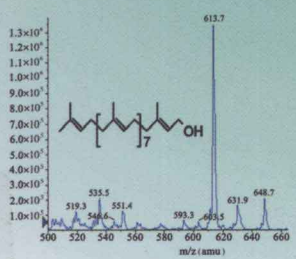
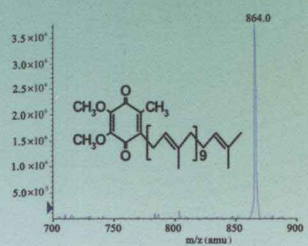
Series of Academic Creative Research Groups in the New Century

Solanesol and Coenzyme Q_{10} in *Nicotiana tabacum*

(烟草中的茄尼醇和辅酶Q_{10})

Series Editor: ZU Yuan-Gang
Authors: ZU Yuan-Gang ZHAO Chun-Jian
LI Chun-Ying YANG Lei
FU Yu-Jie





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Solanesol and Coenzyme Q_{10} in *Nicotiana tabacum*

The book was divided into two parts and total eleven chapters were included. In the first part, the distribution of solanesol in *Nicotiana tabacum* was discussed and on the basis above, the extraction and separation technologies of solanesol were described by using our patented technologies including homogenate, negative pressure cavitation suspension extraction, two-phase saponification, medium-pressure column chromatography and other extraction technologies. In the second part, seasonal and low temperature effects on CoQ_{10} accumulation were described. In addition, the separation and purification technologies of CoQ_{10} by homogenate, saponification, column chromatography and recrystallization were discussed. This book provides a reference for the separation and purification of other plant extracts and promotes the development of the plant extract industry in China.

This book provides a reference for scientific researchers, teachers and students who work on botany, phytochemistry or plant physiology.

烟草中的茄尼醇和辅酶 Q_{10}

全书共两部分十一章：第一部分首先对茄尼醇在烟草中的时空分布差异进行了探讨，在此基础上对利用匀浆提取、负压空化混旋萃取、双相皂化萃取、中压柱层析等一系列具有自主知识产权的技术从烟草中分离茄尼醇的工艺过程进行了阐述；第二部分对烟草中辅酶 Q_{10} 含量的季节变化及低温胁迫对其含量的影响规律进行了阐述，在此基础上对利用匀浆提取、皂化、柱层析、重结晶纯化辅酶 Q_{10} 的工艺进行了初步探讨。本书对其他植物提取物的分离纯化具有借鉴作用，对我国植物提取物产业的发展具有启示意义。

本书可供植物学、植物化学、植物生理学等领域的科研、教学人员及学生参考。

Foreword to the Series

Since the Big Bang, by a mode of the random collision of particles of quarks and others at meson-cosmic level, with direction from meson-, nano-, micro-, middle-, macro- to astro-cosmic level, and with the headspring for natural evolution of the heterogeneity of movement, celestial and natural bodies including sizeable solar system, earth, life system even our human-being with high intelligent brains are evolved and developed in the cosmos.

However, the eyesight for human perceiving the nature solely limited at the macro-cosmic level. From the meson- to astro-cosmic level, people can but cognize the complexity of nature from partial, qualitative to numerable and quantitative concept step by step with help of variable tools, which undergoes a long-term course of thousands of years, and this process therefore drives the development of science and technology from qualitative study to quantitative study and intelligence study, from mono-disciplinary study to interdisciplinary study and also regularizes our scientific research from individual study to the study with a scholar group. Since the 1990s, quick share of global scientific and technological resources and the conformity of interdisciplinary scientific studies instead of individual ones have further strengthened the ability to entirely and completely cognize the essence of nature. Accordingly, the important breakthrough in clarifying the essence of nature has been gestating in the process of innovation studies from academic groups in the promising 21st century.

I began to touch life science in 1972 and devoted my scientific career to this field since 1978. During more than 30 years of academic studies, I gradually realized the limitation of study in a single discipline and by an individual scientist, so, I opened my mind and set up an interdisciplinary academic group by way of organized in the key laboratory since 1990. With the advantage of grouped intelligence from scientists, we try to link the studies at macro-cosmic and micro-cosmic levels and try to understand the underlying mechanisms for the interaction between life system and environmental system. Through the efforts over decades, we have achieved some original and initiative results. Here, I would like to publish it in the form of "Series of Academic Creative Research Groups in the New Century". I wish this will be beneficial for the academic integration and development of freely exploring scientific studies.

ZU Yuan-Gang
January 2004
Harbin

丛书序言

自从宇宙大爆炸以来，自然天体即在介观的水平上，以夸克等粒子的随机碰撞为基本的能量运动形式，由介观向纳观、微观、中观、宏观、宇观方向，以运动的异质性为自然演化的源泉，以无限性的宇量规模演化成太阳系、地球、生命系统，直至形成具有高度发达大脑的人类。

然而，人类直观认知自然界的视野仅限于宏观水平，对于从介观到宇观无限性宇量规模的认知，人类也只能借助于各类观测工具由局部、定性、可数计量开始逐渐加深对自然界复杂性的认知，其间经历了数万年的发展历程，因而也推动着科学技术由定性研究到定量研究再到智能研究，由单一学科到学科交叉，向学科融合的方向发展，这规范着科学研究的行为由个体化向群体化方向发展。进入20世纪90年代，人类开始迅捷共享全球科技资源，科学研究的群体化整合进一步增强了科学家在整体观上全面认知自然界本质的凝聚力，这意味着人类在21世纪通过学术团队创新来实现对自然界整体本质认知的重大突破。

我于1972年开始接触生命科学研究，1978年开始从事生命科学研究，在30多年的学术生涯中，逐渐认识到单一学科和个体化研究的局限性。为此，我于1990年开始，下决心以重点实验室的形式组建学术团队，发挥集体智慧的优势，试图将宏观研究与微观研究结合，全面揭示生命系统与环境系统相互作用的内在机理。经过十几年的努力，积累了一些原始创新性的研究成果，现以《新世纪学术创新团队著作丛书》的形式陆续刊行，以利于自由探索式学术交流和集成发展。

祖元刚

2004年1月于哈尔滨

Foreword

The growth quantity of tobacco (*Nicotiana tabacum*) throughout China is vast and about 2 000 000 tons of tobacco leaves are harvested every year. During the course of harvesting, some tobacco leaves must be discarded due to plantation technologies and weather conditions. During the course of manufacture, the residues which can't be used in tobacco products are also discarded. The above tobacco residues are burned, which results in waste of resources and air pollution. It is better to extract and purify the active ingredients from the tobacco residues so that the active ingredients may be used in botanical drug, cosmetic and functional food industries. Solanesol is necessary medical intermediate to synthesize coenzyme Q_{10}(CoQ_{10}) and tobacco is considered to contain the highest amounts of solanesol. In the 1970s, the technology of extraction and purification of solanesol was developed in Japan. However, the material resources were limited in Japan. So Japanese researchers had to purchase the crude extracts of solanesol from other countries. At present, there are abundant tobacco resources in China, but the technologies for production of solanesol are out-of-date. Herein, we have been developing a series of patented technologies for the separation and purification of solanesol since 2002. I tutored my student, Zhao Chunjian, to conduct an in-depth study of the above subject and the results were summarized in his doctoral dissertation. In the course of extraction of solanesol, Professor Yang Lei and Professor Fu Yujie had given valuable advice and help.

CoQ_{10} is natural antioxidant and has prominent medical effects in cardiovascular disease, cancer, atherosclerosis and so on. CoQ_{10} is found in many plants, but it does not easily be used in separation technology due to the low content. At present, CoQ_{10} is mainly obtained by the chemosynthesis and microorganism zymotechnics. In 2003, while we were studying the extraction technology of solanesol in tobacco, CoQ_{10} was occasionally found in tobacco. The content of CoQ_{10} varies in different growth periods of tobacco and it can be accumulated by maintaining low temperature stress. Based on the study of the change of CoQ_{10} content, the separation technology of CoQ_{10} was discussed in 2004. I tutored my student, Li Chunying, to study the above subject in-depth and the results were summarized in her doctoral dissertation.

After Zhao Chunjian and Li Chunying's doctorial defense, we made a critical revision on the structure and also content extensions for each chapter. I recommend that this book be included in the Series of Academic Creative Research Groups in the New Century. Surely, there is always room for improvement, we welcome suggestions, advices and comments from the readers.

ZU Yuan-Gang
April 2007
Harbin

序　言

中国是全球最大的烟草生产国，每年收获烟叶 200 万吨左右。在烟草采收过程中，一些因为受种植技术、气候等因素的影响而达不到采收标准的烟叶被留在烟株上或被丢弃；在烟叶加工过程中，会产生部分不能用于生产烟草制品的碎片。这些烟草剩余物露天堆放或焚烧处理，均会造成巨大的资源浪费和环境污染。对烟草剩余物中的目的有效成分进行提取、精制，应用于植物药、化妆品和功能食品等行业，将是一个一举两得的解决办法。茄尼醇在烟叶中含量较高，是合成辅酶 Q_{10} 的必需中间体。日本于 20 世纪 70 年代就研制出茄尼醇粗提和精制的生产技术并获得专利，没有原料来源，主要从国外收购茄尼醇的粗提物，进行精制，垄断了茄尼醇的国际主流市场。目前我国茄尼醇生产的现状是，虽有资源优势，但生产技术落后。鉴于此，从 2002 年开始，我们的科研团队研制和开发了一系列具有自主知识产权的技术，并将它们应用于茄尼醇分离工艺中，最终对其放大，应用于生产。赵春建同学在我的指导下，与团队的其他成员一道协同攻关，并将研究结果总结，形成他的博士论文。在赵春建论文完成过程中，杨磊和付玉杰教授做了大量工作，在茄尼醇提取工艺熟化关键技术方面发挥了重要作用。

辅酶 Q_{10} 是细胞产生的天然抗氧化剂，在防治心血管系统疾病方面具有明显的作用。辅酶 Q_{10} 存在于多种植物中，但含量均较低，不能为分离工艺所利用，因此目前工业上辅酶 Q_{10} 主要通过化学合成和微生物发酵获得。2003 年，我们在对烟草中的茄尼醇进行研究的同时，偶然发现烟草也含有辅酶 Q_{10}，并且在烟草生长的不同阶段辅酶 Q_{10} 的含量差异显著，适度的低温胁迫有助于辅酶 Q_{10} 的累积，这为获得辅酶 Q_{10} 含量高的烟草并从中直接提取辅酶 Q_{10} 提供了可能。鉴于此，从 2004 年开始，我们在充分探索烟草中辅酶 Q_{10} 含量变化规律的基础上，对辅酶 Q_{10} 的分离工艺进行了研究。李春英同学在我的指导下开展上述工作，并将研究结果总结，形成她的博士论文。

在赵春建和李春英同学的学位论文通过答辩后，我们对两篇论文的内容进行了整合、完善，进一步整理出本书。现将本书收录于我主编的《新世纪学术创新团队著作丛书》，不足之处，殷盼指正。

祖元刚

2007 年 4 月于哈尔滨

Preface

In China, plant extracts industry is growing and has great market potential. Our supervisor, Professor Zu Yuangang is an expert in this field and has engaged in the research and development of plant extracts since 1990. Under his supervision, a series of patented technologies and manufacture equipments for separation and high efficient utilization of objective active ingredients were developed and used in the production of plant extracts. This book is based on the above long-term work by the entire team, with Professor Zu Yuangang choosing the subject of separation and purification of solanesol and coenzyme Q_{10} (CoQ_{10}) from tobacco and instructing the team members to conduct in-depth study on the subject. Consequently, the research results are summarized in this book.

Solanesol, a 45-carbon, all-*trans*-nonaprenol, is naturally distributed in *Nicotiana tabacum*. Solanesol itself can be used as antiulcer and hypertension treating agent. In addition, solanesol is a necessary medical intermediate in the industrial synthesis of CoQ_{10}. Although there are abundant tobacco resources in China, the product of solanesol can not enter into the top international market due to outdated production technologies. In the first part of this book, distribution of solanesol in *Nicotiana tabacum* was discussed and on the basis of this, the extraction and separation technologies of solanesol were described using our patented technologies including of homogenate, negative pressure cavitation suspension solid-liquid extraction, two-phase saponification, negative pressure cavitation suspension liquid-liquid extraction and continuous medium-pressure column chromatography.

CoQ_{10} has prominent medical effects on many diseases due to its special physiological function. In China, the consumption of CoQ_{10} is increasing. However, since the production of CoQ_{10} is very low, the demand is satisfied by importing. Therefore, an ideal method for producing CoQ_{10} must urgently be developed. In the second part of this book, the seasonal and low temperature effects on CoQ_{10} accumulation were described. In addition, the separation and purification of CoQ_{10} by homogenate, saponification, column chromatography and recrystallization were also discussed.

This book has been carefully revised with the help of our supervisor, Professor Zu Yuangang and it is the culmination of a five-year study. The book will become a reference for the highly efficient use of plant extract and it will play an important role in promoting the development of the plant extracts industry.

We sincerely welcome your suggestions, advices and comments, which will help us to make improvements in the future.

ZHAO Chun-Jian LI Chun-Ying YANG Lei FU Yu-Jie

April 2007

Harbin

前　言

我国的植物提取物产业是一个方兴未艾的高科技产业，有良好的发展前景和空间。我们尊敬的导师祖元刚教授长期以来一直关注植物提取物产业的发展，自1990年开始从事以目的活性物质高效利用为主要内容的植物提取物研究与开发，研制出一整套具有自主知识产权的植物目的活性成分分离纯化及生产装备的理论和技术体系，并应用这些理论和技术对多种植物活性物质的高效利用做了深入研究。作为上述长期研究工作的一部分，由祖元刚教授设计、我们参与完成的烟草中茄尼醇和辅酶 Q_{10} 高效利用研究项目的成果汇总而成本书的主要内容。

茄尼醇是烟草中天然存在的四倍半萜烯醇，本身具有抗溃疡和降血压等作用，同时是合成辅酶 Q_{10} 的关键中间体。我国虽有大量烟草资源，但茄尼醇的生产技术落后，产品不能进入国际高端市场。鉴于此，本书第一部分深入探讨了茄尼醇在烟草中时空分布的差异，对以烟叶采收和加工后的剩余物为生产原料，采用匀浆萃取、负压空化混旋固液萃取、双相皂化萃取、负压空化混旋液液萃取、连续中压柱层析纯化等一系列自主创新技术高效生产茄尼醇的工艺优化过程进行了阐述。

辅酶 Q_{10} 具有特殊的生理功能，对多种疾病具有显著的疗效，我国对辅酶 Q_{10} 的需求量大，目前主要依赖进口以满足需要。因此，亟待开发一种理想的辅酶 Q_{10} 生产方法。本书第二部分对烟草中辅酶 Q_{10} 含量的季节变化及低温胁迫对其含量的影响规律进行了阐述，在此基础上对利用匀浆提取、皂化、柱层析、重结晶纯化辅酶 Q_{10} 的工艺进行了初步探讨。

本书在我们的导师祖元刚教授的精心指导下认真修改而成，是对祖元刚教授和我们历经5年获得的相关研究结果的总结和升华。本书对其他植物提取物的高效利用具有借鉴作用，对我国植物提取物产业的发展具有启示意义。由于作者水平有限，疏漏之处在所难免，恳请各位读者不吝赐教斧正！

赵春建　李春英　杨　磊　付玉杰

2007年4月于哈尔滨

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