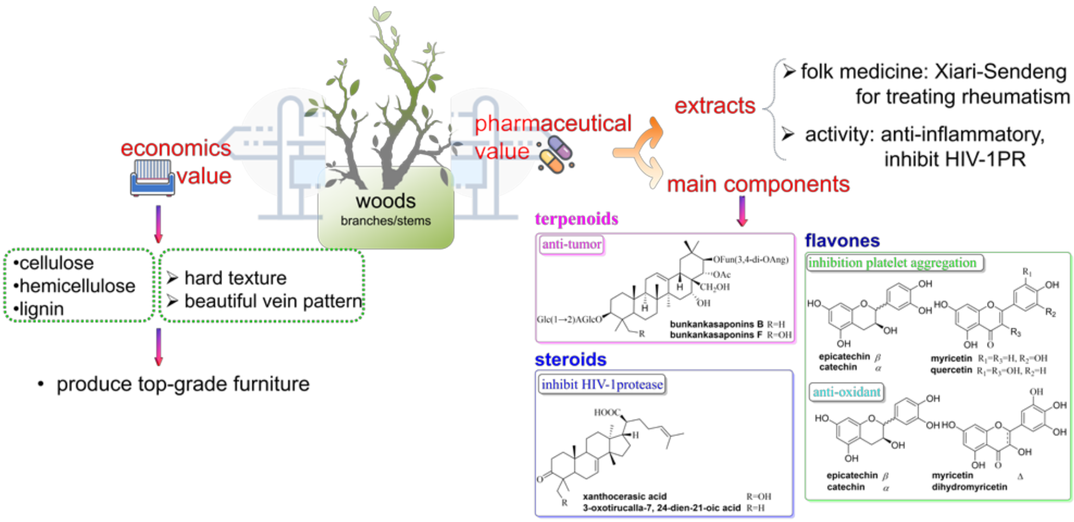

Figure 2. The uses of wood/branches/stems of *X. sorbifolia*.

4.3. Fruit (Figure 3)

4.3.1. Pharmaceutical Value

The ripe fruit of *X. sorbifolia* has several parts, including the seed kernel, seed coat/testa, husk/shells, carpophore, etc. Almost 200 compounds have been purified and identified from those parts [19,27–29].

Fruits: Early research focused on clarifying the chemical basis of the whole fruit and suggested that the triterpenes were the key active ingredients in the ripe fruit of *X. sorbifolia* [30,31]. Afterward, researchers analyzed the composition of different parts from the fruit of *X. sorbifolia*.

Husk and carpophore: Our previous phytochemical investigation showed the material basis of its husk and carpophore were saponins, polyphenols, and alkaloids (some characteristic compounds are shown in Figures S1–S6, Tables S1 and S2. Among them, a triterpene with R1-barrigenol skeleton (bunkankasponin E), the main component both in the husk (>0.2%) and carpophore (>0.4%), elicited significant antitumor activities and showed the function of improving intelligence [6]. Moreover, another principal component in the husk, named xanthoceraside, exerted an anti-Alzheimer's disease effect by modulating the community of gut microbiota [32].

Seed: The seed, especially the kernel, is high in oil, and several phenolic acids, terpenes, saponins, and alkaloids have been obtained from the oil residue [29,33–35]. Zhang et al. reported that the total saponins extracted from the kernel could induce apoptosis of HepG2 cells and cell cycle arrest in the S phase [34]. Moreover, triterpene saponins from the defatted residue of *X. sorbifolia* kernels exhibited substantial DPPH scavenging activity [35].

4.3.2. Food Value

The young, pre-lignified fruits of *X. sorbifolia* are called woody melons and are eaten as a snack food in Shaanxi province. The seeds are extensively rich in lipids (55%–65%). Among them, fatty acids are the main components of lipids accounting for 95% [7,36,37]. Meanwhile, *X. sorbifolia* oil is also rich in unsaturated fatty acids, accounting for about 85%–93%, especially linoleic acid [37,38]. Its practical application as an edible oil has a long history in Chinese folklore [38,39]. Hence, *X. sorbifolia* oil has high comprehensive economic value in edible, medicinal, and economic terms.

4.3.3. Economic Value

In addition to their pharmaceutical and food values, the seed coats are an ideal resource for the preparation of activated carbon [40], bio-sorbent for Hg (II) removal from aqueous solution [41], and wood vinegar [42]. Moreover, the native woody oil plant *X. sorbifolia* can be used for biodiesel production [42].

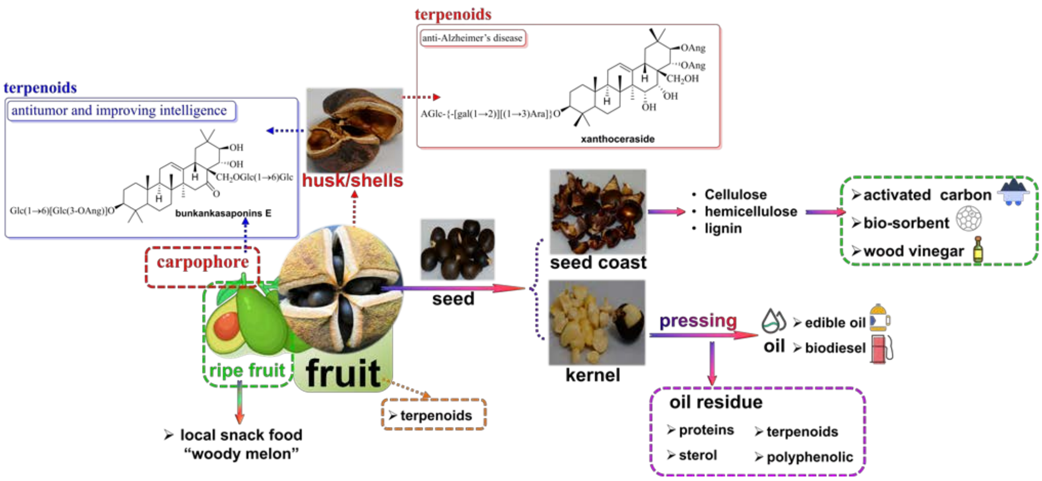

Figure 3. The uses of the fruit of *X. sorbifolia*.

4.4. Flower (Figure 4)

4.4.1. Pharmaceutical Value

Several phytochemical studies showed that the bioactive basis of the flowers and buds are triterpenoids, flavonoids, and phenolic acids [10,43] and showed significant bioactivities, such as antioxidant and ROS inhibitory effects. Interestingly, extracts from the flowers showed significant activity against benign prostatic hyperplasia [44].

4.4.2. Food Value

Recently, the health benefits of drinking tea have attracted extensive attention because they could be tentatively used as chemo-preventative agents against diseases. Wenguan Tea, a unique beverage with a pleasant flavor and various health benefits, is used as a commercial commodity, especially in the north of China. This functional tea is commonly produced with the dried buds and flowers of *X. sorbifolia*, and our previous study demonstrated that polyphenols, in particular flavonoids, were the critical components responsible for its antioxidant activities [10].

The flowers also show great potential for supplying honey plant resources to produce nectar [45].

4.4.3. Ecological Value

X. sorbifolia is an ornamental shrub highly prized for its flowers, which commonly exhibit a white to purplish color, although red varieties have been cultivated recently [45]. In addition, its flowering period is long (more than 40 days) [3,45].

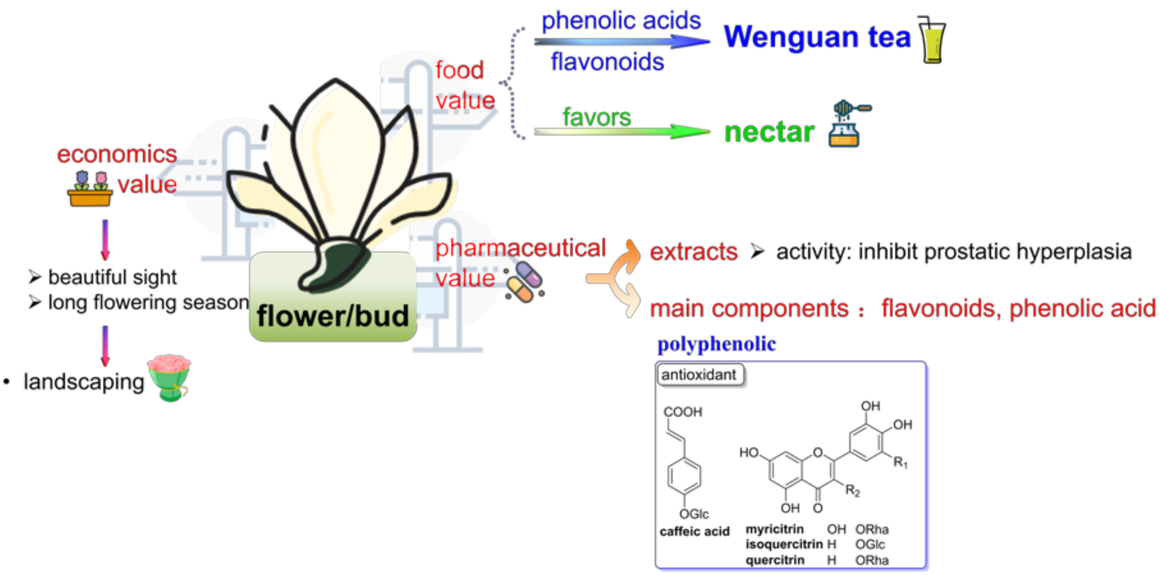

Figure 4. The uses of flower/bud of *X. sorbifolia*.

4.5. Leaf (Figure 5)

4.5.1. Pharmaceutical Value

Extracts from the leaves show potential heat-clearing and detoxifying activities [46]. Zhang et al. reported that 70% ethanol-H_2O extracts showed certain antitumor and antioxidant activities [47]. Primary active components have been isolated and identified as triterpenoids, flavones, flavanes, coumarin, and lignanoids [6]. Among them, phenolic acid compounds (hyperoside, catechin, and syringaresinol-4-O-β-D-glucopyranoside) have stronger inhibitory effects than minocycline against NO production in overactivated BV2 cells, suggesting they have great potential in treatment for neurodegenerative diseases [48]. The characteristic coumarin component of fraxetin demonstrated antimicrobial activities against *Pseudomonas aeruginosa, Escherichia coli, and Bacillus subtilis* [49]. Moreover, several barrigenol-type triterpenoids (compounds **1** and **2**, Figure 5) showed significant cytotoxic activities against Hela, MCF-7, and HepG2 cell lines [6].

4.5.2. Food Value

The leaves are composed of about 20% protein and 16 kinds of amino acids [50]. Moreover, the leaves contain 12 trace elements, such as strontium, zinc, iron, and copper. The iron content reached 255.5 µg/g, which is much higher than sardines and the content of copper is fivefold higher than shrimp [51,52]. In addition, the leaves are commonly used as a popular tea because of their unique taste and flavor [6].

4.5.3. Cosmetic Value

In addition to the pharmaceutical and food values, its polysaccharide has good antioxidant activity, which suggests that it could be developed as medicine and cosmetics [53].

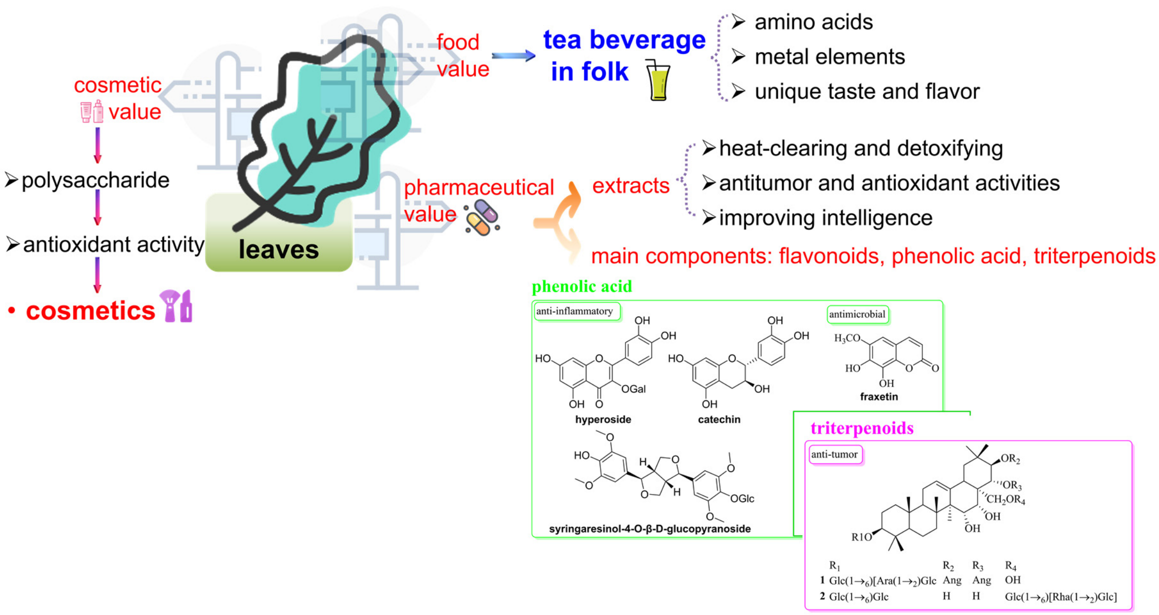

Figure 5. The uses of leaves of *X. sorbifolia*.

5. Conclusions and Recommendations

Fuel is still the most important energy source in the world. Biomass originating from plants is especially attractive because it can be used as a green and renewable substitute for fossil fuels [54]. Among the various types of forest-based bioenergy, woody oil plants have gradually become the optimal solution to cover the current shortage problems. Due to its potential to mitigate climate changes, develop medicines, provide raw materials for soil and water conservation, and revenue generation in rural areas [55], the comprehensive utilization of woody oil plants is a global phenomenon, especially in Europe, China, and India [55–57].

China has great potential to exploit woody oil plants due to its vast territory, with more than 43.75 million ha of marginal land that can potentially be used for planting [58]. Moreover, as a mainly woody biomass plant, *X. sorbifolia* receives special support from the Chinese government [3]. With its long history, sufficient resources, and multi-functionalities, *X. sorbifolia* has broad applications in medicine, health products, biofuels, and the landscape.

Although previous studies have obtained promising results, the in-depth study of *X. sorbifolia*'s exploitation and utilization is far from complete. First, despite a total of 223 references that have reported chemical constituents from the husk, flowers, seed, carpophore, kernel, and wood, some compounds are distributed in more than one part. Hence, it is difficult to clearly elaborate on the relationship between the different parts of

X. sorbifolia and their chemical composition. Second, the research on the bio-activities and nutritional values associated with chemical compounds is not systematic enough. Although the vast majority of pharmacological activities studied the characteristics of triterpenoids, research on their anti-HIV and antitumor mechanisms is limited. There is also a lack of abundant commercial applications based on its characteristic compounds. Additionally, the increasing plantation of *X. sorbifolia* has produced millions of tons of leaves and flowers. However, there is limited research on their utilization. *X. sorbifolia* was considered to be a "waste" in the past and has long been used for land-spreading, incineration, and animal feeding. Recently, several tea drinks made from flowers or leaves have been invented and have shown a broad range of benefits. However, there is still a long way to go to further develop and exploit the critical components responsible for antioxidant activities.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/f14010086/s1, Figure S1 The structures of characteristic compounds identified from the wood of *X. sorbifolia*; Figure S2 The structures of characteristic compounds identified from the testa of *X. sorbifolia*; Figure S3 The structures of characteristic compounds identified from the husk of *X. sorbifolia*; Table S1 The name of characteristic compounds identified from the husk of *X. sorbifolia*; Figure S4 The structures of characteristic compounds identified from the carpophore of *X. sorbifolia*; Table S2 The name of characteristic compounds identified from the carpophore of *X. sorbifolia*; Figure S5 The structures of characteristic compounds identified from the flower of *X. sorbifolia*; Figure S6 The structures of characteristic compounds identified from the leaves of *X. sorbifolia*; Table S3 The name of characteristic compounds identified from the leaves of *X. sorbifolia*.

Author Contributions: Conceptualization, J.X., G.C. and N.L.; Software, J.X. and L.S.; Validation, Y.P.; Formal analysis, J.X. and X.B.; Investigation, J.X. and N.L.; Resources, J.X. L.S. and Y.P.; Data curation, J.X. and X.B.; Writing—original draft preparation, J.X.; Writing—review and editing, J.X. and N.L.; Visualization, J.X., X.Z. and X.C.; Supervision, N.L.; Project administration, N.L.; funding acquisition, J.X. and N.L. All authors have read and agreed to the published version of the manuscript.

Funding: The project was funded by the Shenyang Young Scientific and Technological Innovators Programme (RC200408), the Scientific Research Fund of Liaoning Province Education Department (LJKZ0945), the National Natural Science Foundation of China (Grant No. 82104061) and Natural Science Foundation of Liaoning Province (2022-MS-242).

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Shen, Z.; Zhang, K.Q.; Ao, Y.; Ma, L.Y.; Duan, J. Evaluation of biodiesel from *Xanthoceras sorbifolia* Bunge seed kernel oil from 13 areas in China. *J. For. Res.* **2019**, *30*, 869–877. [CrossRef]
2. Karmakar, A.; Karmakar, S.; Mukherjee, S. Properties of various plants and animals feedstocks for biodiesel production. *Bioresour. Technol.* **2010**, *101*, 7201–7210. [CrossRef] [PubMed]
3. Yao, Z.Y.; Qi, J.H.; Yin, L.M. Biodiesel production from *Xanthoceras sorbifolia* in China: Opportunities and challenges. *Renew. Sustain. Energy Rev.* **2013**, *24*, 57–65. [CrossRef]
4. Ling, J.H.; Liu, L.L.; Wang, Y.X.; Li, Z.Y.; Liu, R.; Li, Q.; Wang, Y.; Yang, B.Z.; Chen, X.H.; Bi, K.S. Characterization and quantification of the triterpenoids in different parts of *Xanthoceras sorbifolia* by HPLC–ESI-MS. *J. Pharm. Biomed. Anal.* **2011**, *55*, 259–264. [CrossRef]
5. Yu, L.L.; Wang, X.B.; Wei, X.C.; Wang, M.M.; Chen, L.X.; Cao, S.J.; Kang, N.; Qiu, F. Triterpenoid saponins from *Xanthoceras sorbifolia* Bunge and their inhibitory activity on human cancer cell lines. *Bioo. Med. Chem. Lett.* **2012**, *22*, 5232–5238. [CrossRef]
6. Xiao, W.; Wang, Y.; Zhang, P.; Li, N.; Jiang, S.; Wang, J.H.; Huang, J.; Li, X. Bioactive barrigenol type triterpenoids from the leaves of *Xanthocera sorbifolia* Bunge. *Eur. J. Med. Chem.* **2013**, *60*, 263–270. [CrossRef]
7. Yu, H.Y.; Fan, S.Q.; Bi, Q.X.; Wang, S.X.; Hu, X.Y.; Chen, M.Y.; Wang, L.B. Seed morphology, oil content and fatty acid composition variability assessment in yellow horn (*Xanthoceras sorbifolium* Bunge) germplasm for optimum biodiesel production. *Ind. Crops Prod.* **2017**, *97*, 425–430. [CrossRef]
8. Li, J.; Zu, Y.G.; Luo, M.; Gu, C.B.; Zhao, C.J.; Efferth, T.; Fu, Y.J. Aqueous enzymatic process assisted by microwave extraction of oil from yellow horn (*Xanthoceras sorbifolia* Bunge) seed kernels and its quality evaluation. *Food Chem.* **2013**, *138*, 2152–2158. [CrossRef]
9. Wang, D.; Su, D.; Li, X.Z.; Liu, D.; Xi, R.G.; Gao, H.Y.; Wang, X.B. Barrigenol triterpenes from the husks of *Xanthoceras sorbifolia* Bunge and their antitumor activities. *RSC Adv.* **2016**, *6*, 27434–27446. [CrossRef]

10. Xiao, J.; Zou, Y.; Wen, X.Y.; Guo, Y.L.; Hu, F.; Chen, G.; Wu, Z.Y.; Lin, Y.H.; Wang, Z.; Sun, L.; et al. Functional contents and antioxidant potency of Chinese Wenguan flower tea. *Food Control* **2022**, *138*, 109002. [CrossRef]
11. Fu, H.W.; Guo, Y.; Li, W.; Dou, D.Q.; Kang, T.G.; Koike, K. A new angeloylated triterpenoid saponin from the husks of *Xanthocerassorbifolia* Bunge. *J. Nat. Med.* **2010**, *64*, 80–84. [CrossRef] [PubMed]
12. Yu, L.L.; Tang, X.L.; Chen, L.X.; Wang, M.M.; Jian, J.F.; Cao, S.J.; Wang, X.B.; Kang, N.; Qiu, F. Oleanane-type triterpenoid saponins from *Xanthoceras sorbifolia* Bunge. *Fitoterapia* **2012**, *7*, 1636–1642. [CrossRef] [PubMed]
13. Liu, Y.L.; Huang, Z.D.; Ao, Y.; Li, W.; Zhang, Z.X. Transcriptome analysis of yellow horn (*Xanthoceras sorbifolia* bunge): A potential oil-rich seed tree for biodiesel in China. *PLoS ONE* **2013**, *8*, e74441.
14. Zhou, Q.Y.; Fu, D.Z. Preliminary studies on the reproductive biology of *Xanthoceras sorbifolia*. *Sci. Silvae Sin.* **2010**, *46*, 158–162.
15. Chai, C.S.; Lu, J.; Cai, G.J.; Wang, S.Y.; Qi, J.L.; Wang, Z.T.; Xue, R. Fruit phenotypic diversity and variation of *Xanthocerassorbifolia* artificial population. *Forest Res.* **2013**, *26*, 181–191.
16. Tian, L. Cultivation advantages and development counter measures of Wenguan fruit in Henan Province. In Proceedings of the Conference of Society of Forestry in Henan Province, Zhengzhou, China, 19 November 2011; pp. 67–69.
17. Li, K.R.; Feng, C.H. Effects of brassinolide on drought resistance of *Xanthoceras sorbifolia* seedlings under water stress. *Acta Physiol. Plant* **2011**, *33*, 1293–1300. [CrossRef]
18. Li, Y.J.; Xu, J.K.; Xu, P.; Song, S.J.; Liu, P.; Chi, T.Y.; Ji, X.F.; Jin, G.; Qiu, S.M.; Hou, Y.P.; et al. *Xanthoceras sorbifolia* extracts ameliorate dendritic spine deficiency and cognitive decline via upregulation of BDNF expression in a rat model of Alzheimer's disease. *Neurosci. Lett.* **2016**, *629*, 208–214. [CrossRef]
19. Chen, X.Q.; Lei, Z.L.; Cao, J.; Zhang, W.; Wu, R.; Cao, F.L.; Guo, Q.R.; Wang, J.H. Traditional uses, phytochemistry, pharmacology and current uses of underutilized *Xanthoceras sorbifolium* Bunge: A Review. *J. Ethnopharmacol.* **2022**, *283*, 114747. [CrossRef]
20. Fan, L.; Ju, A.H.; Liu, L.J.; An, N.; Xu, J.Y. Effect of ultramicro powder of *Xanthoceras sorbifolia* Bunge on adjuvant arthritis in rats. *Cent. South Pharm.* **2014**, *12*, 318–321.
21. Chen, G.R.; Chang, L. Study on anti-inflammatory effect of Mongolian medicine Wenguan wood. *J. Med. Pharm. Chin. Minorities* **2010**, *12*, 40–41.
22. Kuang, R.; Bao, W.F.; Zhao, M.H.; An, Y.F.; Liu, Y.L. The anti-inflammatory effects of the n-butanol extract of *Xanthoceras sorbifolia* Bunge. *J. Shenyang Pharm. Univ.* **2010**, *18*, 53–56.
23. Ai, R.N. *Preliminary Study on Mongolian Medicine Xanthoceras sorbifolia Bunge Anti-Rheumatoid Arthritis Material Basic Research*; Inner Mongolia Minzu University: Tongliao, China, 2015.
24. Ma, C.M.; Nakamura, N.; Hattori, M.; Kakuda, H.; Qiao, J.C.; Yu, H.L. Inhibitory effects on HIV-1 protease of constituents from the wood of *Xanthoceras sorbifolia*. *J. Nat. Prod.* **2000**, *63*, 238–242. [CrossRef] [PubMed]
25. Cui, C.B.; Chen, Y.J.; Yao, X.S.; Qu, G.X.; Xian, Y.L. Studies on the chemical constituents of *Xanthoceras sorbifolia* Bunge promoting blood circulation. *Chin. Trad. Herbal Drugs.* **1987**, *18*, 9–10+18.
26. Zhang, Y.; Ma, J.N.; Ma, C.L.; Qi, Z.; Ma, C.M. Simultaneous quantification of ten constituents of *Xanthoceras sorbifolia* Bunge using UHPLC-MS methods and evaluation of their radical scavenging, DNA scission protective, and α-glucosidase inhibitory activities. *Chin. J. Nat. Med.* **2015**, *13*, 873–880. [CrossRef] [PubMed]
27. Chen, G.; Xie, Y.M.; Yang, Y.Q.; Zhou, D.; Hao, Y.; Liu, Y.; Cheng, M.; Hou, Y.; Li, N. Natural therapeutic agents for neurodegenerative diseases from the shells of *Xanthoceras sorbifolium*. *Bioorg. Chem.* **2020**, *101*, 104038. [CrossRef]
28. Li, Z.L. Study on the Chemical Constituents and Biological Activities of the Husks of *Xanthoceras sorbifolia* Bunge. Ph.D. Thesis, Shenyang Pharmaceutical University, Shenyang, China, 2007.
29. Yu, L.L.; Liu, J.C.; Yu, L.Q.; Chen, L.X.; Qiu, F. Chemical constituents of seed oil leavings of *Xanthoceras sorbifolia*. *Chem. Nat. Compd.* **2018**, *54*, 769–771. [CrossRef]
30. Chen, Y.J.; Takeda, T.; Ogithara, Y. Studies on the constituents of *Xanthoceras sorbifolia* Bunge. III. Minor prosapogenins from the fruits of *Xanthoceras sorbijblia* Bunge. *Chem. Pharm. Bull.* **1985**, *33*, 127–134. [CrossRef]
31. Chen, Y.J.; Takeda, T.; Ogihara, B.Y.; Iitaka, Y. Studies on the constituents of *Xanthoceras sorbijblia* Bunge. II. Major sapogenol and a prosapogenin from the fruits of *Xanthoceras sorbijblia* Bunge. *Chem. Pharm. Bull.* **1984**, *32*, 3378–3383. [CrossRef]
32. Zhou, H.X.; Zhao, J.M.; Liu, C.H.; Zhang, Z.F.; Zhang, Y.; Meng, D.L. Xanthoceraside Alzheimer's disease effect by remodeling gut microbiota and modulating microbial-derived metabolites level in rats. *Phytomedicine* **2022**, *98*, 153937. [CrossRef]
33. Jiang, L.; Fang, S.A.; Du, W.; Ruan, C.J. LC-MS/MS detection of flavonoids in *Xanthoceras sorbifolum* Bunge kernel. *China Oils Fats* **2022**, *61*, 1099.
34. Zhang, D.Y.; Wang, K.; Li, H.; Liu, J.Y.; Deng, H.; Qi, N. Antioxidant and anti-hepatoma activities of total saponins from kernel of *Xanthoceras sorbifolia* Bunge. *Nat. Prod. Res. Dev.* **2016**, *28*, 1012–1019.
35. Li, J.; Zu, Y.G.; Fu, Y.J.; Yang, Y.C.; Li, S.M.; Li, Z.N.; Wink, M. Optimization of microwave-assisted extraction of triterpene saponins from defatted residue of yellow horn (*Xanthoceras sorbifolia* Bunge.) kernel and evaluation of its antioxidant activity. *Innov. Food Sci. Emerg. Technol.* **2010**, *11*, 637–643. [CrossRef]
36. Ruan, C.J.; Yan, R.; Wang, B.X.; Mopper, S.; Guan, W.K.; Zhang, J. The importance of yellow horn (*Xanthoceras sorbifolia*) for restoration of arid habitats and production of bioactive seed oils. *Ecol. Eng.* **2017**, *99*, 504–512. [CrossRef]
37. Zhang, S.; Zu, Y.G.; Fu, Y.J.; Luo, M.; Liu, W.; Li, J.; Efferth, T. Supercritical carbon dioxide extraction of seed oil from yellow horn (*Xanthoceras sorbifolia* Bunge.) and its anti-oxidant activity. *Bioresour. Technol.* **2010**, *101*, 2537–2544. [CrossRef]

38. Zheng, Y.L.; Gao, P.; Wang, S.; Ruan, Y.L.; Zhong, W.; Hu, C.R.; He, D.P. Comparison of different extraction processes on the physicochemical properties, nutritional components and antioxidant ability of *Xanthoceras sorbifolia* Bunge kernel oil. *Molecules* **2022**, *27*, 4185. [CrossRef]
39. Yang, F.; Han, S.S.; Nan, Y.; Chen, X.J.; Sun, Y.B.; Liu, S.C.; Ma, B.P. Progress in research and development of *Xanthoceras sorbifolia*. *China. J. Chin. Matrria. Med.* **2021**, *46*, 4334–4343.
40. Hao, Y.N.; Wang, X.M.; Ding, L.J. *Study on the Preparation of Activated Carbon from Seed Capsule of Xanthoceras sorbiflia Bunge*; International Symposium on Biomass Material Science and Technology: Huangshan, China, 2009.
41. Yao, Z.Y.; Wei, C.; Qi, J.H. Hg (II) biosorption on *Xanthoceras sorbifolia* testae. *J. Southwest Forestry Uni.* **2016**, *28*, 170–174.
42. Zhang, Y.L.; Li, S.Y.; Tang, Z.S.; Song, Z.; Sun, J. *Xanthoceras sorbifolia* seed coats derived porous carbon with unique architecture for high rate performance supercapacitors. *Diamond Relat. Mater.* **2019**, *91*, 119–126. [CrossRef]
43. Zhao, D.D.; Li, D.Y.; Wei, J.X.; Hua, H.M.; Li, Z.L. Isolation and structural identification of the chemical constituents from the flowers of *Xanthoceras sorbifolia* Bunge. *J. Shenyang Pharm. Univ.* **2012**, *29*, 514–518.
44. Song, L. The Extracts of Flowers of Xanthoceras sorbifolia Showed Activity on Prevention of Benign Prostatic Hyperplasia. CN 110898119 A, 24 March 2020.
45. Shang, H.Q. Research progress of comprehensive utilization of *Xanthoceras sorbifolia*. *Biol. Teach.* **2010**, *35*, 16–17.
46. Zhang, Y.S.; Guo, S.Z.; Wei, Q.; Qiu, C.L.; Mao, X.L.; He, C.L. The production process and health benefits of *Xanthoceras sorbifolia* Bunge leaf tea. *Tea Fujian* **2016**, *3*, 26.
47. Zhang, Y.L.; Shi, H.X.; Lei, L.Y.; Song, Z.X.; Tang, Z.S. Screening of inhibition of proliferation of human hepatocellular carcinoma cell line hepg2 and antioxidant activity parts of *Xanthoceras sorbifolia* leaf. *Mod. Chin. Med.* **2016**, *18*, 1451–1469.
48. Li, N.; Wang, Y.; Li, X.Z.; Zhang, H.; Zhou, D.; Wang, W.L.; Li, W.; Zhang, X.R.; Li, X.Y.; Hou, Y.; et al. Bioactive phenols as potential neuroinflammation inhibitors from the leaves of *Xanthoceras sorbifolia* Bunge. *Bioorg. Med. Chem. Lett.* **2016**, *26*, 5018–5023. [CrossRef]
49. Wang, P. Study on the Chemical Composition of the Leaves of *Xanthoceras sorbifolia* Bunge. Master's Thesis, Shaanxi University of Science & Technology, Xi'an, China, 2010.
50. Wang, H.D. Research progress on chemical composition and comprehensive utilization of *Xanthoceras sorbifolia* Bunge. *Chin. Wild Plant Resour.* **1998**, *17*, 13–16.
51. Zhu, D.; Wang, H.D.; Li, X.B.; Hu, Q. A preliminary study on the chemical composition of the leaves of *Xanthoceras sorbifolia*. *Chin. Wild Plant Resour.* **1994**, *3*, 33–36.
52. Wang, L.H. The edible and medicinal value of *Xanthoceras sorbifolia*. *Guide China Med.* **2006**, *10*, 43.
53. Zhang, Y.L.; Shi, H.X.; Lei, L.Y.; Song, Z.X.; Tang, Z.S. Study on ultrasonic assisted extraction technology and preliminary pharmacodynamics research of polysaccharide from *Xanthoceras sorbifolia* Leaf. *Mod. Chin. Med.* **2016**, *18*, 1636–1640.
54. Yang, Y.M.; Zhang, J. Zhang, Jia. Liu, Q. Qian, G.R. Influence of catalysts on bio-oil yield and quality: A review. *Environ. Sci. Pollut. Res.* **2022**, *29*, 30986–31001. [CrossRef]
55. Dai, G.H.; Yang, J.; Lu, S.R.; Huang, C.H.; Jin, J.; Jiang, P.; Yan, P. The potential impact of invasive woody oil plants on protected areas in China under future climate conditions. *Sci. Rep.* **2018**, *8*, 1041. [CrossRef]
56. Moiseyev, A.; Solberg, B.; Kallio, A.M.I.; Lindner, M. An economic analysis of the potential contribution of forest biomass to the EU RES target and its implications for the EU forest industries. *J. For. Econ.* **2011**, *17*, 197–213. [CrossRef]
57. Qiu, Y.; Yu, Y.; Lan, P.; Wang, Y.; Li, Y. An overview on total valorization of Litsea Cubeba as a new woody oil plant resource toward a zero-waste biorefinery. *Molecules* **2021**, *26*, 3948. [CrossRef] [PubMed]
58. Zhuang, D.F.; Jiang, D.; Liu, L.; Huang, Y.H. Assessment of bioenergy potential on marginal land in China. *Renew. Sustain. Energy Rev.* **2011**, *15*, 1050–1056. [CrossRef]