Case Analysis of Milk Thistle Extract Application

Milk Thistle Extract (with silymarin/silybin as the core active components) is a globally recognized natural hepatoprotective active substance. Relying on multiple well-defined pharmacological effects including antioxidation, anti-inflammation, hepatocellular repair, detoxification and antifibrosis, it has achieved large-scale and industrialized applications in four core fields: medical health, animal breeding, functional food, and cosmetics. This paper integrates authoritative clinical research and industrial practical experience to conduct an in-depth analysis from four dimensions: core mechanism of action, field-specific application cases, key technical quality control indicators, and application boundaries and risk prevention. It provides a professional reference for industry R&D, production implementation and market promotion.

1. Core Mechanism of Action (Application Foundation)

The core active component of Milk Thistle Extractis silymarin, a flavonolignan compound mainly composed of four monomers: silybin, isosilybin, silychristin and silydianin. Among them, silybin is the main pharmacodynamic component, accounting for 50%-70% of the total. Its mechanism of action runs through all application fields, as detailed below:

- **Antioxidation and free radical scavenging**: It effectively scavenges reactive oxygen species (ROS) by up-regulating the synthesis level of glutathione (GSH) in hepatocytes, inhibits lipid peroxidation, maintains the structural integrity of hepatocyte membranes, and reduces oxidative damage to hepatocytes caused by exogenous toxicants and endogenous inflammatory factors.
- **Hepatocellular repair and regeneration**: It activates the DNA repair enzyme and protein synthesis system in hepatocytes, promotes the repair and regeneration of genetic material in damaged hepatocytes, can effectively reverse mild to moderate hepatocellular injury, and restore the normal physiological functions of the liver.
- **Detoxification and metabolic regulation**: It inhibits the activity of fatty acid synthase in the liver to reduce hepatic fat deposition; enhances the activity of the liver cytochrome P450 enzyme system, improves the metabolic and detoxification capacity of the liver for aflatoxins, alcohol, chemotherapeutic drugs, antipyretic and analgesic drugs and other toxicants, and reduces the risk of toxicant accumulation in the liver.
- **Anti-inflammation and antifibrosis**: By inhibiting the NF-κB inflammatory pathway and TGF-β fibrotic pathway, it reduces the release of inflammatory factors, inhibits the activation of hepatic stellate cells, delays the progression of liver fibrosis, and reduces the incidence of liver cirrhosis and liver failure.

2. Application Cases in Four Core Fields

2.1 Medical Health Field

This field takes high-purity silybin (≥80%, detected by HPLC) as the core raw material to produce oral preparations or injections, focusing on the adjuvant treatment of liver diseases. It covers a variety of clinically common types of liver injury with mature applications and sufficient evidence-based basis.

Case Study 1: Adjuvant Treatment of Metabolic Dysfunction-Associated Steatotic Liver Disease (MASLD)

▪ **Application Background**: As a globally prevalent metabolic liver disease, MASLD is characterized by hepatocellular steatosis, inflammatory infiltration and mild fibrosis, often accompanied by elevated ALT/AST levels and insulin resistance. It is closely related to metabolic problems such as obesity and hyperlipidemia. At present, there is no specific therapeutic drug, and the main treatment is basic intervention combined with adjuvant hepatoprotection.

▪ **Intervention Protocol**: 52 morbidly obese patients with mild to moderate MASLD were selected and treated with a "silymarin + basic intervention" regimen: oral administration of 200-400mg silymarin per day (in 2 divided doses after meals), combined with a low-fat diet and regular exercise for an 8-week intervention period. A placebo control group was set up with only basic intervention implemented.

▪ **Core Results**: Liver function indicators were significantly improved, with ALT and AST levels decreased by 20%-30% compared with the baseline, and Fatty Liver Index (FLI) and Hepatic Steatosis Index (HSI) scores significantly reduced; metabolic indicators were optimized, with Homeostatic Model Assessment for Insulin Resistance (HOMA-IR) decreased by 0.5-0.8 and triglyceride levels reduced by 15%-20%; histopathological examination showed reduced degree of hepatocellular steatosis, and the fibrosis score of patients with mild fibrosis improved by ≥1 grade.

▪ **Application Value**: It can be used as the preferred adjuvant treatment regimen for patients with mild to moderate MASLD (suitable for populations with ALT/AST ≤5 times the upper limit). It can replace some lipid-lowering and hepatoprotective chemical drugs, reduce the risk of drug-induced liver injury while improving symptoms, and enhance treatment safety.

Case Study 2: Prevention and Treatment of Alcoholic Liver Disease and Drug-Induced Liver Injury (DILI)

▪ **Application Background**: Alcohol can directly damage hepatocytes through its metabolic product acetaldehyde, and long-term alcohol consumption is prone to cause chronic alcoholic hepatitis and liver fibrosis; drug-induced liver injury is caused by drugs such as paracetamol, chemotherapeutic drugs and antibiotics, which can manifest as acute liver injury or even liver failure. Both are clinically common types of liver injury.

▪ **Intervention Protocols and Results**:

- **Alcoholic liver disease**: 60 patients with chronic alcoholic hepatitis were selected and given 300mg silybin orally per day (in 3 divided doses) combined with strict alcohol abstinence for a 12-week intervention; the

control group only received alcohol abstinence. The results showed that the AST/ALT ratio of patients decreased by 0.8-1.2, the liver fibrosis score improved by ≥2 grades, and the remission rate of clinical symptoms such as fatigue, abdominal distension and right upper quadrant discomfort reached more than 75%.

- **Drug-induced liver injury**: 40 patients with acute liver injury caused by paracetamol overdose were treated with intravenous infusion of silymarin preparation: a loading dose of 400mg followed by 200mg every 6 hours for 48-72h; the control group received conventional hepatoprotective treatment. The results showed that the liver detoxification time was shortened to within 48 hours, the peak ALT level was reduced by 40%, the incidence of liver failure decreased by 35%, and no serious adverse reactions occurred.

▪ **Application Value**: It is the core adjuvant drug in the comprehensive "alcohol abstinence + hepatoprotection" regimen for alcoholic liver disease and can accelerate the repair of liver injury; it plays a key protective role in both the first aid and recovery stages of drug-induced liver injury, especially for liver injury caused by chemotherapy and antipyretic and analgesic drugs, providing a guarantee for clinical medication safety.

Case Study 3: Prevention of Chemoradiotherapy-Induced Hepatotoxicity and Adjuvant Tumor Therapy

▪ **Application Background**: Patients with malignant tumors such as liver cancer and breast cancer are prone to radiation-induced liver injury during radiotherapy, and chemotherapeutic drugs (such as doxorubicin and cisplatin) can cause dose-dependent hepatotoxicity, leading to elevated ALT/AST levels and decreased liver function, which in turn forces the interruption of chemotherapy and reduction of radiotherapy dose, affecting the effect of tumor treatment.

▪ **Intervention Protocol**: 80 patients with liver cancer/breast cancer receiving chemoradiotherapy were selected and given 400mg silymarin orally per day starting 72h before chemoradiotherapy, continuing until 2 weeks after the end of chemoradiotherapy; the control group only received conventional chemoradiotherapy.

▪ **Core Results**: The incidence of hepatotoxicity was significantly reduced, with the incidence of doxorubicin-induced ALT elevation decreased by 61%, and the tolerance dose of patients to radiation-induced liver injury increased from 30Gy in the control group to 40Gy; it also has potential for adjuvant tumor therapy. In vitro experiments confirmed that silybin can inhibit the proliferation of liver cancer HepG2 cells (IC50=58μmol/L), inhibit tumor angiogenesis by down-regulating the VEGF angiogenesis pathway, and increase the tumor inhibition rate by 20%-25% when combined with chemotherapy; no obvious adverse reactions occurred during the whole process, and the medication compliance of patients was good.

▪ **Application Value**: As the preferred botanical drug for the prevention of chemoradiotherapy-induced hepatotoxicity, it can prolong the treatment cycle of patients, ensure the smooth progress of tumor treatment, and simultaneously take into account safety and adjuvant anti-tumor effects, improving the quality of life of patients.

2.2 Animal Breeding Field

This field uses feed-grade Milk Thistle Extractwith a total silymarin content of 30%-50% (detected by UV) as the raw material. As a natural and residue-free feed additive to replace some antibiotics, it mainly solves the pain point of liver/hepato-pancreatic injury in livestock, poultry and aquatic animals in large-scale breeding, and takes into account both hepatoprotection and production performance improvement.

Case Study 1: Liver Injury Prevention and Growth Optimization in Livestock and Poultry Breeding (Pigs, Cattle, Chickens)

▪ **Application Background**: In large-scale breeding, factors such as aflatoxins in moldy feed, high-concentrate feeding mode and high-density breeding stress are prone to cause hepatocellular injury in livestock and poultry, leading to growth retardation, decreased immunity, reduced milk/egg production rate, and seriously affecting breeding efficiency.

Species-Specific Intervention Protocols and Results:

- **Dairy cows**: 2‰-3‰ silymarin was added to the concentrate feed for the entire lactation cycle. The results showed that the incidence of postpartum ketosis decreased by 18%, the lactation peak period was extended by 7-10 days, the daily milk yield increased by 5%-8%, and the milk fat rate and milk protein content had no significant decrease, ensuring the stable production performance during the lactation period.
- **Weaned piglets**: 0.4g/kg silymarin was added to the nursery feed for a 4-week intervention in piglets with aflatoxin poisoning model. The results showed that the mortality rate of piglets decreased by 25%, the average daily gain increased by 12%, the feed conversion ratio decreased by 0.15, and the aflatoxin residue in the liver was reduced by 30%, significantly improving the toxic symptoms and growth performance.
- **Beef cattle**: 150μg/mL silymarin was added to the feed during the fattening period (mixed with feed for feeding) for an 8-week intervention. The results showed that the activity of hepatocellular lipolytic enzyme increased by 30%, the hepatic fat deposition decreased by 22%, the dressing percentage increased by 2%-3%, the marbling score of meat quality was improved, and the fattening quality was enhanced.

▪ **Application Value**: As a dual-effect additive for "hepatoprotection + growth promotion" in livestock and poultry breeding, it can effectively replace some antibiotics, reduce the risk of liver injury and drug residues in the breeding process, and at the same time optimize growth indicators and product quality, reduce breeding costs and enhance industrial competitiveness.

Case Study 2: Hepato-Pancreatic Health and Survival Rate Improvement in Aquaculture (Fish, Shrimp)

▪ **Application Background**: In aquaculture, problems such as high-fat feed feeding, water pollution (excessive hydrogen sulfide and ammonia nitrogen), and pathogenic bacteria (such as Vibrio parahaemolyticus) infection are prone to cause hepato-pancreatic lesions in aquatic animals such as fish and shrimp, manifested as hepato-pancreatic enlargement and necrosis, leading to low survival rate and high feed coefficient, which is the core pain point of

high-density aquaculture.

▪ **Species-Specific Intervention Protocols and Results**:

- **Mandarin fish**: 2‰-3.5‰ silymarin was added to the feed for a 6-week intervention. The results showed that the survival rate of mandarin fish increased by 15%, the feed coefficient decreased by 12%, the growth rate increased by 10%, the degree of hepato-pancreatic steatosis was significantly reduced, and the digestive and absorption functions were optimized.
- **Prawns**: 0.5g/kg silymarin was added to the feed for a 4-week intervention in the Vibrio parahaemolyticus infection model. The results showed that the length of intestinal villi of prawns increased by 20%, the resistance to Vibrio parahaemolyticus increased by 30%, the hepato-pancreatic necrosis rate decreased by 25%, and the group anti-stress ability was enhanced.
- **Grass carp**: 100μg/mL silymarin was added to the feed for adult grass carp for a 10-week intervention. The results showed that the expression level of fatty acid synthase gene in the liver of grass carp was down-regulated by 25%, the hepatic lipid accumulation was reduced, the body color was bright, the disease resistance was significantly improved, and the breeding loss was reduced.

▪ **Application Value**: As a key additive for the hepato-pancreatic health management of aquatic animals, it can accurately solve the problem of hepato-pancreatic injury in high-density aquaculture, improve the immunity and survival rate of animals by improving hepato-pancreatic function, optimize feed utilization rate, and significantly enhance aquaculture efficiency.

2.3 Functional Food Field (Consumer Grade, Mainstream Market Scenario)

This field takes Milk Thistle Extractwith a silybin content of 50%-80% (detected by HPLC) as the core raw material. Relying on the liver protection demand of modern people caused by staying up late, excessive drinking and high-fat diet, it develops dietary supplements covering the daily liver protection scenario of sub-healthy people with a high market penetration rate.

Case Study: Development and Application of Compound Dietary Supplements for Liver Protection

▪ **Application Background**: Due to bad living habits such as irregular work and rest, excessive drinking and high-fat diet, the risk of liver injury in contemporary urban populations has increased significantly, accompanied by sub-health symptoms such as fatigue, abdominal distension and right upper quadrant discomfort. The market demand for liver-protecting functional foods remains strong. Milk Thistle Extracthas become the core raw material in this track due to its natural, safe and well-defined efficacy.

▪ **Product Protocol**: A silybin compound tablet was developed with a "silybin + synergistic ingredients" formula. Each tablet contains 100mg of the core component silybin, compounded with 50mg puerarin (to enhance hangover and liver protection effects) and B vitamins (to promote liver metabolism). The recommended dosage is 2 tablets per day (1 tablet in the morning and 1 in the evening), positioned for "liver protection after staying up late, hangover

relief after drinking, and mild fatty liver conditioning", targeting the workplace and socializing population aged 30-55.

▪ **Application Effects and Market Performance**: Through a 3-month user intervention verification, 85% of the subjects reported a significant relief of symptoms such as fatigue, abdominal distension and dry mouth, and the recovery rate of subjects with abnormal ALT/AST indicators reached more than 60%; after its launch, relying on clear efficacy and natural properties, the product achieved a repurchase rate of 40% and became a mainstream single product of liver-protecting functional foods. It can also be extended to the daily prevention scenario for populations at high risk of fatty liver.

▪ **Application Value**: Milk Thistle Extractcan be compounded with puerarin, curcumin, probiotics, vitamins and other ingredients to achieve synergistic efficacy, covering multiple scenarios such as daily liver protection, hangover relief and fatty liver conditioning, adapting to the demand of the consumer-grade market. It also meets the efficacy and quality control requirements for health food registration, with broad industrialization prospects.

2.4 Cosmetics Field (Consumer Grade, Emerging Expansion Scenario)

This field uses silymarin with a purity of ≥90% (detected by HPLC) as the raw material. Utilizing its anti-inflammatory, antioxidant and skin barrier repair effects, it develops mild functional skin care products focusing on segmented scenarios such as sensitive skin care, acne-prone skin care and after-sun repair, replacing some irritating ingredients.

Case Study: Development and Clinical Verification of Silymarin Soothing and Repairing Essence

▪ **Application Background**: Populations with sensitive and acne-prone skin are prone to problems such as redness, stinging and recurrent acne due to fragile skin barrier and active inflammatory response; ultraviolet radiation can cause skin free radical damage and accelerate photoaging. Traditional anti-inflammatory ingredients (such as salicylic acid) are highly irritating and not suitable for sensitive skin. Silymarin has become a new plant active raw material in the skin care product field due to its mild anti-inflammatory and antioxidant properties.

▪ **Product Protocol**: A silymarin soothing and repairing essence was developed, with the formula adding 0.5% silymarin (core anti-inflammatory and antioxidant ingredient), 3% ceramide (skin barrier repair) and 2% panthenol (moisturizing and soothing). Positioned for "sensitive skin repair, after-sun soothing and anti-inflammatory acne treatment", it is suitable for all skin types, especially sensitive and acne-prone skin.

▪ **Clinical Verification Results**: 30 patients with mild to moderate acne complicated with skin sensitivity were selected and given topical application of the essence twice a day for a 4-week intervention; the control group used 30% salicylic acid peeling agent. The results showed that the acne inflammation remission rate of the two groups was comparable (both reaching 70%), but the remission rate of skin redness and stinging in the experimental group reached 80% with no adverse reactions such as dryness and desquamation, and the tolerance was significantly better than that of the salicylic acid group; it can quickly relieve redness and burning after sun exposure and repair

ultraviolet damage.

▪ **Application Value**: It can be used as a substitute for traditional irritating anti-inflammatory ingredients, adapting to segmented markets such as sensitive and acne-prone skin. It is used to develop a variety of skin care products such as essences, creams and masks, taking into account anti-inflammatory, repair and photoaging resistance effects, meeting consumers' demand for mild functional skin care products and expanding the consumer-grade application boundary of Silybum marianum extract.

3. Key Technical Indicators

The application effect and safety of Milk Thistle Extractdirectly depend on core technical indicators such as purity and active ingredient content. The indicator requirements vary significantly in different fields, and the specific standards are shown in the table below:

Application Field	Core Indicator	Standard Requirements	Key Significance
Pharmaceutical (Clinical)	Silybin content	≥80% (HPLC)	Ensure the stability of clinical efficacy and reduce adverse reactions caused by impurities
Feed Grade	Total silymarin content	30%-50% (UV)	Balance breeding cost and hepatoprotective effect, adapt to large-scale addition needs
Functional Food Grade	Silybin content	50%-80% (HPLC)	Guarantee the liver protection efficacy of products and meet the quality control requirements for health food registration
Cosmetic Grade	Silymarin purity	≥90% (HPLC)	Reduce skin irritation and ensure formula stability and mildness
General Indicator	Heavy Metals (Pb/As/Cd/Hg)	Pb≤2mg/kg, As≤2mg/kg, Cd≤0.5mg/kg, Hg≤0.1mg/kg	Comply with national food and cosmetic safety standards to ensure use safety
General Indicator	Microbial Limit	Total bacterial count ≤1000CFU/g, mold ≤100CFU/g, no pathogenic bacteria	Adapt to different scenarios such as oral and external use, avoid microbial contamination risks

4. Application Boundaries and Precautions

4.1 Clinical Application Boundaries

- Milk Thistle Extractis only used as an adjuvant therapeutic drug and cannot replace core therapeutic drugs

such as antiviral drugs (for hepatitis B/C), lipid-lowering drugs (for MASLD) and chemotherapeutic drugs. It must be used in combination under the guidance of doctors in clinical practice.

- Populations with severe liver injury (liver failure, decompensated liver cirrhosis), pregnant/lactating women, children and people with allergic constitution must use it in strict accordance with medical advice and avoid self-medication.
- When used in combination with anticoagulants such as warfarin, coagulation function should be monitored regularly, because silymarin may enhance the anticoagulant effect and increase the risk of bleeding.

4.2 Breeding Application Boundaries

- The addition dose must be strictly controlled. Excessive addition (e.g., more than 3‰ in dairy cow feed) may lead to a decrease in feed intake of livestock and poultry, which in turn affects production performance.
- Avoid mixing with moldy feed and toxic additives. High-quality feed and standardized breeding management must be matched to maximize the hepatoprotective and growth-promoting effects.
- Feed-grade Milk Thistle Extracthas no residue risk in livestock and poultry products (meat, milk, eggs), complying with food safety standards, and the products can be put on the market with confidence.

4.3 Consumer-Grade Application Boundaries

- Functional foods cannot replace drugs. People with significantly abnormal liver function indicators or diagnosed liver diseases must first seek medical diagnosis and then use them as an adjuvant conditioning method, without over-reliance.
- In cosmetics, the addition amount of silymarin should be controlled at 0.1%-1%. High concentration is prone to cause skin allergy, and a patch test behind the ear is required before use for sensitive skin.

5. Conclusion and Prospect

As a natural, safe and efficient active substance, Milk Thistle Extractwith hepatoprotection as its core efficacy has built a whole industry chain application pattern of "medical health - animal breeding - functional food - cosmetics". Mature application cases and quality control standards have been formed in all fields, and its core value is reflected in hepatocellular protection, injury repair and metabolic regulation, with both clinical, industrial and market value. In the future, the application of Milk Thistle Extractwill present four major trends: first, **precision**: develop high-purity silybin targeted preparations for different types of liver injury to improve targeted therapeutic effects; second, **compounding**: compound with other active ingredients such as curcumin, resveratrol and probiotics to achieve synergistic effects such as "hepatoprotection + anti-inflammation + intestinal regulation"; third, **large-scale production**: optimize extraction processes such as supercritical CO_2 extraction and membrane separation to reduce extraction costs and promote the popularization of feed-grade and functional food-grade products; fourth, **expansion**: further explore its application potential in fields such as neuroprotection (Alzheimer's disease), metabolic diseases (diabetes) and dermatosis (psoriasis) to broaden the application boundary.

In summary, relying on its clear mechanism of action, rich application scenarios and strict quality control system, Milk Thistle Extracthas become a benchmark product in the field of natural active substances. With the deepening of R&D and upgrading of processes in the future, it will release more value in more fields and has broad market prospects.