Research progresses and prospects of medicated oil dual-purpose crop safflower based on patent mining

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ABSTRACT

Safflower is widely cultivated and used as a dual-purpose medicinal oil worldwide. This research used the incoPat patent database to search the global safflower patents for nearly 20 years, aiming to reveal the development process and current situation of the safflower industry in China and around the world by analyzing patent application trends, patent technology characteristics, advantageous industries and regions, patent quality, etc. The analysis shows that safflower patent applications are generally increasing, and the period 2010-2016 is characterized by the rapid development of patent applications. The technical features of global patents are mainly concentrated in pharmaceutical preparations, cosmetics, food and health care, various beverages, animal feed, safflower cultivation and harvesting equipment, and safflower seed oil. During the rapid development of patent applications, safflower was further developed in cosmetics, edible oil, and harvesting equipment. In addition, patent applications in rheumatism and bone diseases have increased, with the potential for development. China is the leading region for researching and developing medicinal safflower patents, especially Shandong and Henan provinces. Foreign patents are more focused on the value development of safflower seed oil in food and chemicals. Compared to the major countries and organizations that apply for safflower patents on a global scale, the quality of Chinese safflower patents is medium, and more awareness of patent protection is required. This paper provides suggestions for the subsequent development of the safflower industry, summarizes and analyzes the development trend of safflower patents, and provides new ideas to obtain innovative patent results.

1. Introduction

Safflower (*Carthamus tinctorius* L.) is an annual Compositae herb with outstanding medicinal and oil value. The United Nations Food and Agriculture Organization officially listed safflower as a dual-purpose medicinal oil in the statistical items of the "Production Yearbook" in 1993 (Peng, 1999; FAO Statistical Series, 1988). In addition, safflower has good application prospects in food, cosmetics, natural pigment additives, new oil, and industrial resources (Zhang et al., 2016; Liu, 2017; Bozan and Temelli, 2008). In 2002, safflower was included in the List of Items That Can Be Used in Health Food announced by the National Health and Health Commission of the People's Republic of China. This species has received extensive attention because of its great value in medical, health care, oil, dye, feed, etc. (Ren et al., 2014; Tian, 2014). However, it has not been fully utilized in reality (Pearl and Burke, 2014; Peng, 2015).

Except for Antarctica, safflower grows on all five continents (Knowles, 1959). At present, more than 60 countries and regions in the world cultivate safflower (Ren et al., 2017). It has been cultivated in China for over 2 000 years since the Han Dynasty brought it from the western regions (Ren et al., 2017). In China, safflower has been widely planted in Xinjiang, Gansu, Sichuan, Yunnan, Hebei, Henan, Zhejiang, Jiangsu, and other places (Lin et al., 2018). Currently, the main producing areas are Xinjiang, Yunnan, and Gansu. Initially planted for dye extraction, safflower has become a vital oil crop because its seeds are rich in unsaturated fatty acids (oleic acid and linoleic acid) (Pearl and Burke, 2014). The seed oil content of safflower is 20%–40%, comparable to sunflower and olive seeds (Kumar et al., 2016). Oleic acid and linoleic acid in seeds account for about 90% of the total fatty acids, of which more than 70% is linoleic acid, one of the most valuable fatty acids in edible oils (Siddiqi et al., 2011). Pharmaceutical safflower is called *Carthami Flos* with dried flowers (Chinese Pharmacopoeia, 2020). It promotes

blood circulation and scattered stasis and relieves pain, and often used in the treatment of coronary heart disease, angina pectoris, gynecological diseases, stroke, and hypertension, in the Japanese Pharmacopoeia, Korean Pharmacopoeia, European Pharmacopoeia, and so on (Yao et al., 2016; Fan et al., 2014; Zhou et al., 2018; Ao et al., 2018; Bai et al., 2020). Safflower dried fruits, called Carthami Fructus (Bai Pingzi), are included in the local standard of Chinese medicinal materials (Jsda, 2016). Safflower oil is resistant to atherosclerosis (Yu et al., 2013) and can be used to treat osteoporosis and rheumatoid arthritis, as contained in the United States Pharmacopoeia (USP, 2020).

Patent is closely related to innovation activities and is one of the most important and direct outputs of scientific and technological innovation (Ruan and Xiao, 2011), including technical and market attributes (Kuang and Lan, 2014). By analyzing patent information, it is possible to spy on the evolutionary history of a particular industry to a certain extent, analyze the technology distribution trend, and indicate the future development trend. The patent information has played a key role in indicating the research and development status, industry-university-research cooperation, and future development trend of traditional Chinese medicine industries such as *Scutellaria baicalensis* Georgi. (Wang et al., 2019), *Xanthium strumarium* L. (Li et al., 2020), *Panax notoginseng* (Burkill) F. H. Chen ex C. Chow & W. G. Huang (Li et al., 2020a), *Curcuma longa* L. (Shi et al., 2017), *Ginkgo biloba* L., and *Salvia miltiorrhiza* Bunge. (Zhang, 2019). As a global species, safflower planting area and output have increased rapidly in recent years, providing enormous opportunities and challenges to the safflower industry. However, safflower's patent and representative industry information have not been accurately counted and understood. Therefore, this article retrieves and analyzes the patent information of safflower from 2001 to 2020, which is conducive to understanding the development of the safflower industry in the past 20 years and has a certain illuminating effect on the development trend prediction and strategy formulation of the safflower industry, providing a scientific basis for the development and utilization of safflower resources and the healthy and sustainable development.

2. Data source and retrieval analysis method

The data source comes from BEIJING INCOPAT CO., LTD. patent information retrieval and analysis platform. The published paper retrieved relevant patent analysis data from this database, such as the Traditional Chinese Medicine *Xanthium strumarium* L. (Li et al., 2020), the Traditional Chinese Medicine compound *Lianhua Qing plague capsule* (Li et al., 2021), etc. In addition, the platform provides titles and abstracts in Chinese and English for global patents, providing convenience and precision for retrieval.

According to the search formula: TIAB=(*Carthami Flos* OR Safflower OR Honghua OR *Carthamus tinctorius* L.) AND TIAB=((Honghua OR Honglanhua OR Cihonghua OR Caohonghua) NOT (Saffron OR Xihonghua OR Fanhonghua OR Zanghonghua)) AND AD = [20010101 TO 20201231], as of April 3, 2021, a total of 24 325 related patents have been retrieved, and there are 19 869 patents after the simple family merger. There are 18 261 invention applications, 104 invention authorizations, 198 utility models, 272 designs, and 1 034 other types of disclosure. After verifying each type, it was found that most design patents involved non-medical plant safflower. After filtering the non-related patents, 24 053 medicinal plant safflower patents were obtained, and there were 19 597 patents for simple homogeneous families. Due to the lag between patent disclosure and patent application, the number of patents retrieved daily has a certain value-added phenomenon. Based on the data retrieved by the incoPat platform, Excel 2019 software was used for statistical sorting, and origin 2021 software was used for graph analysis.

3. Overall layout of global safflower patents

3.1. Regional distribution of global safflower patents

More than 30 countries, regions and organizations have applied for safflower patent. Search results show that 18 541 safflower patents have been filed in China over the past 20 years, significantly more than other countries and regions, accounting for 94.61% of all applications (Fig. 1). South Korea ranks second with 541 patents, which has a clear advantage over the next country, accounting for 2.76%. Japan, the United States, and the World Intellectual Property Organization have similar numbers of applications, accounting for 0.5% of all patents. The number of patents in other countries, regions, and organizations is relatively small, with more than 10 patents. From the side, it is clear that safflower is widely cultivated and used in a wide range of areas (Ren et al., 2017), and the rich uses of safflower and its tenacious adaptability to the environment play an important role.

3.2. Global safflower patent application trends

After a simple homogeneous family merger, 21 632 safflower patents were obtained. It was found that before 2000, the number of safflower-related patents was about 100 per year. Before 1990, the number was even less. In March 1933, the first safflower-related patent appeared, the country of application was the United Kingdom, and the content was related to safflower seed oil.

Therefore, this paper analyzes the safflower patent applications in the past 20 years, accounting for 91.85% of the total applications. Statistics on the number of annual patent applications for safflower show an overall upward trend in global safflower patent applications from 2001 to 2020, and the number of applications reached a peak in 2016 with 2 441 applications (Fig. 2). The steady increase in safflower patent applications from 2001 to 2010 was the first rising period. While the rapid increase in the number of applications from 2010 to 2016 was the second rising period, and it was also a stage of rapid development. From 2016 to 2020, the number gradually decreased but remained stable after 2010, indicating a period of adjustment.

The number of safflower patent applications in China is much higher than in other countries and regions. Moreover, the overall trend is similar to the global trend, which plays a leading role. The annual number of applications from other countries, regions, and organizations is less than 100, but safflower patent applications are filed earlier. Its application situation stabilized in 2001 and peaked in 2015 with 95 applications. Since the patent is announced within 18 months from the filing date, and there may be a lag in the publication time and data collection, the patent data of the past two years will not be analyzed for the time being.

3.3. Global safflower patent IPC sub-class technology composition

The International Patent Classification (IPC) categorizes patents based on the technical fields involved, and it is a valuable classification and retrieval tool (Gao et al., 2020). Counting the classification information of the IPC sub-categories of safflower patents, it can be found that safflower patent applications mainly focus on medicine (A61), food or food ingredients and their processing (A23), juice, wine, and other alcoholic beverages and their preparation (C12G), and measurement or analysis material class (G01 N) (Table 1). A61K (medical, dental, or cosmetic preparations) and A61P (specific therapeutic activity of compounds or pharmaceutical preparations) are the main IPC categories of safflower patents, accounting for 88.99% of all patents. The two representative categories are safflower-related traditional Chinese medicine composition and its preparation method and safflower therapeutic effect. These are the main technical components of the safflower patent. A61Q

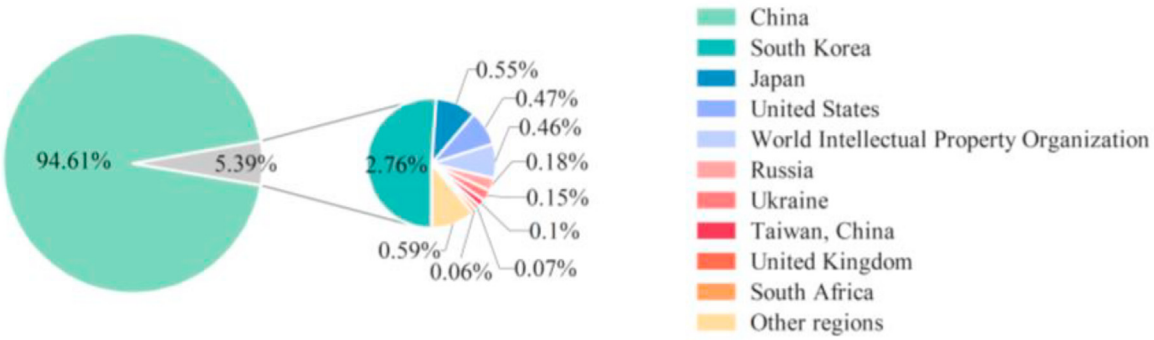

Fig. 1. The top ten countries, regions and organizations in terms of the number of safflower patents.

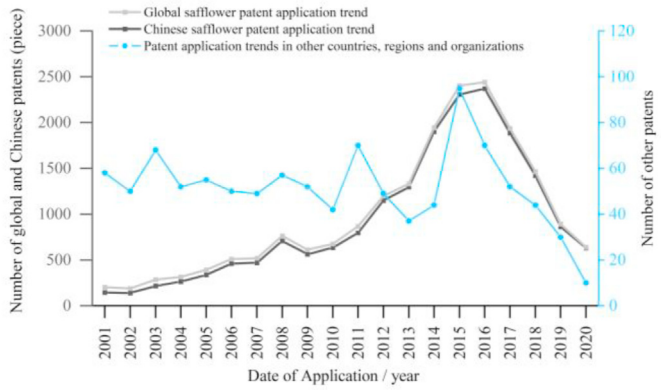

Fig. 2. Annual safflower patent application trends in the world, China and other countries, regions and organizations.

(special use of cosmetics or similar cosmetic preparations), A23L (food or non-alcoholic beverages), and C12G (fruit juice, wine, and other alcoholic beverages) are in the second front, indicating that cosmetics, food health care, medicinal wine, and other aspects occupy a certain position in the field of safflower patents. The three sub-categories together account for 7.30% of all the patents. The remaining IPC sub-categories accounted for less than 1% of the total. From the top ten sub-categories, safflower patents in the past two decades have covered pharmaceutical preparations, cosmetics, food and health care, various beverages, animal feed, equipment for safflower cultivation and harvesting, and related industries of safflower seed oil.

3.4. Global safflower patent IPC group distribution

We delve into the IPC technical distribution to more precisely divide IPC groups into sub-categories, the result is similar to the large group. Sometimes, one patent has attributes of several large groups so that it will simultaneously belong to different types of large groups. The top ten groups are from A61K and A61P, indicating that safflower has the largest number of patents developed as traditional Chinese medicine (Table 2). In all IPC groups, the number of A61K36 and A61K35 far outnumbers the other groups. In the A61P sub-category, safflower has the largest number of patents for treating rheumatism (A61P29), which means it was developed for dissipate blood stasis and relieve pain. Furthermore, the number of patents developed for the treatment of bone diseases (A61P19), skin diseases (A61P17), cardiovascular system diseases (A61P9), and reproductive or sexual diseases (A61P15) also ranks among the top.

The overall application trend of the large group is similar to the global application trend, which gradually increased with the passage of time, indicating that various pharmacological effects of safflower have been more developed and applied (Fig. 3). In 2004, the number of A61K36 patents began to exceed other large group, and since then, there has been an explosive growth, with the annual number of patents twice that of A61K35. In 2012, the number of patents in the A61P29 group surpassed that of the other A61P groups. Some scholars (Guo et al., 2014) sorted out 331 prescriptions containing "safflower" from the "Ministry of Traditional Chinese Medicine Standards", taking medicine as the smallest unit. The top three TCM diseases treated by safflower formula are arthralgia, bruises, and dysmenorrhea. The syndromes involved were mostly wind-cold and dampness stagnation of muscles and bones, damaged muscles and bones, stasis of muscles and bones, and qi stagnation and blood stasis syndrome. Therefore, it is consistent with the direction of patent application research and development.

3.5. Analysis of global safflower patent applicants

Counting the top ten global safflower patent applicants by several patents, we can find applicants who have accumulated more innovation achievements and further analyze their patent competitiveness. The top ten applicants are from China, including enterprises, private non-enterprise units, universities, and individuals (Fig. 4). Changsha Xiehaoji Biological Engineering Co., Ltd. is ranked first. The company concentrated on the application of patents from 2016 to 2017, and the patent content is mainly: a preparation method of enzyme acne-removing day cream, eye cream, night cream, wrinkle-removing sunscreen, and other cosmetics. Shihezi University ranked second in the number of applications and was the only university in the top ten. Its patent applications mainly focus on safflower harvesting methods and equipment, such as the safflower picking positioning method, safflower picking robot picking performance test bench, swinging safflower cutter, etc. Most of the safflower-related patents of several biopharmaceutical companies are traditional Chinese medicine compositions and preparation methods for treating symptoms such as amenorrhea, menstrual headache, skin itching, joint pain, low back and leg pain, abdominal pain, and chest pain. Individuals' patent content is more concentrated than that of enterprises. For example, the applicant of Yu Neixun pays attention to the development of safflower food and health products, and his patents are mainly micron Songhua deer fetus female ear red warming kidney yogurt, soy milk powder, milk tablets, milk powder, the preparation method of oral liquid and the like. Applicant Zhou Xiaodong focuses on beverages for treatment and health care products. The patent is mainly for medicinal liquors, promoting blood circulation, removing blood stasis and phlegm, dispelling cold, and regulating qi.

4. Advantageous industries and regions of China's safflower patent development

4.1. Development of Chinese safflower patent IPC sub-categories

As can be seen from the trend chart of China's patent applications,

Table 1
Top ten IPC sub-categories of safflower patents.

IPC	Meaning	Number of patents/piece	Proportion/ %
A61K	Preparations for medical, dental or cosmetic use (devices or methods specially adapted for the preparation of medicinal products into special physical or oral forms; air deodorization, disinfection or sterilization, or bandages, dressings, absorbent pads or surgical Chemical aspects of supplies, or use of materials into A61L; soap compositions into C11D)	20874	45.56
A61P	Specific therapeutic activity of a compound or pharmaceutical preparation (7);	19901	43.43
A61Q	Specific uses of cosmetic or similar cosmetic preparations (8)	1239	2.70
A23L	Foodstuffs, foodstuffs or non-alcoholic beverages not included in subclasses A21D or A23B to A23J; their preparation or treatment, such as cooking, improvement of nutritional quality, physical treatment (not formed or processed into A23P); general preservation of food or food ingredients (preservation of flour or dough for baking A21D)(4, 8)	1271	2.77
C12G	Fruit wines; other alcoholic beverages; their preparations (beer into C12C)	840	1.83
A23F	Coffee; tea; substitutes thereof; their manufacture, preparation or brewing	340	0.74
A23K	Feeds specially adapted for use in animals; methods for their production	333	0.73
A61 M	Devices for the introduction of media into or onto the human body (devices for the introduction of media into or onto animals A61D7/00; devices for inserting tampons A61F13/26; for feeding food or oral medicines A61J; Containers for the collection, storage or transfusion of blood or medical fluids A61J1/05); instruments for the transfer of human media or for the removal of media from the human body (surgical A61B, Chemical Aspects of Surgical Supplies A61L; A61N2/10 for magnetic therapy in which magnetic elements are placed into the body; devices used to induce or end sleep or coma(4, 5)	307	0.67
A23D	Edible oils or fats, such as margarine, shortening, cooking oils (obtained, refined, preserved as C11B, C11C; hydrogenated as C11C3/12)	300	0.65
G01 N	Testing or analysing materials by means of determining their chemical or physical properties (including enzymatic or microbial measurements or assays other than immunoassays C12 M, C12Q)	235	0.51
A47G	Household or table utensils (book end A47B65/00; knives B26B)	180	0.39

Table 2
The top ten IPC groups of safflower patents.

IPC	Meaning	Number of patents/piece
A61K36	Pharmaceutical preparations containing undetermined structures derived from algae, mosses, fungi or plants or their derivatives, such as traditional herbal medicines(8)	18919
A61K35	Medical preparations containing raw materials of unknown structure or their reaction products(2)	10268
A61P29	Noncentral pain relievers, antipyretics, or anti-inflammatory agents, such as antirheumatic drugs; nonsteroidal anti-inflammatory drugs (NSAIDs)(7)	5508
A61K9	Pharmaceutical formulations characterized by special physical shapes	5514
A61P19	Medications for Bone Disorders(7)	5350
A61P17	Medications for skin disorders(7)	3488
A61K31	Pharmaceutical preparations containing organic active ingredients(2)	3449
A61P9	Drugs for the treatment of cardiovascular diseases(7)	3311
A61K33	Medical preparations containing inorganic active ingredients(2)	2830
A61P15	Drugs for the treatment of reproductive or sexual disorders (drugs for the treatment of sex hormone disorders A61P5/24); contraceptives(7)	2502

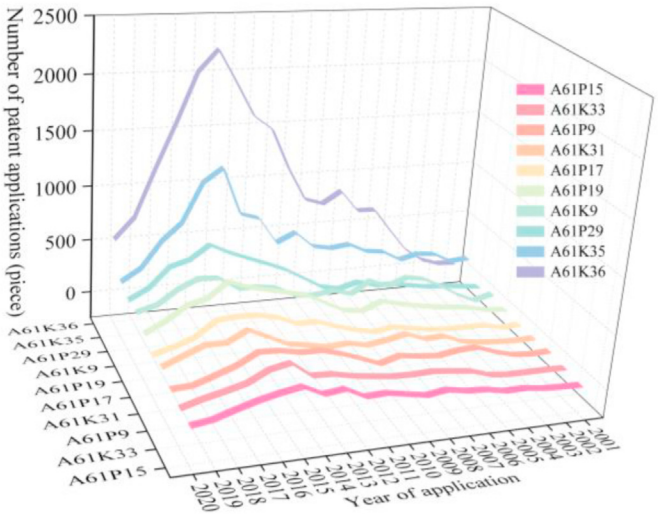

Fig. 3. Annual patent application trends of the top ten IPC groups.

2008 and 2016 showed the most prominent growth in the number of patents, and to some extent, they are particularly representative in patent topics and classification. Therefore, by analyzing the patent topics of the two years, we can observe the patent types and industrial changes during the two periods of safflower development.

When the top ten sub-categories of the two years were counted, C05F and C05G fall off the list, while A23D and A01D entered the top ten (Table 3). C05F refers to organic fertilizers that do not contain C05B and C05C, such as fertilizers made from waste or garbage. C05G refers to the mixture of fertilizers in each sub-category under the C05 category; a mixture composed of one or more fertilizers and substances without special fertilizer effects, such as pesticides, soil conditioners, and wetting agents (organic fertilizers containing added bacterial cultures, mycelium or the like are C05F 11/08; organic fertilizers containing plant vitamins or hormones such as C05F 11/10); fertilizers characterized by sharp. As a result, the relative proportion of the two sub-categories decreased in the current year, which means the patents related to the development decreased.

A23D refers to edible oils or fats such as margarine, shortening, and cooking oils (obtained, refined, preserved as C11B, C11C; hydrogenated as C11C3/12). A01D means harvest; mowing. In 2016, the relative number of the two sub-categories increased, indicating that the development efforts were strengthened. The relative number of A61Q (special use of cosmetic or similar cosmetic preparations) sub-categories rose from fifth to third. Other sub-categories have not changed much, and the number of patents for A61K and A61P is still at the forefront. From the changes in the proportion of several sub-categories in the current year, the proportion of A61K, A61P, A61Q, A23D, A01D, and other sub-categories increased in 2016 compared with 2008.

It is speculated that between 2008 and 2016, the safflower patents developed as a traditional Chinese medicine still occupy a dominant

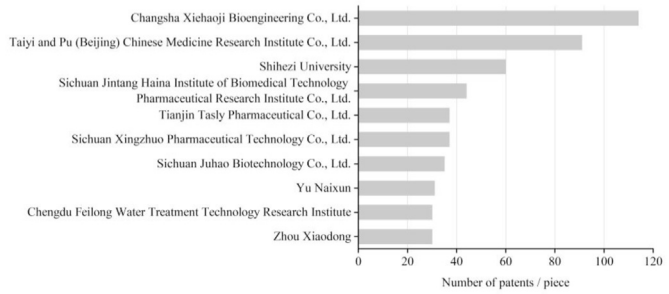

Fig. 4. The number of patent applications for the top ten applicants of safflower patents.

position. In addition to the development of safflower seed as feed, more patents now focus on safflower seed oil as edible oil and margarine development. Furthermore, safflower harvesting equipment research, cosmetic coloring and other aspects of the patent is also relatively increased, which indicating that the use of safflower has become more and more extensive.

4.2. Patent applications for provinces in China

The number of patents applied for in Shandong Province is 4355, accounting for 23.49%, which is almost a quarter of the national patent number in China (Table 4). The following rankings are Henan Province, Jiangsu Province, and Anhui Province. There is little difference in the number of patents among the three provinces, which is about 1400. The number of patents in other provinces decreased significantly. Guangdong Province ranked fifth with 972 patents, Sichuan Province ranked seventh with 777 patents. Most of the rest are in the eastern or southern coastal provinces, such as Guangxi, Zhejiang, and Liaoning. The patent application period in Shandong Province was mainly from 2012 to 2016 (Fig. 5). In addition, the two regions of Anhui and Guangdong have only vigorously applied for safflower patents since 2010.

The cultivation area of safflower in China is widely distributed, from Heilongjiang on the edge of the subarctic zone to Guangdong on the edge of the tropics, from the high-altitude Qinghai-Tibet Plateau to the low-altitude coastal areas of Jiangsu, Zhejiang, and Fujian (Wang and Chen, 1995). However, with the development of society, the main producing areas of safflower have gradually changed. The "Chuan Safflower" in Jianyang, Sichuan, and the "Huai Safflower " in Henan has a planting history of more than 2 000 years and are relatively famous in various production areas. Currently, principal producing areas of safflower are distributed in Xinjiang, Yunnan, and Gansu provinces, among which Xinjiang safflower accounts for more than 80% of the national safflower production (Lu et al., 2011).

However, it is worth noting that, there is no overlap between main producing areas of safflower and the top ten patent application areas. The literature has reported that safflower-producing areas such as the Yili Valley producing area (Peng, 2015) were faced with problems such as low comprehensive utilization rate of resources, single safflower product, and insufficient development. As a result, the production areas have fewer patent applications and lack industrial innovation compared to areas with developed safflower patent applications. In addition, the patent application situation is also closely related to the technological development capability of the region. For example, Shandong, Jiangsu, Zhejiang, and other regions are the main application areas for other Chinese medicine patents such as *Xanthium strumarium* L. (Li et al., 2020) and *Curcuma longa* L. (Shi et al., 2017).

4.3. Distribution of safflower patent in different economic industries and types of innovation entities

The quantity and quality of patents in different economic industries can reflect the innovation activity of the industry. Thus, it is necessary to

Table 4
The number and proportion of safflower patent applications in the top ten Chinese provinces and regions.

Ranking	Chinese provinces	Number of patents/piece	Proportion/%
1	Shandong	4355	23.49%
2	Henan	1488	8.03%
3	Jiangsu	1449	7.82%
4	Anhui	1309	7.06%
5	Guangdong	972	5.24%
6	Guangxi	838	4.52%
7	Sichuan	777	4.19%
8	Beijing	720	3.88%
9	Zhejiang	640	3.45%
10	Liaoning	588	3.17%

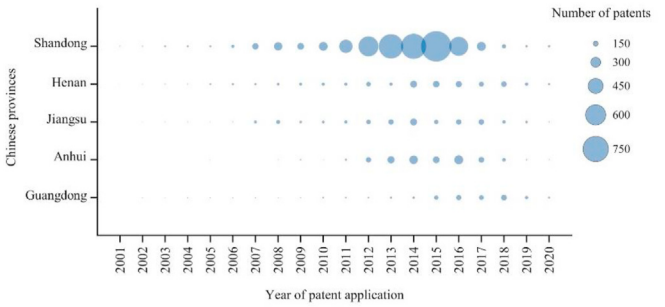

Fig. 5. Annual patent applications in the top five regions of China's safflower patent ranking.

Table 3
Top ten IPC sub-categories and the number and proportion of patents in 2008 and 2016.

Ranking	Year 2008			Year 2016		
	IPC subclass	Number of patents/piece	Proportion/%	IPC subclass	Number of patents/piece	Proportion/%
1	A61K	672	43.75	A61K	2090	44.03
2	A61P	632	41.15	A61P	1989	41.90
3	A23L	52	3.39	A61Q	149	2.55
4	C12G	36	2.34	A23L	121	1.87
5	A61Q	33	2.15	C12G	89	3.14
6	A61 M	22	1.43	A23K	49	0.57
7	A23K	21	1.37	A23F	44	1.03
8	A23F	18	1.17	A23D	28	0.93
9	C05F	12	0.78	A61 M	27	0.06
10	C05G	12	0.78	A01D	21	0.17
	A23D	7	0.46	C05G	8	0.59
	A01D	1	0.07	C05F	3	0.44
	others	18	1.17	others	129	2.72

analyze the distribution of China's safflower patents in various national economic industries. The C27 (pharmaceutical manufacturing) industry ranks first, with 15 547 patents, accounting for 79.33% of the total number of patents (Table 5). That is to say, safflower patents are mainly produced and applied in the pharmaceutical manufacturing industry. Additionally, safflower has significantly developed the C26 (chemical raw material and chemical product manufacturing) industry, with 1 335 patents, ranking second, accounting for 6.81%. Food and wine, beverages, and refined tea manufacturing had 709 and 633 patents, respectively. They are the third and fourth economic industries of the safflower industry. The agricultural and sideline food processing and special equipment manufacturing industries also occupy a certain position, and other industries account for less than 1%.

By understanding the subject nature, R&D strength and R&D purpose of the patent applicants, we can analyze whether the innovation achievements are more inclined to basic research or commercial application, locate the position of the technology in the industrial chain and the possible operation mode, and provide a basis for further identifying the various innovative entities with significant influence in the industry. Among all applicant types, individuals applied for the most safflower patents, accounting for 59.4%, followed by enterprises, accounting for 25.8% (Fig. 6). Universities and scientific research units accounted for a relatively small proportion, accounting for 4% and 2.5% respectively, and institutions and organizations accounted for 2.5%. The subject content of individual patent applications is relatively simple, based on the patent subjects of the top ten applicants. Therefore, there is less basic research on safflower, and its patented achievements are more inclined to commercial applications.

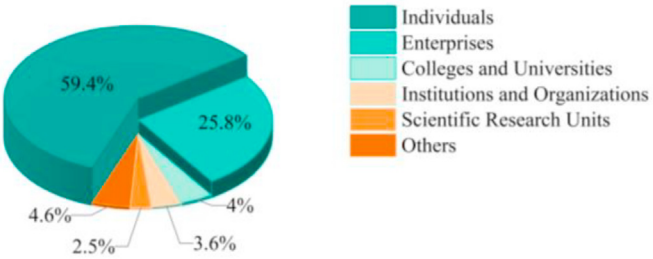

Fig. 6. Distribution of types of patent applicants in China.

5. Safflower patent quality

5.1. Patent value

BEIJING INCOPAT CO., LTD independently develop the patent value evaluation system. It evaluates the quality of patents with the comprehensive index of the joint value. The patent value degree has three evaluation indicators: technological advancement, stability, and protection scope. Patent-related indices such as the number of citations, the number of IPC groups involved, the number of R&D personnel invested, whether there is a license, and whether there is a transfer are used to assess technological advancement. Judging the scope of protection is mainly based on the number of claims. Generally, the higher the patent sharing value, the better the patent's advanced nature, quality, and competitiveness.

The safflower patent value of the top ten countries, regions, and organizations in the number of patents was counted (Table 6). China has the highest number of patents, with a value of 2, 4,556, accounting for 24.57% of the total. Most patents score in the range of 1–6, with fewer patents scoring high in value. It is divided into two parts according to the size of the patent value. The number of patents with a value of 1–5 accounted for 68.49%, and patents with a value of 6–10 accounted for 31.51%. In short, China's patent value score is relatively low, and the quality needs to be improved. South Korea, Japan, the United States, and the World Intellectual Property Organization accounted for 72.21%, 88.30%, 95.24%, and 86.75% of the total patents, with a patent value of 6–10, indicating most of the patents were high-quality patents. The remaining countries and regions have fewer patents, but their patent value is evenly distributed. With a patent value of 1–2, Ukrainian patents accounted for 73.68%, the country with the lowest patent quality among the top ten patents. Furthermore, the average patent value degree of the top ten is analyzed, and the highest patent quality is the United States, with an average value degree of 8.95 (Fig. 7). The World Intellectual Property Organization and Japan's patent quality are next at 7.98 and 7.87, respectively. South Africa has a small number of safflower patents but a high patent value degree of 7.13. South Korea ranks second in the number of safflower patents, and the average patent value is above the middle level at 6.64. The quality of patents in Russia, Taiwan, and the United Kingdom are at an intermediate level, at 5.27, 5.18, and 5.12, respectively. China's patent value degree is 4.51, and the overall level is moderately low compared to other countries. To summarize, while China has far more patents than other countries, most are of poor quality, lowering the overall patent level. The number of safflower patents in other countries, regions, and organizations is small, but the quality of patents is relatively high, especially in the United States and Japan.

Table 5
National economic industry classification of China's safflower patents.

National economic industry classification/ category	Number of patents/piece	Proportion/ %
C27 (pharmaceutical manufacturing)	15547	79.33
C26 (Manufacturing of chemical raw materials and chemical products)	1335	6.81
C14 (Food Manufacturing)	709	3.62
C15 (Wine, Beverage and Refined Tea Manufacturing)	633	3.23
C13 (Agricultural and sideline food processing industry)	504	2.57
C35 (Specialized Equipment Manufacturing)	297	1.52
C21 (furniture manufacturing)	123	0.63
C40 (Instrument and Meter Manufacturing)	86	0.44
A01 (agriculture)	49	0.25
C17 (textile industry)	45	0.23
others	269	1.37

5.2. Ranking by number of citations

Taking the most in-depth and common patent citations and the number of claims as indicators (Ma et al., 2012) can indicate the high-quality representative patents in a field to a certain extent. Among the top ten safflower patents cited, Articles 1 and 9 are from Japan, and the rest are from China (Table 7). The patent "glycation inhibitor and its use" ranked first in the number of citations, was cited 97 times, and the family was cited 121 times. Another Japanese patent, "Cold-sensitive constitution improving agent, cold-sensitive constitution-improving composition, and cold-sensitive constitution-improving food and drink," was cited 57 times. The second-ranked patent, "A Traditional Chinese Medicine Preparation for the Treatment of Rheumatism and Rheumatoid Diseases", was cited 80 times, and the family was cited 82 times. The topics of the top ten Chinese patents include two categories: the medical effect of treating rheumatism, cervical and lumbar diseases, and cerebral thrombosis, and the health care effect of food and drinks. This shows that the safflower patent has in-depth and high-quality development in the above aspects. Additionally, by classifying these 10 patents by country, we found that the number of claims of Japanese patents was higher than that of Chinese patents when the number of citations is similar, indicating that high-quality Chinese patents do not pay enough attention to patent protection and need to be further improved.

Table 6
Patent value and proportion of the top ten countries, regions and organizations.

Patent value	China	South Korea	Japan	United States	World Intellectual Property Organization	Russia	Ukraine	Taiwan, China	United Kingdom	South Africa
	Quantity/piece (Proportion/%)	Quantity/piece (Proportion/%)	Quantity/piece (Proportion/%)	Quantity/piece (Proportion/%)	Quantity/piece (Proportion/%)	Quantity/piece (Proportion/%)	Quantity/piece (Proportion/%)	Quantity/piece (Proportion/%)	Quantity/piece (Proportion/%)	Quantity/piece (Proportion/%)
1	519 (2.80)	2 (0.28)	0 (0.00)	0 (0.00)	0 (0.00)	1 (2.27)	11 (36.84)	0 (0.00)	3 (20.00)	0 (0.00)
2	4556 (24.57)	15 (2.79)	0 (0.00)	1 (0.60)	0 (0.00)	5 (13.64)	11 (36.84)	2 (9.09)	0 (0.00)	0 (0.00)
3	1626 (8.77)	31 (5.73)	3 (2.66)	1 (1.19)	1 (0.66)	5 (13.64)	3 (10.53)	6 (30.30)	1 (4.00)	0 (0.00)
4	2548 (13.74)	32 (6.01)	4 (3.72)	1 (1.19)	6 (6.62)	5 (13.64)	2 (5.26)	3 (15.15)	2 (12.00)	0 (0.00)
5	3449 (18.60)	70 (12.99)	6 (5.32)	2 (1.79)	5 (5.96)	4 (11.36)	0 (0.00)	0 (0.00)	4 (28.00)	0 (0.00)
6	2637 (14.22)	138 (25.42)	14 (13.30)	2 (1.79)	5 (5.96)	6 (15.91)	2 (5.26)	2 (12.12)	0 (0.00)	3 (26.67)
7	1232 (6.64)	75 (13.83)	22 (20.21)	8 (8.93)	13 (13.91)	3 (9.09)	0 (0.00)	1 (6.06)	2 (16.00)	5 (40.00)
8	681 (3.67)	35 (6.42)	11 (10.11)	12 (13.10)	17 (19.21)	1 (2.27)	2 (5.26)	2 (12.12)	1 (8.00)	3 (26.67)
9	1098 (5.92)	76 (14.11)	13 (11.70)	15 (16.07)	22 (23.84)	5 (13.64)	0 (0.00)	3 (15.15)	1 (4.00)	1 (6.67)
10	195 (1.05)	67 (12.43)	36 (32.98)	51 (55.36)	22 (23.84)	2 (4.55)	0 (0.00)	0 (0.00)	1 (8.00)	0 (0.00)

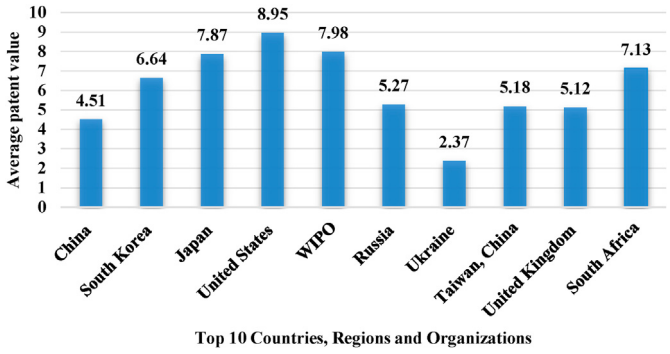

Fig. 7. Average value of patents in the top ten countries, regions and organizations.

5.3. Ranking by number of power requirements

In general, high-value patents have more claims than ordinary patents. The World Intellectual Property Organization, Canada, South Korea, and the United States have the top ten patents regarding the number of statistical power requirements (Table 8). The patent titled "Wild bird food essential nutrition products" comes from the World Intellectual Property Organization and has the largest number of claims, up to 367. The second-ranked patent is a Canadian patent titled "High oleic acid oils," with 94 claims. The titles of the remaining patents are "Highly functional epoxidized resins and coatings," "Microreactor process for making biodiesel," "Antiphlogistic, antioncotic, and analgesic Chinese herbal composition, preparative method and usage thereof," "Conjugated linoleic acid compositions," "Olive-oil-based functional oils," "Methods and compositions for affecting taste and aroma profile of substances suitable for consumption," "Conjugated linoleic acid compositions." Therefore, it can be concluded that the top ten patents mainly focus on the edible and chemical applications of safflower oil. The number of claims can reflect the technical content and coverage of the patented technology from the side and the number of technical solutions. The higher number of claims of the above organizations and national patents indicates that their patentees attach great importance to the degree of patent protection, and the patent quality is high. On the other hand, the overall number of claims for Chinese safflower-related patents is low, and most patents are less than 10.

6. Summary and discussion

After summarizing the patent applications, distribution, classification, quality, and themes of Safflower in the past 20 years, it can be found that: (1) China is a major country for Safflower patent applications, and the beginning of the 21st century has seen the most growth in the number of applications. About 80% of patents are medicine related. Internationally, the patent application time is earlier, and the patent application for the medicinal theme of safflower is concentrated in Asian regions such as South Korea and Japan with a small number. The application area is widely distributed, which is in line with the historical transmission route of safflower, its excellent adaptability, and its value. (2) The technical fields A61K and A61P involved in safflower patents account for 88.99% of all IPC categories, indicating that safflower-related traditional Chinese medicine compositions and their preparation methods, and the therapeutic effects of safflower, the two types of industries, have the most in-depth and extensive development. Second, safflower has been used and developed in cosmetics, food and health care, beverages, animal feed, cultivation and harvesting equipment, and safflower seed oil. Safflower is also the most common ingredient in treating various diseases and is widely used in treating rheumatism, lumbar, cervical joints, and other bone diseases and skin diseases. (3) During the development of China's safflower patent from 2008 to 2016, the research and development of the safflower industry in feed and organic fertilizers have relatively weakened, and more attention has been paid to cosmetics, edible oil, and harvesting equipment. (4) The number of safflower patents in Shandong Province, China, began to emerge in 2007, and the province ranked first in the country until 2017. In 2015, the number of patents was 4.5 times that of the second-ranked province, accounting for 1/4 of the country. In addition, China's eastern and southern coasts are the main application areas for safflower patents. (5) From the national economic structure of the safflower industry represented by the Chinese safflower patent, the primary active industries of the safflower industry are pharmaceutical manufacturing, chemical raw material, and chemical product manufacturing, food manufacturing, wine, beverage, and refined tea manufacturing, agriculture and sideline food processing industry and special equipment manufacturing industry. (6) Generally, enterprises have more significant development potential and assets than individuals. Only two of the top ten patent applicants are individual patent applicants, and the subject matter of the patent application is single. The types of Chinese safflower patent applicants include individuals accounting for 59.4% and enterprises accounting for 25.8%. The research and development purpose of safflower patents is more inclined to commercial applications, and basic research is relatively weak. (7) Regarding patent quality, the average patent value of Chinese safflower-related patents is 4.51, which is generally moderate. The number of patents has been mentioned numerous times, but there is a general lack of understanding about patent protection. The average patent value of the United States, Japan, the World Intellectual Property

Table 7
The top ten patents cited in safflower patents.

Serial number	Title	Public (announcement) number	Application date	Applicant	Number of claims	Citations	Family citations	Cited country	Number of patent families
1	Glycation inhibitor and its use	JP2004250445A	2004/1/29	YAKULT HONSHA KK	7	97	121	Japan; European Patent Office; Spain; United States; World Intellectual Property Organization; China; Russian Federation; South Korea	3
2	A kind of traditional Chinese medicine preparation for treating rheumatism and rheumatoid disease	CN1966018A	2006/10/25	Luo Hongzhi	1	80	82	China	2
3	Traditional Chinese medicine for treating cervical and lumbar vertebra disease and preparation method thereof	CN102125672A	2010/1/12	Yao Yujian	2	66	66	China	1
4	A kind of natural five-color lipid-lowering slimming tea beverage and preparation method thereof	CN101623038A	2008/7/8	Liu Yonghong	5	64	64	China	1
5	A kind of peach sweet dried bean curd	CN104273239A	2014/10/24	Hefei Fengluohe Soybean Food Co., Ltd.	2	60	60	China	1
6	Dietary flour for treating diabetes and preparation method thereof	CN1348717A	2001/5/10	The People's Government of Yongan Township, Shizhong District, Zaozhuang City	3	58	58	China; Russian Federation	1
7	A kind of traditional Chinese medicine preparation for treating human cervical vertebra, lumbar vertebra protrusion and hyperplasia	CN102058823A	2009/9/21	Wang Jieqing	1	57	57	China	1
8	A drug for the treatment of cerebral thrombosis	CN1951481A	2006/10/12	Zhang Yuandao	3	57	57	China	1
9	Cold-sensitive constitution improving agent, cold-sensitive constitution improving composition and cold-sensitive constitution improving food and drink containing the same	JP2003040788A	2001/7/30	MARUZEN PHARMA	13	57	62	Korea; World Intellectual Property Organization; Japan; United States; European Patent Office	2
10	Traditional Chinese medicine composition for treating cardiovascular and cerebrovascular diseases	CN101181600A	2007/11/20	Wang Zhencai	3	55	58	China	2

Table 8
The top ten patents in safflower patents with the number of claims.

Serial number	Title	Public (announcement) number	Application date	Open country	Number of claims	Citations
1	Wild bird food essential nutrition products	WO2012118993A1	2012/9/7	WO	367	0
2	High oleic acid oils	CA2871503A1	2013/10/31	CA	94	0
3	Highly functional epoxidized resins and coatings	WO2011097484A1	2011/8/11	WO	75	19
4	Microreactor process for making biodiesel	WO2007142983A2	2007/12/13	WO	74	12
5	Antiphlogistic, antioncotic and analgesic Chinese herbal composition, preparative method and usage thereof	KR1020160149765A	2016/12/28	KR	73	0
6	Conjugated linoleic acid compositions	US20040058998A1	2004/3/25	US	65	11
7	Conjugated linoleic acid compositions	US20040225142A1	2004/11/11	US	52	6
8	Olive-oil-based functional oils	WO2010149815A1	2010/12/29	WO	61	15
9	Methods and compositions for affecting taste and aroma profile of Substances suitable for consumption	RU2701852C2	2019/10/1	RU	54	0
10	Lubricated sheet product and lubricant composition	US20040018947A1	2004/1/29	US	52	6

Organization, and other countries and organizations is above 7 points. The patent research and development efforts are in-depth, which means the patent quality is high, and the protection of patents is emphasized.

In the past fifty years, the primary purpose of international safflower

cultivation has been to extract vegetable oil from its seeds (Bozan and Temelli, 2008). Safflower oil is odorless, colorless, and nutritionally similar to sunflower oil and is mainly used in the production of cosmetics and edible oils, salad dressings, and margarine (Khalid et al., 2017). In this country, fewer and fewer varieties of safflower oil are planted, and they are frequently replaced by medicinal varieties, which are unrelated to the purpose of safflower in the rest of the world. Many Chinese applicants are concerned about the functional effects of safflower seed oil, based on the development of safflower patent applications. While developing and utilizing medicinal safflower, developing more safflower products is necessary to fully use safflower resources and innovate the industry. However, in the past two years, safflower patent applications have entered a bottleneck period, and the number and quality of patent applications have been significantly lower than those in 2015 and 2016. In addition, the safflower producing areas (Ren et al., 2014), such as the production area of Qabqal County, Yili, have the problem of single safflower products and insufficient development. Therefore, innovative safflower research and development and safflower patent protection are critical.

The development of the safflower industry in the future can focus on the following aspects: (1) From the current research and development theme of patents, in addition to focusing on the research and development direction of safflower as a prescription drug for various diseases, there are more and more patents that safflower medicinal materials and safflower seed oil have therapeutic effects on rheumatism and bone diseases. Therefore, the medicinal value of safflower seed oil needs to be further developed. (2) The research and development of safflower as a health food, beverage, and cosmetics is also a potential development, especially in food and health products. Many China mainland enterprises have vigorously developed safflower seed oil health products. (3) The picking of safflower after maturity still requires much labor. In recent years, mechanized planting and picking have been the hot spots of safflower patent applications. The breeding of fine varieties is the cornerstone of industrial development. In addition to the solution of harvesting mechanization for the complex problem of safflower harvesting, it is also possible to improve the performance of varieties, improve their agronomic traits, and cultivate excellent varieties. (4) It is necessary to deepen the basic research of safflower, combine production, study, and research, and increase the transformation of achievements. Since individuals and enterprises account for 85.2% of the applicants for safflower patents, safflower patents are heavily biased towards commercial applications, and basic research is weak. Universities and scientific research units should actively participate in research and development, collaborate, and consult with enterprises and individuals. They will guide and support research and development, promote the link between scientific research results and industry, and eventually aid in the long-term development of the safflower industry.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ocsci.2022.10.001.

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