Curriculum Design for Natural Product Extraction of Millettia Speciosa (Hainan Niudali) Based on Project-Based Learning

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Abstract: *This curriculum focuses on the natural product extraction of specialty medicinal plants of Hainan, Millettia Speciosa in the light of the project-based teaching philosophy, and has established a curriculum system integrating "theory - practice - industry", with the core project of "Efficient Extraction of Active Ingredients from Millettia Speciosa (Hainan Niudali) and Its Industrialization" as the core. The system is designed into four gradually progressing stages: resource survey, traditional craft practice, modern technological innovation, and industrialization scheme design, integrating medicine wisdom of the Li nationality with modern separation techniques. By setting three goals of knowledge, skills and quality, a "double-position" teaching team is built. And by making use of the resources of both on-campus and off-campus training bases, a method combining process evaluation and summative evaluation is adopted to focus on enhancing students' ability in experimental operation, problem-solving ability and adaptability to the industry.*

Keywords: *Project-Based Learning; Curriculum Design for Natural Product Extraction of Millettia Speciosa (Hainan Niudali); Integration of Industry and Education*

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1.Introduction

Millettia Speciosa (Hainan Niudali) is a perennial woody climber belonging to Millettia of Leguminosae. It is widely and frequently used to tonify deficiency, moisten the lungs, relieve rigidity of muscles and activate collaterals due to it contains various bioactive components, such as flavonoids, saponins, and polysaccharides. In the field of tropical medicine and health industry, it occupies a decisive position. In recent years, due to the increasing demand in the natural medicine market, its development potential has gradually been value. This curriculum is guided by educational ideal to lead students to fully grasp the key technologies of solvent extraction and ultrasonic-assisted extraction, explore extraction efficiency, optimum use of resources, and the dialectical connection between traditional experience and modern technology, striving to achieve the teaching objective of "Application-Oriented Learning, Innovation-Driven Development" through on-site investigation, technological innovation, industrial planning and other links. From the perspective of industrial value, this curriculum combines tightly the real demands of the planting and processing enterprises of Millettia Speciosa (Hainan Niudali) to promote the transformation of scientific research achievements into actual productive forces, and help the industries with local characteristics to achieve sustainable development and enhance economic benefit.

2.Curriculum Objective System

2.1 *Knowledge and Ability*

This curriculum aims to cultivate students' systematic thinking ability, deeply explore the biological characteristics of Millettia Speciosa and its classification theory of natural products, and comprehensively analyze the chemical structure and pharmacological effects of flavonoids and saponins bioactive compounds. And the teaching content involves core technical principles and operational details of solvent extraction, ultrasonic-assisted extraction, and microwave-assisted extraction, and compares the effectiveness and speed of various means. Students must grasp the quality control elements, purity assessment, determination of effective constituent ratios and other links involved in the extraction process of natural products. Moreover, in light of the resources of Millettia Speciosa in Hainan and the policies for sustainable development, they should think about how to strike a balance between extraction techniques and ecological protection. Emphasis should be placed on cultivating students' innovation ideas

and autonomous planning ability, encouraging them to properly select routings based on the characteristics of the target compounds, and accurately determine key indicators, such as material ratios, temperature data, and reaction time. Students should learn to operate rotary evaporators, ultrasonic extractors and other experimental tools to do well pre-processing of samples, except for purification and refining, by themselves, use high-grade equipment such as ultraviolet-visible spectrometers to analyze the composition of the extract, and find out the improvements according to these data analyses, solve technical problems (such as elimination of emulsification, removal of impurities) by means of group collaboration, thereby training their practical skills. The ultimate goal is to transform the research achievements into executable industrial strategies, and provide technical support with economic value or tailor-made solutions for enterprises [1].

2.2 *Quality*

This curriculum aims to cultivate students' green extraction concept, reinforce their ecological responsibility through experimental practices in solvent recovery and waste valorization, cultivate their spirit of scientific research to evaluate technological innovation achievements through comparative experiments, and gradually form strict scientific research thinking, and lead students to strengthen regional industrial identity. During the project implementation, students are expected to deeply understand the significant importance of Millettia Speciosa industry for the rural vitalization in Hainan, thereby inspiring their sense of responsibility in serving local development, and optimize their cultural inheritance literacy to absorb the medicine wisdom of the Li nationality, and promote the integration of traditional culture and modern technology, and innovative development.

3.Curriculum Content Design

3.1 *Project Theme and Task Decomposition*

This curriculum takes "Efficient Extraction of Active Ingredients from Millettia Speciosa (Hainan Niudali) and Its Industrialization" as its theme, designs a gradually progressing teaching framework from "cognitive basis - technology practice - optimization and improvement - application and expansion", and breaks down the main tasks into four interrelated parts. In the first stage, students need to conduct on-site investigations at the cultivated lands of Millettia Speciosa to record all the habitat characteristics, cultivation and management methods and resource protection measures. They also need to submit a complete investigation report. In addition, they should carefully read relevant domestic and foreign literature and make a PPT literature review containing important research results. In the second stage, the main task shifts to the practical operation of traditional extraction techniques. Students are guided to extract total flavone from Millettia Speciosa using the ethanol solvent extraction, improve extraction parameters such as ethanol concentration and temperature through single-factor experiments, then compare the differences of water extraction and alcohol extraction in the content of target components like polysaccharides and saponins, and finally, clearly present the research conclusions in the form of charts. The subsequent research will focus on the renewal and development of modern extraction techniques to plan the experimental schemes for ultrasonic-assisted extraction. By adjusting key parameters, such as ultrasonic power and extraction time, and conducting a comparative analysis with traditional extraction methods, the efficiency will be evaluated. Additionally, microwave-ultrasonic co-extraction technique can be incorporated to carefully explore its potential in protecting heat-sensitive components. On this basis, industrialized technological design is completed and implemented to test the purity and biological activity of the products under various working conditions, and then find out the best solution suitable for small and medium-sized enterprises to promote combining with cost-benefit analysis. Finally, industrialization feasibility reports including equipment selection, environmental protection measures, quality control system and other content are written to provide support for corporate performance outcomes and their promotion and application [2].

3.2 *Theoretical Module Support*

To ensure the smooth completion of projects, the curriculum has set up three theoretical frameworks, integrated

in the blended teaching method of “micro-lesson preview + classroom discussion”, and also incorporated practical activities. When explaining the basic knowledge of biology and chemistry of Millettia Speciosa, it will elaborate plant taxonomy, growth periods, and the structural properties of active ingredients in detail, and combine with traditional identification methods of medicinal herb growers of the Li nationality to help students develop their cognitive competence to connect the appearance of plants and substance accumulation. When elaborating on the technical principles of extraction and the operation of equipment, animations are used to depict important parts, such as solvent diffusion and ultrasonic cavitation. Special attention is paid to the practical usage of rotary evaporators and vacuum filtration devices, and safety protection issues are especially reminded. When explaining the laws on the protection of medicinal plant resources in Hainan Island, the rationality of solvent recovery, waste utilization and other aspects during the extraction process is broken down in detail. And a tool called “Green Extraction Index” is introduced to improve the technological process of production.

3.3 *Training Resource Allocation*

This curriculum relies on the resources of local enterprises in Hainan province and selects the roots and stems of Millettia Speciosa at different growth stages as experimental materials to ensure the authenticity and richness of the materials. The laboratories are equipped with basic chemical experimental apparatus (such as beakers, separating funnels, etc.), advanced extraction equipment (such as ultrasonic extractors, microwave reactors, etc.) and precise analysis apparatus (such as ultraviolet spectrophotometers, (high performance liquid chromatographs, etc.). An online teaching platform is established to upload operational videos of extraction techniques, casebooks of industrial application, virtual simulation experiment modules to allow students to learn and practice independently. A training base is jointly built with three Millettia Speciosa planting and processing enterprises. Students are organized to visit the industrial extraction process, and participate in small-scale production practice activities there.

4.Teaching Implementation Process

Teaching implementation consists of three steps: teaching preparation, teaching implementation and teaching reflection. The design framework of this project consists of three stages: implementation, presentation, and summary, with a total of 22 class hours. In the preparation stage (2 class hours), teachers need to publish the project assignment papers to determine the goals and evaluation criteria for each stage, and lead students to form teams of 5 to 6 people, and divide them into different function modules, such as technical breakthroughs, data analysis, and report writing, and conduct pre-instructional diagnostic assessment through online platforms. Based on the assessment results, teachers provide personalized preview materials. senior industry experts should be invited to give special lectures to elaborately analyze the bottleneck problems encountered in the process of industrialization of Millettia Speciosa extraction techniques, such as low extraction efficiency and difficulty in cost control and stimulate students’ enthusiasm for practice and consciousness of innovation.

This project will be done in all 16 class hours, with four tasks advancing in chronological order. The first stage lasts for three hours: Firstly, students are arranged to conduct an on-site investigation at the cultivated lands of Millettia Speciosa to meticulously record the main environmental index, such as the PH value of the soil and the Illumination time, and then have a heart-to-heart talk with the farmers to know about their feelings and the impact of the timing of harvest on the product quality. In the following two class hours, students will carry out component screening work in the laboratories to determine whether flavonoids and saponins exist by means of color reactions, and also draft investigation reports by referring to some literature. The second stage also lasts for four hours. In the fourth and the fifth class hours, the instructor will explain the key points of solvent extraction technique clearly. Students will be divided into groups to carry out water extraction or alcohol extraction, and they also need to pay attention to controlling the temperature, time, the amount of water after each filtration and other detail problems about extraction conditions. In the sixth and seventh class hours, teachers will explain how to deal with the extracted products. Students need to use centrifuges and filtration devices to separate the extracted products from the liquid,

measure the total content of flavone using ultraviolet spectrophotometers, and draw the standard curves to evaluate the effectiveness of extraction. The third task consists of five class hours of teaching content. Starting from the eighth class, teachers mainly explain the operation specifications of ultrasonic extraction equipment, and use the three-level four-factor orthogonal experimental design to explore the optimal combination of ultrasonic power (100-300W), extraction time (20-60min) and other factors. From the tenth to the twelfth class hours, teachers will focus on the extraction technique combining microwave and ultrasonic wave, and conduct research and discussion on the performance outcomes of the synergistic benefits based on the comparison of antioxidant activity of preparations （such as DPPH free radical clearance） under different process conditions. The fourth task is divided into four parts. In the thirteenth and fourteenth class hours, students respectively calculate and analyze the cost and economic benefits generated by various extraction processes in combination of purity detection value. In the fifteenth and sixteenth class hours, the groups summarize and organize all the experimental data, write reports on industrial implementation plans, and then make PowerPoints. At this point, the teachers can provide specific suggestions and guidance on the layout and logicality of their train of thoughts [3].

The demonstration and reflection sessions are scheduled for four class hours. In the session of result demonstration, each group selects a representative to give a report for about ten minutes, covering technical routes, key data, industrialization plans, and innovation points, etc., and has to deal with the questions and evaluations from the panel of judges composed of enterprise representatives and instructors. After that, it's time for the peer evaluation and reflection session. Students are required to fill out the peer evaluation questionnaires, conduct self-evaluation from collaboration efficiency, task allocation and other aspects. They also need to write personal reflection reports to summarize their own gains and analyze the shortcomings in collaboration. Outstanding schemes will be recommended to the cooperating enterprises for pilot scale tests, promoting the practical application of classroom research results.

5.Teaching Evaluation System

5.1 *Process Evaluation (60%)*

Process evaluation exists throughout the entire period of curriculum teaching, prioritize the examination of students' dynamic performance during the project implementation. The normalization of experimental operations accounts for 20%. Laboratory monitoring system in combination with on-site guidance is used to record the usage of equipment, reagent preparation scenarios, and waste disposal steps, and emphasize on evaluating students' safety awareness and technical skills, whether the parameter settings of the ultrasonic extraction equipment are accurate, and whether the leak prevention measures have been implemented when the organic solvents are transferred, etc. Both data authenticity and analytical ability account for 20%. Teachers will conduct rigorous examination on the original experimental data and the reasoning process to ensure the reliability and integrality of the data, and prevent data tampering, and assess students' understanding of the experimental results, for example, whether they can explain the mechanism of action of process parameters by extraction efficiency curves, and whether they can draw scientific and reasonable conclusions from comparative analysis? The proportion of team collaboration efficiency is 10%. Through group task allocation tables, meeting summary, communication records and other materials, teachers comprehensively evaluate the participation and contribution portion of students in the links of program planning, experimental operations, and problem-solving to prevent the occurrence of "free-riding" situations. The proportion of phased report quality is also 10%, which focuses on checking the depth of research, the scientific nature of experimental design, and the rationality of conclusions. It is also necessary to check whether the literature citations are standardized and whether the research perspective is innovative, for example, whether the resource research report reflects the unique value of the growth characteristics of Millettia Speciosa (Hainan Niudali) and whether the technical summary includes concrete proposals for technical improvement.

5.2 *Summative Evaluation (40%)*

The summative evaluation mainly focuses on the effectiveness and comprehensive benefits generated after a project's implementation. In the industrialization proposals, technical feasibility accounts for 25%, which is divided into several parts: rationality of benefit-sharing plan (5%), cost budget (5%), environmental protection measures (5%), and market trend analysis (5%). The technical feasibility evaluation should carefully examine whether the plan meets the actual production needs of small and medium-sized enterprises. The selection of equipment should take into account the convenience of operation and the rationality of operation and maintenance cost. When calculating the expenses, it is essential to accurately calculate the solvent consumption, energy utilization rate and labor cost, and provide suggestions for improvement. Environmental protection measures should take into account the technical feasibility and originality of solvent recovery and utilization as well as waste disposal. Market trend analysis should be based on the examination of the changes in market demand for Millettia Speciosa products to judge the application prospects of this raw material in health care products, especially the potential for the development and utilization of high-purity extracts. When writing reports, attention should be paid to the logical coherence and the correctness of professional terms. Report defense accounts for 15% of the total evaluation score, which mainly examines presentation skills, for example, whether the reasoning process is rigorous in technology industrialization, whether the core ideas can be accurately conveyed, and whether to answer questions in a timely manner (such as how to solve the problem of "challenge of technological scale-up"). It is recommended to use data-visualization tools, such as heat maps and bar graphs to enhance the persuasiveness of arguments and optimize the holistic exhibition effect [4].

6.Conclusion

This curriculum design takes project-based learning as the framework and builds a task-driven teaching system around the three major links of "resource survey - technology development - industrial transformation", striving to form a complete chain from basic research to practical application for the natural product extraction of Millettia Speciosa (Hainan Niudali). It has been proven through practice that this model can promote the formation of a virtuous cycle of "student growth - enterprise innovation - teaching improvement". Students grow into high-quality applied talents to serve local economic development, and enterprises improve manufacturing techniques and enhance resource utilization rate based on teaching achievements. The curriculum scheme provides reference for higher education in the field of tropical medicinal plants. Next, virtual simulation laboratories will be built emphatically, and it is also necessary to strengthen cooperation and exchanges with the Li nationality, and accelerate the transformation of scientific research achievements to achieve the goal of synergetic development of education, economy and culture.

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