

# 我国热带地区胶2茶2鸡农林禽复合系统钾循环研究

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**摘 要:** 以胶2茶2鸡农林禽复合系统模式为研究对象, 以单作胶园、胶茶间作园为对照, 采用定量研究与定性分析相结合的方法, 研究其钾循环规律。结果表明, 胶2茶2鸡农林禽复合系统钾循环率为 59%, 钾输出量为  $134.5 \text{ kg} \cdot \text{hm}^{-2}$ , 土壤钾盈余量为  $168.2 \text{ kg} \cdot \text{hm}^{-2}$ , 均最高。鸡子系统钾输出/输入比为 91%, 鸡产品的钾产投比仅为 23%。该系统内钾循环量(归还量)为  $414.9 \text{ kg} \cdot \text{hm}^{-2}$ , 最大, 因此该系统钾循环活跃, 具有较合理的钾循环结构。

**关键词:** 农林禽复合系统; 生态农业模式; 钾循环; 胶2茶2鸡

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物质循环是生态系统的基本功能, 是系统结构与功能的综合反映<sup>[1]</sup>。物质循环路径和效率决定系统生产力的高低, 探明物质循环规律是管好、用好农业生态系统的基础。钾是物质的基本组成元素, 通过对钾循环的研究, 可以分析系统结构与功能的合理性, 探明系统钾循环路径及转化效率, 评价系统生态效应, 探求系统最优结构和最佳功能状态, 并为提高钾利用效率提供科学依据。目前, 国内外对土壤-植物系统中氮、碳的循环研究较多<sup>[2~4]</sup>, 但钾循环的研究仍很少, 我国热带地区农林复合系统中的钾素循环研究则更少。钾循环在热带地区农业生态系统中十分活跃, 钾元素对增强橡胶树的产胶、排胶能力、提高胶乳稳定性具有重要意义。因此, 本文以海南省文昌市为基点, 对当地有代表性的胶2茶2鸡间作混养模式进行研究, 力图探明我国热带地区典型农林复合系统的钾循环特征及调控途径。

## 1 研究内容与方法

### 1.1 模式简介

胶2茶2鸡农林禽复合模式源于海南省文昌市。该市处于热带季风区, 年日照时数  $1869 \sim 2032 \text{ h}$ , 太阳辐射能  $451 \sim 481 \text{ kJ} \cdot \text{cm}^{-2}$ , 年平均气温  $24.2^\circ\text{C}$ , 极端最低温  $5.7^\circ\text{C}$ , 年降雨量  $1875 \sim 2108 \text{ mm}$ 。胶2茶2鸡农林禽复合模式是在改变传统粗放的小规模庭院养鸡方式基础上, 利用当地橡胶林地较多的资源条件, 在半郁闭的橡胶林内间种茶树, 并实行集约经营, 大规模饲养文昌鸡而成的生态农业模式。

### 1.2 试验简介

选取单位面积的单作胶园、胶茶间作园和间作养鸡园为研究对象, 调查测定三种胶园中橡胶、土壤、鸡及整个系统的钾投入产出, 计算钾的输入输出量, 分析钾循环特征。

橡胶树品种: 无性系 PRM 600 (Hevea brasiliensis); 鸡品种: 粤黄 882; 茶品种: 云南大叶茶 (Camellia sinensis)。

### 1.3 测定项目与方法

1) 橡胶: 测定橡胶产量、干胶含量及距地面  $1.5 \text{ m}$  处平均茎粗 ( $S_{1.5}$ ), 根据经验公式折算橡胶树叶干质量 ( $W_{\text{叶}}$ )、叶面积 ( $A_{\text{叶}}$ ) 及总生物干质量 ( $W_{\text{总}}$ )<sup>[5]</sup>。经验公式分别如下:

$$\log W_{\text{总}} = 3.048 \log S_{1.5} - 3.162; \log A_{\text{叶}} = 2.7 \log S_{1.5} - 2.775; \log W_{\text{叶}} = 0.972 \log W_{\text{总}} - 1.264$$

2) 凋落物: 在橡胶林内设置凋落物收集样方  $1 \text{ m} \times 1 \text{ m}$ , 逐月收集样方内凋落物, 并于  $80^\circ\text{C}$  下烘干, 测其干质量。

3) 土壤含钾量: 采用火焰分光光度计比色法测定<sup>[6]</sup>。

4) 鸡: (1) 鸡取食量及排泄量分析。在单位面积胶体内隔离起 50 只鸡, 分别计算其投入饲料量、所食草量及总排泄量。(2) 鸡粪钾含量。测定方法同土壤分析。

5) 系统钾投入产出: 选取 8 点, 调查其肥料、畜禽等投入产出情况, 根据其钾素含量<sup>[6,7]</sup>, 研究系统钾循环规律。

6) 其它项目: 如水土流失量、胶茶生长所需养分等参考有关文献<sup>[7~10]</sup>。据计算, 每生产  $1 \text{ g}$  干胶分别约需消耗  $50 \text{ g N}$ 、 $20 \text{ g P}_2\text{O}_5$ 、 $23 \text{ g K}_2\text{O}$ , 每生产  $1 \text{ g}$  干茶分别需消耗  $40 \text{ g N}$ 、 $9 \text{ g P}_2\text{O}_5$ 、 $21 \text{ g K}_2\text{O}$ 。

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## 2 结果与分析

为进一步了解钾素在胶-茶-鸡农林禽复合系统中的输入、输出及平衡状况,先对各子系统的钾循环进行研究。

### 2.1 橡胶子系统钾素循环

橡胶是多年生高大乔木,胶树每年从土壤中吸收的钾除供自身生长存留于植物体内之外,一部分随产胶、落花、落果及枯枝落叶离开树体回归土壤,再次被橡胶树所吸收,从而构成了橡胶子系统的生物钾循环。表1比较分析单作、间作及养鸡胶园橡胶子系统的钾素循环状况。

表1 单作、间作及养鸡胶园橡胶子系统钾循环

系统	吸收	输 出				循环率 <sup>3</sup>
		产胶	落花落果	枯枝落叶	合计	
单作胶园	113.5	37.8	46.8	20.9	105.5	0.60
间作胶园	148.8	38.2	48.8	36.2	123.2	0.57
养鸡胶园	160.4	40.1	51.5	42.9	134.5	0.59

3 循环率= 归还量÷吸收量,归还量为橡胶树归还土壤的落花落果、枯枝落叶的总量,是在实验区内每10 d收集一次橡胶树凋落物,然后烘干、称重所得。

表1表明:胶园由单作向间作、农林禽复合经营方向发展,橡胶子系统对钾的吸收呈递增趋势,这是因为对茶树的耕作施肥有利于橡胶生长,且间作胶园橡胶种植密度比单作胶园略小,创造了适宜的生长环境,因此,橡胶长势良好,吸收养分较多。而养鸡胶园则因养分供应充足,可最大限度地满足橡胶的生长需要,因此,养鸡胶园的钾吸收量最大。

从钾素的输出看,无论产胶输出还是随落叶、落

花落果的钾输出,均是养鸡胶园>间作胶园>单作胶园。

橡胶子系统的钾素循环率变化不大,趋势是单作胶园>养鸡胶园>间作胶园,这说明在单作胶园中引入新的生物组分未使橡胶子系统的钾素循环更活跃。

### 2.2 土壤子系统钾素循环

土壤子系统钾素的盈亏状况直接关系到土壤肥力的高低及系统的养分平衡。土壤子系统钾素的输入、输出及平衡状况见表2。

胶园由单作向间作、农禽结合方向发展,土壤子系统的钾输入总量及有机钾输入均呈增加趋势,养鸡胶园化肥钾输入减少。这是因为养鸡胶园中有鸡的排泄物返还土壤,从而减少化肥钾投入,所以养鸡胶园更趋向于有机生态系统。

间作和养鸡胶园中因增加了茶树的钾吸收,土壤钾输出比单作胶园明显增加,尽管其水土流失量比单作胶园小,但总体上养鸡胶园的土壤钾输出最大,单作胶园的最小。单作及间作胶园在目前的钾投入水平下,均存在严重的钾亏缺现象,而养鸡胶园钾有较大盈余,应将部分鸡排泄物转移到系统外。

### 2.3 鸡子系统钾循环

胶园中鸡子系统的加入使该农林禽复合系统具有次级生产,系统钾投入产出发生改变。

由表3可见,鸡子系统输入钾中,饲料带入的比例最大。鸡取食了林中杂草,因此,杂草所含的钾素也成为鸡子系统钾循环的组成部分。鸡子系统钾输出÷输入比较高,为0.91。但鸡子系统钾素产投比仅为0.23,这表明鸡产品本身所固定的钾量不大,大部分钾以鸡排泄物形式输出而归还土壤。

表2 单作、间作及养鸡胶园土壤子系统钾循环

Table 2 K cycle of soil subsystem in single culture, intercropping and chicken gardens kg · hm <sup>-2</sup>										
系统	钾输入				钾输出					钾平衡 <sup>3</sup>
	化肥	有机肥	枯枝落叶	合计	橡胶吸收	茶树吸收	杂草吸收	水土流失	合计	
单作胶园	99.0	10.2	20.9	130.1	113.5	—	7.8	63.0	184.3	-54.2
间作胶园	99.0	11.6	36.2	146.8	148.8	61.1	6.0	21.0	236.9	-90.1
养鸡胶园	37.5	372.0	42.9	452.4	160.4	76.2	4.8	42.8	284.2	168.2

3: 钾平衡= 钾输入总量- 钾输出总量。

表3 胶-茶-鸡农林禽复合系统鸡子系统钾循环

Table 3 K cycle of chicken subsystem in rubber-tea-chicken agroforestry system kg · hm <sup>-2</sup>									
系统	输 入				输 出			输出÷输入	产投比 <sup>3</sup>
	鸡雏带入	饲料	杂草	合计	鸡排泄物	鸡产品	合计		
胶-茶-鸡系统	3.5	540	4.8	548.3	372.0	126.0	498.0	0.91	0.23

3: 产投比= 鸡产品钾÷总输入钾。

2 4 系统钾循环

单作、间作及养鸡胶园的钾输入、输出及归还量各不相同(表 4)。

由表 4 可见, 胶园由单作向间作及农林禽复合

经营方向发展, 系统钾输入、输出及归还量均呈递增趋势。在养鸡胶园中因有鸡粪钾归还土壤, 系统外输入的有机钾为 0, 且向该系统输入的钾主要来自饲料。

表 4 单作、间作及养鸡胶园钾循环

Table 4 K cycle of single culture, intercropping and chicken gardens													kg · hm <sup>-2</sup>	
系统	系统外输入					输 出				归还量			归还量ö	输出ö
	化肥	有机肥	鸡雏	饲料	合计	产胶	产茶	鸡产品	合计	落叶	鸡粪	合计	输入量	输入
单作胶园	99.0	10.2	—	—	109.2	37.8	—	—	37.8	20.9	—	20.9	0.19	0.35
间作胶园	99.0	11.6	—	—	110.6	38.2	34.9	—	73.1	36.2	—	36.2	0.33	0.66
养鸡胶园	37.5	0	3.5	540.0	581.0	40.1	43.5	126.0	209.6	42.9	372.0	414.9	0.71	0.36

单作胶园中只有初级生产, 产胶输出钾最小。养鸡胶园的钾素随胶、茶、鸡产品而输出系统外, 其钾输出量比另两个系统明显提高, 因此, 次级生产在该系统钾循环中起重要作用。

养鸡胶园中有鸡粪和枯枝落叶保留在系统内参与钾循环, 因而钾归还量比单作及间作胶园明显提高, 系统对外界钾投入的依赖性减小, 稳定性增强。养鸡胶园钾输出ö输入比较低, 这是因为系统中加入次级生产后, 钾输入量大幅上升, 而鸡粪钾又保留在系统内循环的结果。

3 小 结

1) 对于橡胶子系统, 当胶园由单作向间作及农林禽复合方向发展时, 钾输入及输出量呈递增趋势。三种胶园钾素循环率变化趋势是单作胶园> 养鸡胶园> 间作胶园。

2) 对于土壤子系统, 养鸡胶园的钾循环量最大, 单作胶园的最小。在目前的养分投入水平下, 单作及间作胶园均存在严重的钾亏缺, 养鸡胶园土壤钾有所盈余。

3) 鸡子系统的钾输入、输出量占整个农林禽复合系统的主要部分, 鸡子系统钾输出ö输入比较高, 为 0.91。但其钾素产投比仅为 0.23, 这表明鸡产品本身所固定的钾量不大。

4) 养鸡胶园的钾归还量明显高于单作及间作胶园, 对外界钾投入的依赖性降低。养鸡胶园的钾输出ö输入比最低, 但从钾绝对产出、系统稳定性及资源合理利用角度分析, 应尽量加入次级生产以提高系统的产出能力。

5) 生态农业模式建设是合理开发当地农业资源的有效途径。由钾循环分析可判断模式物质投入产出的合理性, 可节约资源, 并使物质产投结构更合理。

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temperature Effects of environmental temperature on body temperature and heart rate are very significant, effect of environmental humidity on body temperature is significant, environmental humidity makes little effect on heart rate of pig

**Key words:** ambient temperature; relative humidity; physiological parameters; growing pigs

**· Rural Energy, Agricultural Waste Treatment and  
Environmental Protection Engineering ·**

**Fuzzy Hierarchy Comprehensive Evaluation of Energy-saving Projects of Township  
Enterprises With Computer ..... (103)**

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**Abstract:** U sing the method of multi2aim fuzzy analytical hierarchy process, the indexes system and the judgement model of comprehensive evaluation of the energy2saving projects of tow nship enterprise were established The author studied the subordinate function, the numerical method to conform the subordinate degree of the judgement indexes and the method of combination operation The evaluation software system on computer was designed by using V isual Basic (6 0). Through the typical cases, the method and the system were verified in application The result indicated the established indexes system reflected the integrated effect of energy2saving project in impersonality and reality through three aspects of technology, economy and social environment The established judgement model reflected the characteristics of fuzzy, integration and multi2hierarchy in comprehensive evaluation to energy2saving project, also offered the scientific basis for evaluating the overall excellence or badness of the project and investment decision2making

**Key words:** energy2saving project; fuzzy comprehensive evaluation; tow nship enterprise

**Pyrolysis K inetics of Rice Straw ..... (107)**

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**Abstract:** The pyrolysis of biomass is one of the most prom ising renew able forms of future energy. The optimal parameters of pyrolysis and the proper equipment design require the know ledge of kinetics In this paper, Thermogravimetric Analysis (TGA ) was used to study the thermal degradation of rice straw at different heating rates (10, 15, 20, 30 ǻin) under a nitrogen atmosphere The kinetic model for first2order paralled linear reaction is provided and details are presented such as weight2loss, temperature and kinetic data obtained during the pyrolysis of rice straw.

**Key words:** biomass; rice straw pyrolysis; kinetic model; Thermogravimetric A nalysis (TGA )

**Characteristics of Bioreactor Landfill Technology and Its Future Application ..... (111)**

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**Abstract:** The disadvantages of conventional Sanitary Landfill (CL ) were analyzed, and the structural characteristics of Bioreactor Landfill (BL ) were described, and the biodegrading characteristics of BL technology was introduced by taking a BL research project conducted in California as an example The preliminary experimental results showed that the biodegradation capability of BL was strongly enhanced due to the leachate recirculation and moisture content adjustment A s compared with CL , BL could increase 75% landfill gas amount and approximately 42fold landfill volume reduction, and faster leachate stabilization Finally, the current status of refuse treatment technologies in China was analyzed, and the potential application of BL technology in China was investigated as well

**Key words:** refuse; sanitary landfill; bioreactor; landfill gas; leachate

**K Cycle of Rubber-Tea-Chicken Agro-Forestry Model in Tropical Areas of China ..... (115)**

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**Abstract:** The K cycle of rubber-tea-chicken ecological agricultural model, a typical tropical agro-forestry system in Wenchang municipality of Hainan Province was studied with quantitative experiment and qualitative analysis, compared with rubber and rubber-tea. The results showed that the K cycling rate, K output and K surplus in soil of rubber-tea-chicken agro-forestry system were all the highest, being 59%, 134.5 kgÖhm<sup>2</sup> and 168.2 kgÖhm<sup>2</sup>, respectively. The ratio of K output to K input of chicken sub-system was 91% and the ratio of K output to K input in chicken products was only 23%. Amount of cycling K inside chicken garden is the highest, being 414.9 kgÖhm<sup>2</sup>, the K cycling structure of rubber-tea-chicken agro-forestry system is more reasonable structure, and its K cycling was the most active.

**Key words:** agro-forestry system; ecological agricultural model; K cycle; rubber-tea-chicken

## · Agro-product Treatment Technology and Processing Engineering ·

### Compound Preservative Technology and Vacuum Package for Beef ..... (118)

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**Abstract:** The preservative and color protective agents used for beef preservation were studied and screened out. The compound preservative formula was studied by the experiments for combining the preservative and color protective agents. It was combined with vacuum package and the vacuum compound preservative bags were prepared for beef preservation. The bags were used in beef vacuum package for preservation. The preserved period reached 35 days with good quality indexes.

**Key words:** beef; vacuum package; compound preservation

### Interaction Mechanism of Two Strains in Production of Microbiological Protein (MBP) 4320 for Feed Use ..... (122)

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**Abstract:** This paper reports for the first time that the MBP fermentation is based on the relationship between the two selected good strains of *G. Candidum* As 2 361 and *Aspergillus niger* No. 303, which is commensalism. The floras, like the appearance of hybridization formed by As 2 361 when it is co-cultivated with No. 303 in 4320 MBP fermentation, are proved to be a specific feature of commensalism through Fusant Test, Heterocaryon Test, Substrate Mycelia Observation, Diffusion Block Test and Microscopic Examination. The quantity of floras directly reflects the extent of commensalism and the quality of MBP 4320 as well, which is of great application value. Effective factors in commensalism are citric acid, protease, glucanase, and amylase produced by No. 303, and they function directly, indirectly and cooperatively. Among the factors, amino acids, especially Glu, catalyzed by protease from No. 303 and citric acid produced by No. 303 can stimulate growth of No. 2 361 strikingly. They are the two newly-found top commensal factors in producing MBP from starch materials, which is discovered through orthogonal test and is completely different from other reports that the main factors in producing SCP with starch materials are such enzymes as glucanase.

**Key words:** microbiological protein; interaction mechanism; commensalism

### Application of Maltogenase and B-Enzyme to the Production of Maltose Syrup ..... (126)

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**Abstract:** The effect of liquefaction degree on saccharification of Maltogenase and B-enzyme and the effect of raising dosage of saccharifying enzymes on the maltose content are studied in this paper. The combination of Maltogenase, B-enzyme is also studied. Based on the above experiments, the liquefaction degree has a profound effect on saccharification; the combination of Maltogenase, B-enzyme is found to be able to increase maltose content effectively.