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Yield and Quality Impacts of Vegetables Irrigated by Rubber Plant Wastewater

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In this study, a series of pot experiments were conducted to investigate irrigation impacts on coriander biomass and quality using effluent from natural rubber processing plants treated at various stages with different levels of nutrients. The results showed that, irrigating with both the UASB anaerobic effluent and the aerobic effluent significantly increased the yield and nutrient contents of coriander. Among those, the efficiency of 50 %-diluted anaerobic effluent was better than compound fertilizer. Skim latex effluent without dilution should not be used to irrigate coriander whereas diluted skim latex effluent made the yield and nutrient contents of coriander increased significantly. The more diluted the skim latex effluent, the better growth the coriander. The 10 %-diluted skim latex effluent was similarly fertile as the 50 %-diluted aerobic effluent. Our study also suggested that: (1) untreated skim latex effluent could be used to irrigate crops and vegetables after being diluted to appropriate pH level. (2) Zero discharge of effluent from natural rubber processing plant would achievable if applying high-concentration skim latex effluent to irrigation and recycling low-concentration effluent.

Key Words: Natural rubber processing effluent, Irrigation, Coriander, Pot experiment.

INTRODUCTION

Natural rubber, with the dual nature of the industrial and agricultural products, has been widely used in industry, agriculture, national defense, transportation, medical and health and other areas of daily life. It is one of the four major industrial raw materials including steel, petroleum and coal[1]. China is the world's largest consumer and importer of natural rubber and the sixth largest producer. It has been mainly grown in Hainan and Yunnan Provinces[2]. In 2010, the national production of natural rubber is as high as 691,000 ton[3]. Hainan, where 490,000 hectares of land are dedicated to rubber plantation, has a total output of 346,000 tons, which ranks the first in China[4].

Wastewater from natural rubber processing plants (so-called rubber wastewater) is generated from a process in which natural rubber latex or collagen gel are used to produce raw rubber as well as using natural rubber latex to produce concentrated latex skim rubber. Rubber wastewater has a complicated composition, mainly containing skim serum size from acid coagulation process, ammonia which is used as preservative, acid used for clotting. Most of them belong to water soluble substances, such as nitrogen, phosphorus and protein, amino acids, organic acids, *etc.*[5]. The COD, BOD, nitrogen and phosphorus are high concentration in acid gel wastewater, which are major sources of wastewater pollutants. In addition, similar ingredients are found in wastewater produced in washing and rinsing process, but the concentrations are lower. Due to the high content of organic matter and phosphorus in rubber wastewater, its treatment is very difficult and costly. On the other hand, rubber wastewater contains N, P, K, Ca, Mg, proteins, amino acids, organic acids and other substances that benefit plants[5,6]. Furthermore, it is free of heavy metals and other toxic substances[7,8]. Thus, it is a good idea to treat rubber processing wastewater as a fertilizer resource for agriculture, which will not only favour the development of ecological and organic agriculture, but also avoid environmental pollution.

Since 1940s, using rubber processing wastewater to irrigate rubber plantation soils has been widely practiced in Malaysia. Up to date, a range of species including forage, oil palm, rubber, rice and other crops, have been irrigated by rubber processing wastewater, which becomes the mainstream method for rubber wastewater treatment in tropical countries

TABLE-1
PHYSICO-CHEMICAL CHARACTERISTICS OF USED SOILS

Experimental soil	Total nitrogen (g/kg)	Alkaline hydrolysis N (mg/kg)	Available phosphorus (mg/kg)	Available potassium (mg/kg)	Organic matter (%)	pH
Latosol	0.529	61.00	161.30	30.90	1.12	5.93

TABLE-2
QUALITY OF WASTEWATER USED IN THE EXPERIMENT

Experimental wastewater	NH_4-N (mg/L)	TN (mg/L)	TP (mg/L)	COD (mg/L)	BOD_5 (mg/L)	SS (mg/L)	pH
Aerobic effluent	50.4	363	43.5	244	63.4	6	8.04
Anaerobic effluent	647	815	49.1	435	–	500	8.46
Rubber wastewater	2660	2850	176	22300	–	2360	4.86

like Malaysia[9-11]. Unfortunately, few domestic reports focused on the applying of rubber processing wastewater in irrigation and its direct influnces on environment and plant[12,13]. Researcher were interested in the application of sewage, livestock and poultry wastewater and paper making wastewater[14-17].

In our research, coriander (New Zealand big-leaf parsley) was irrigated by rubber wastewater in order to investigate the impacts of such irrigation model on the yield and quality of coriander. This paper aims to explore the feasibility of applying rubber wastewater as a liquid fertilizer for agriculture, provide scientific support for systemizing the utilization of rubber wastewater in China.

EXPERIMENTAL

The soil samples (Granitic Latosol) used for the pot experiments were collected from the experimental base. The basic characteristics of soil samples were presented in Table-1. The soil was air-dried and screened through 2 mm sieve, Then a plastic pot of 25 cm in diameter and 15 cm in height was filled with 5.5 kg of sieved soil per pot. The coriander (New Zealand big-leaf parsley) was supplied by Hangcheng Zhongye Corporation. The rubber wastewater was collected from the rubber processing plant. The processing plant adopted UASB-Activated sludge mechanical forced aeration oxidation method. Three kinds of wastewater in different stages were collected: processing terminal effluent (aerobic effluent); UASB treated midway effluent (anaerobic effluent); and the untreated skim wastewater. Their properties were shown in Table-2. Fertilizer were an imported Norway 45 % N-P-K fertilizer (N: 15 %, P_2O_5: 15 %, K_2O: 15 %).

Experimental design: Pot experiment was carried out in green house of the experimental base. The soil irrigation treatments with fresh water and without fertilizer were conducted as blank comparison. The other treatments were listed in Table-3. 2.5 g seeds were planted in each pot. One hundred twenty young plants were kept in 10th day after seedling. Plants were irrigated every 7 days after the 1st week post-seedling. In total, each pot was irrigated for 5 times. Every time, 200 mL fresh water or rubber wastewater were applied. 0.5 g compound fertilizer was given during each irrigation in N.

Sampling and analytical methods: Every 7 days after irrigation (except in the 5th time, 12 days), 5 plants in each pot that grow well and were fairly similar in height were selected to measure the dry weight of shoot (above-ground portion). Coriander grew a month and a half before the harvest. Firstly, plants with similar height were selected to measure its fresh sample indicators such as vitamin C and chlorophyll. Dry sample indicator (total soluble sugars) was measured subsequently. Another 20 plants in good shape and similar height were selected to measure their dry weight of both above-ground and underground portions.

TABLE-3
SCHEMES OF POT EXPERIMENT

Processing name	Level1	Level 2	Level 3	Level 4
Clear water	CK	–	–	–
Compound fertilizer	N	–	–	–
Aerobic effluent	C	–	–	–
Anaerobic effluent	Y_{100}	Y_{50}	Y_{25}	Y_{10}
Rubber wastewater	S_{100}	S_{50}	S_{25}	S_{10}

Dry weight of plants was measured by drying it to a constant weight at 80 ºC before heating fresh sample at 105 ºC for 0.5 h. At last it was measured by 0.001 g precision balance[18]. Chlorophyll was measured by colorimetry with acetone-ethanol mixture. Vitamin C was measured by colorimetry with 2,6-dichlorophenol indophenol. Total soluble sugars were measured by anthrone colorimetric assay[19]. Methods for soil physical and chemical properties were: Kjeldahl distillation method for total nitrogen, alkaline hydrolysis diffusion for hydrolytic nitrogen (alkaline hydrolysis N), ammonium fluoride & hydrochloric acid leaching & Mo-Sb colorimetry method for soil available phosphorus, oil-bath heating potassium dichromate oxidation capacity method for organic matter, Potentiometric method for soil pH[18].

Data analysis: SAS9.0 statistical analysis software was applied for multiple comparisons among treatments. The DUNCAN test was carried out at a significance level of 0.05. Microsoft office excel 2010 was also helpful for editing data and charts.

RESULTS AND DISCUSSION

Impacts of aerobic effluent on the coriander biomass and quality: The results showed that the aerobic effluent (C) has significant promotion in dry matter accumulation of above-ground shoot compared to no fertilizer (CK) whereas a similar impacts was found in clear water (N). Due to coriander's slow growth in early stage, the difference among three treatements were not evident in the first three samplings. Since the fourth sampling as the coriander entered into the rapid growth phase, the differences have become evident (Fig. 1). At the harvest, the dry weight of above-ground shoot in C was 216.3 and

2.7 %, higher than those in CK and N, respectively. The dry weight of the underground shoot in C was 17.8 and 39.7 % significantly higher than those in CK and N ($P < 0.05$) (Fig. 2).

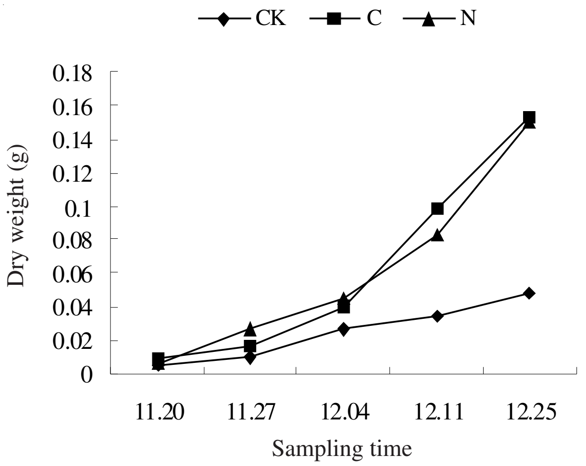

Fig. 1. Dry weight of aboveground coriander irrigated by aerobic effluent

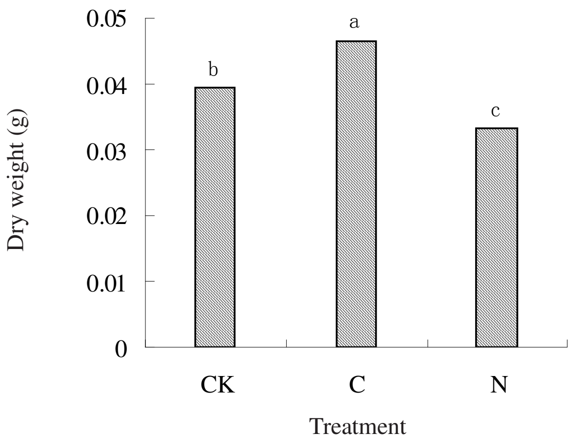

Fig. 2. Dry weight of underground coriander irrigated by aerobic effluent

Chlorophyll, vitamin C and soluble sugar content are commonly used indicators to evaluate the nutritional quality of leafy vegetables. Chlorophyll is a unique and important nutrient in green plants, impacting the production of vegetables. The amount of chlorophyll usually reflects the level of nitrogen nutrition in green plants and has an important role in breeding and stress-resistance. Thus, chlorophyll is, one of the quality indicators for leafy vegetables[20]. Vitamin C that humans can not synthesize and retain therefore need to take at daily basis is on the most important vitamins. The lack of vitamin C is the direct cause of scurvy and triggers a variety of disease. Thus, vitamin C plays a critial role in human health. Sugar-acid ratio is another important indicator to evaluate the merits of the quality of vegetables, sugar acid ratio, vegetables palatability, better quality. High content of soluble sugar will be a corresponding increase in the ratio of sugar to acid[21].

Table-4 shows that the content of chlorophyll and soluble sugar flowed as N > C > CK. C and N are more than CK significantly. The content of vitamin C flowed as C > CK > N. C and CK are more than N significantly. The chlorophyll and soluble sugar content of C are 7.1 and 63.7 % more than CK, respectively. And its vitamin C content is 11.2 % more than N.

TABLE-4
PRINCIPAL NUTRIENT CONTENTS IN CORIANDER IRRIGATED BY AEROBIC EFFLUENT

Processing	Total chlorophyll (mg/g)	Vitamin C (mg/kg)	Total soluble sugar (%)
CK	1.954±0.071b	40.98±0.21a	7.47±0.48b
N	2.135±0.013a	37.63±0.14b	14.55±1.10a
C	2.093±0.041a	41.86±1.10a	12.23±1.06a

The aerobic effluent irrigation can significantly improve the biomass of coriander, its role in promoting the aboveground biomass of coriander is the same with fertilizer and its growth promoting effect on the coriander root is even better than fertilizer. In terms of quality, aerobic effluent irrigation can significantly improve coriander total chlorophyll content and total soluble sugar content, compared with no fertilizer, it can significantly improve vitamin C content of the coriander compared with fertilizer. Aerobic effluent irrigation has certain improvement of the quality of coriander biomass, the effect is the same with fertilizer, but much better than fertilizer on the root biomass and vitamin C and other indicators.

Effect of anaerobic effluent irrigation on the coriander biomass and quality: Fig. 3 showed a comparison with CK treatment, different levels of anaerobic effluent irrigation (Y) could promote dry weight on aerial parts of coriander. Starting from the fourth sample, when the coriander entered a rapid growth phase, its impact is more apparent. When harvest, different levels of anaerobic effluent irrigation treatments have dry weights of above-ground followed as Y50 > Y100 > Y25 > Y10, which were higher than CK treatment by 284.4, 262.7, 203.3 and 173.3 %. Compared with the N treatment, Y100 and Y50 treatments have are 17.8 and 24.9 % higher than the N treatment on dry weights of above-ground, but the treatments of Y25 and Y10 are 1.5 and 11.2 % lower than N treatment on dry weights of above-ground. When harvest, different levels of anaerobic effluent water treatments have the underground dry weight followed as Y50 > Y10 > Y25 > Y100 and there are significant differences among different treatments, the Y100 treated underground dry weight is much lower than other Y treatment (Fig. 4). However, different levels of Y treatment lies between 5.9 and 58.2 %, higher than CK treatment and higher than N treatments from 25.6 and 87.5 %, respectively.

From Table-5, the different treated corianders' total chlorophyll content followed as Y50 > N > Y25 > Y10 > CK > Y100. Y100 treatment is significantly lower than that of N and Y50 treatments. Y50 is significantly higher than the CK and Y10 treatements. Different treatments of vitamin C content followed as Y50 > Y25 > Y100 > Y10 > CK > N, Y50 id significantly higher than other treatment. N treatment is lower than other treatments. Y100 and Y25 treatments are significantly higher than the Y10 and CK. Different treatments of total sugar content followed as Y50 > Y10 > Y25 > N > Y100 > CK. CK treatment is significantly lower than the other treatments. Y50 treatment is significantly higher than the N treatment. In different levels of anaerobic water treatment, the role of 50 % diluted Y50 treatment has biggest improvement on coriander quality, its total chlorophyll, vitamin C and total soluble sugar content are 16.5, 16.6 and 146.6 % higher than

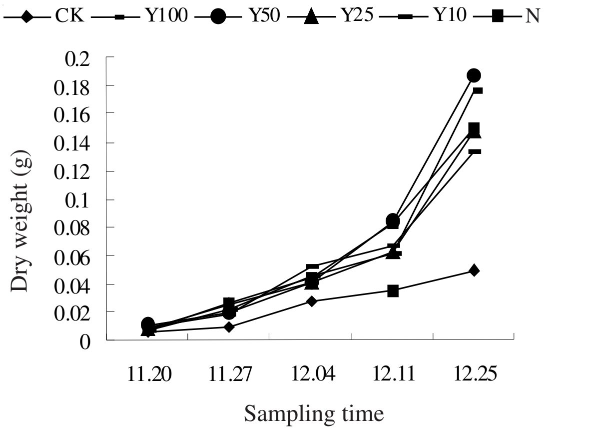

Fig. 3. Effect of anaerobic effluent on dry weight of aboveground of coriander

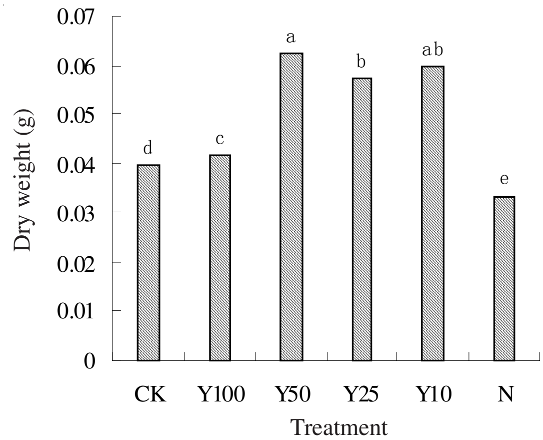

Fig. 4. Effect of anaerobic effluent on dry weight of underground of coriander

TABLE-5
PRINCIPAL NUTRIENT CONTENTS IN CORIANDER IRRIGATED BY ANAEROBIC EFFLUENT

Processing	Total chlorophyll (mg/g)	Vitamin C (mg/kg)	Total soluble sugar (%)
CK	1.954±0.071bc	40.98±0.21c	7.47±0.48 d
N	2.135±0.013ab	37.63±0.14 d	14.55±1.10 bc
Y100	1.860±0.201c	45.25±1.04 b	13.14±1.73 c
Y50	2.276±0.084a	47.78±0.40a	18.43±0.97 a
Y25	2.040±0.182abc	45.64±1.47 b	15.84±1.90 abc
Y10	2.002±0.143bc	41.62±0.96 c	16.98±1.27 ab

no fertilized CK treatment, also 27.0 and 26.7 % higher than the application of fertilized N treatment.

Compared with no fertilized, different levels of anaerobic effluent irrigation can significantly improve aboveground and underground biomass quality of coriander, in addition to the little effect of 10 % dilution of anaerobic effluent on the vitamin C content, different levels of anaerobic effluent can significantly improve the coriander vitamin C content and total soluble sugar content, the 50 % diluted anaerobic effluent can significantly improve the chlorophyll content of coriander. Compared with the application of fertilizer, different levels of anaerobic effluent irrigation can significantly improve coriander root biomass, undiluted and 50 % dilute anaerobic effluent have more significant impact in promoting coriander aboveground biomass accumulation, different levels of anaerobic treatment effluent irrigation could significantly increase the biomass of the underground coriander, in terms of quality, the 50 % diluted anaerobic effluent irrigation can significantly increase the coriander vitamin C content and total soluble sugar content. Different levels of the anaerobic effluent irrigation could improve the yield and quality of coriander, 50 % diluted anaerobic effluent can promote most coriander in yield and quality indicators and it is not only significantly higher than no fertilization treatments, but also higher than the application of fertilizer treatment on the other outside indicators except chlorophyll.

Effect of skim wastewater irrigation on the coriander Biomass and quality: Fig. 5 shows that aerobic water treatment is similar with anaerobic water treatment, skim wastewater treated coriander aboveground biomass started rapid growth from the fourth sampling and had significant difference with CK treatment. Different levels of skim serum treated coriander of dry matter increase with decreasing wastewater concentration, when harvest, S10, S25 and S50 treatments are respectively 2 times, 1.9 times and 2.8 times higher than the CK treatment, while the S100 treatment is 7 % lower than CK. Compared with the N treatments, except S10 treatment is 23.9 % higher than N treatment. The remaining treatments are lower than the N treatment. As for the coriander underground biomass when harvest, the different levels of skim wastewater treatment reached a significant level and similar with aboveground biomass, with the reduction of the skim wastewater concentration, is gradually increased (Fig. 6). Except S10 treatment was 33.2 % higher than CK treatment, S100, S50 and S25 treatments are respectively 50.8, 18.8 and 11.6 % lower. Compared with N treatment, S10 and S25 treatment are 57.9 and 4.8 % higher, S100, S50 are respectively 41.7 and 3.8 % lower.

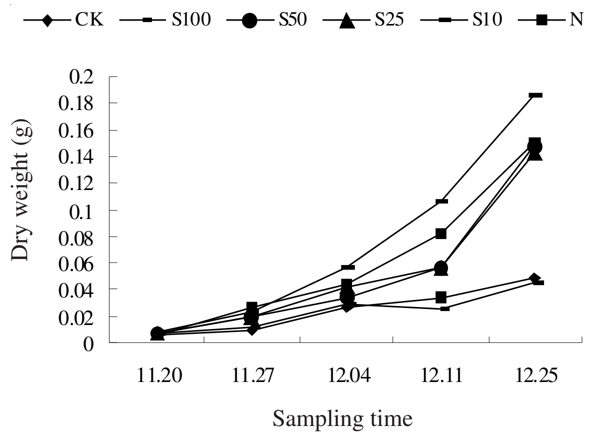

Fig. 5. Dry weight of aboveground coriander irrigated by untreated skim latex effluent

Due to the S100 treatment coriander has seldom survived strains, the number is unable to meet the demand for quality measurement, so the S100 treatment coriander quality indicators are not determined. Different diluted skim wastewater treated total chlorophyll and vitamin C content of the wastewater treatment are significantly higher than CK and N treatments (Table-6). On total soluble sugar content, S10 and S25 treat-

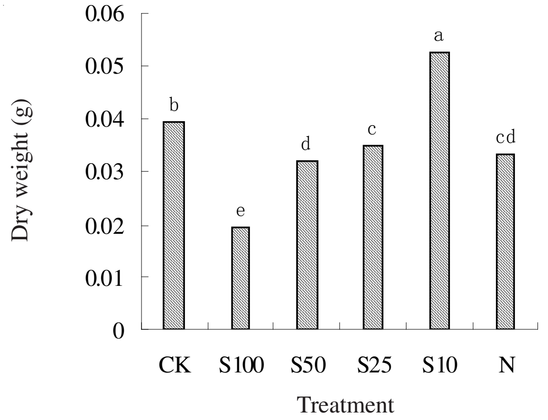

Fig. 6. Dry weight of underground coriander irrigated by untreated skim latex effluent

ments are significantly higher than CK treatment and S10 treatment is also higher than N treatment. Among the different levels of skim wastewater, 10 % diluted skim serum can promote the most coriander quality, the total chlorophyll, vitamin C and total soluble sugar content are respectively 20.69, 5.66 and 212.52 % higher than CK, 10.4, 15.1 and 18.0 % higher than the N treatment.

TABLE-6
PRINCIPAL NUTRIENT CONTENTS IN CORIANDER IRRIGATED BY UNTREATED SKIM LATEX EFFLUENT

Processing	Total chlorophyll (mg/g)	Vitamin C (mg/kg)	Total soluble sugar (%)
CK	1.954±0.071c	40.98±0.21c	7.47±0.48d
N	2.135±0.013b	37.63±0.14d	14.55±1.10b
S50	2.274±0.135a	44.55±0.03a	7.34±0.18d
S25	2.234±0.111a	44.58±0.45a	10.02±1.01c
S10	2.358±0.104a	43.30±0.40b	17.17±0.48a

Undiluted skim serum for direct irrigation has a great inhibitory effect to both coriander aboveground part and underground part biomass accumulation. Different levels of diluted skim wastewater treatment can promote the accumulation of aboveground biomass of coriander, while 10 % diluted skim wastewater have a significant role in promoting the growth of and coriander root, but 50 and 25 % diluted skim serum has certain extent of inhibition effect. Different dilutions of skim wastewater can improve the quality of coriander, 10 % skim serum has the best fertilizer effect, its promotion function in the coriander biomass and quality is significantly better than the compound fertilizer.

Conclusion

(1) Natural rubber processing wastewater of UASB anaerobic treatment after the middle effluent or aerobic treatment of the final effluent can be used for agricultural irrigation and can improve the yield and quality of coriander. The effect of aerobic effluent irrigation is quite the same on coriander yield and quality with fertilizer. And 50 % diluted anaerobic effluent irrigation is more superior than fertilizer. But the anaerobic effluent original water irrigation has some negative impact on coriander underground biomass accumulation, which may because the anaerobic effluent contains large amount of reducing substances in the soil thus which affect coriander root growth.

(2) Skim serum severely inhibit the growth of coriander, which indicated that it was not suitable for irrigation. Higher concentration of skim serum also inhibit the root biomass accumulation of coriander due to the high content of the organics, nitrogen, phosphorus and other nutrients[22]. Meanwhile, high concentrations of base cations in the wastewater may also affect the coriander growth. Diluted skim serum irrigation has a significant role in the yield and quality promoting of coriander and with the increase of dilution degree. The effects of promoting is more obvious. 10 % diluted skim has equivalent promoting effect on the coriander biomass and quality with 50 % diluted anaerobic effluent. They are both significantly superior to aerobic effluent and compound fertilizer. After simple dilution, high concentration of skim serum can be used to direct irrigation, but the pH value of the skim serum is quite low for agricultural irrigation, it needs to be adjusted to a suitable level.

(3) The rubber wastewater, as a recycled resource, is difficult to discharge after treatment and will increase the cost of production. Utilization and recycling use of different levels of rubber wastewater can replace the current natural rubber processing methods of biological treatment of wastewater which are widely used by current rubber enterprises. After dilution and simply adjusting the pH value, high concentrations of acid coagulation skim serum could directly used for farmland irrigation or after biogas production by anaerobic digestion, through appropriate dilution the biogas slurry can be used for farmland irrigation. And it can also be processed into liquid fertilizer which possess large economic value. After appropriate purification treatment, the low concentrations rubber wastewater and rinse water can be reused in rubber production which will achieve zero discharge of rubber processing wastewater in the rubber production.

REFERENCES

1. S.L. Zhang and J.C. Guo, *Issues of Forestry Economics*, **193**, 30 (2010).
2. H.Q. Liu, J. Fang, H.J. Zhang and G.H. Li, *Guangdong Agric. Sci.*, **240**, 9 (2009).
3. China National Bureau of Statistics, China Statistical Yearbook, China Statistics Press, Beijing (2011).
4. Hainan Bureau of Statistics, Hainan Statistical Yearbook, China Statistics Press, Beijing (2011).
5. L. Ding and M. Chen, *Chin. J. Trop. Agric.*, **64**, 25 (2005).
6. C.C. Goldthorpe, *The Planter*, **123**, 72 (1996).
7. H.M. Collier, *The Planter*, **439**, 53 (1977).
8. P.R. Kulkarni, *The Planter*, **307**, 49 (1973).
9. S.H. Tang, *World Trop. Agric. Inform.*, **6**, 6 (1996).
10. C.L. You, *World Trop. Agric. Inform.*, **28**, 6 (1978).
11. C.L. You, *World Trop. Agric. Inform.*, **16**, 4 (1978).
12. H.Y. Wang and B.Q. Fu, *J. Yunnan Trop. Crops Sci. Technol.*, **13**, 22 (1999).
13. X.F. Zhou and C.L. Qi, *Trop. Agric. Sci.*, **59**, 2 (2000).
14. W.L. Xia, A.C. Luo, Y. Zhou and Z.L. Guo, *Bull. Sci. Technol.*, **79**, 21 (2005).
15. L.J. Dong, Z.H. Lu, Q. Jia, D.Y. Pei, H.R. Tong, W. Li, J.F. Zhu and M.J. Xia, *Acta Ecolog. Sinica*, **6821**, 30 (2010).
16. L.T. Wan and X.B. Qi, *Agric. Res. Arid Areas*, **99**, 25 (2007)..
17. M.K. Zhang, L.J. Liu and C. Huang, *J. Soil Water Conserv.*, **87**, 25 (2011).
18. R.K. Lu, The Soil Agricultural Chemical Analysis Methods, China Agricultural Science and Technology Press, Beijing (2000).
19. H.S. Li, Plant Physiology and Biochemistry Experimental Principles and Techniques, Higher Education Press, Beijing (2000).
20. L.P. Zhang, H.X. Liao, Y. Liu, X. Li and D.L. Liu, *Hunan Agric. Sci.*, **48**, 7 (2011).
21. J.L. Huang, S.Q. Liu, J.J. Wang and H.J. Tian, *Acta Agric. Boreall-Sin.*, **182**, 17 (2002).
22. X.Y. Zang, *World Trop. Agric. Inform.*, **28**, 3 (1980).