

Research and Application Effects of Biochar-based Fertilizer on Fruit Trees

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Abstract Biochar and biochar-based fertilizer are effective ways to realize the resource utilization of agricultural and forestry wastes. Because of its soil improvement, yield increase, quality improvement and significant environmental effects, it has become a research hotspot, and its application in agriculture has also increased. In this paper, the preparation, types, application methods and effects of biochar-based fertilizer on fruit trees were summarized. Finally, this paper discussed the application prospects of biochar-based fertilizer on fruit trees.

Key words Biochar-based fertilizer, Fruit trees, Fertilizer application method, Application effects

1 Introduction

In recent years, the use of chemical fertilizers in China is continuously rising, which poses a serious challenge to the farmland soil ecosystem. Excessive application of chemical fertilizers not only damages the soil microbial community structure, but also destroys the physical structure of the soil, leading to soil acidification, hardening and other problems, and exacerbating the loss of soil inorganic carbon, accordingly weakening the buffer capacity of the soil^[1]. With the in-depth implementation of the national "carbon peaking and carbon neutrality" strategy and "two reductions", biochar-based fertilizer, as an innovative form of fertilizer, has received extensive attention and research in the past decade. Biochar-based fertilizer has shown great application potential in agricultural and forestry production and ecological protection because of its unique physical and chemical properties, such as improving soil structure, optimizing soil microbial community, improving crop yield and quality, and significant environmental friendly effects.

Specifically, biochar is usually a solid substance prepared from agricultural and forestry wastes by low temperature and limited oxygen pyrolysis technology. This material is rich in organic matter, and has developed pore structure and large specific surface area, so it has high stability. These characteristics of biochar make it play an important role in reducing water eutrophication, improving soil quality, promoting crop yield and controlling greenhouse gas emissions^[2]. In addition, hydrophilic groups such as

carboxyl, hydroxyl and aliphatic double bonds on the surface of biochar endow it with strong adsorption capacity and ion exchange performance, making it an ideal material for the preparation of slow-release adsorption carriers^[3]. Biochar-based fertilizer is a new type of fertilizer based on the growth needs of different plants, soil conditions in different regions and scientific fertilization principles, with biochar as the basic carrier, through blending, adsorption, coating, reaction and mixing granulation and other ways, compounded with N, P, K and other nutrients. Such fertilizer can not only effectively improve the soil and maintain its stability, but also show great advantages in improving soil fertility and promoting crop growth. It has significant nitrogen reduction and synergistic effect, and is a typical ecological and environment-friendly fertilizer^[4–6]. Findings of Wang Weihua *et al.*^[5] indicate that although long-term single application of chemical fertilizer can increase the content of total nitrogen and total phosphorus in soil, the effect on organic matter is not significant; while biochar-based fertilizer can significantly increase the content of organic matter, total nitrogen, total phosphorus and other nutrients in soil. Therefore, compared with the single application of chemical fertilizer or biochar, biochar-based fertilizer has a more stable and efficient effect, and has a significant role in promoting plant growth and yield^[4].

In this study, we summarized the existing research results in China from four aspects: the preparation process of biochar-based fertilizer, the classification of biochar-based fertilizer, the application method of biochar-based fertilizer in fruit trees and the application effect of biochar-based fertilizer. On this basis, we present the development trend and application prospects of biochar-based fertilizer in fruit tree production, so as to provide a scientific basis and practical guidance for the application of biochar-based fertilizer in the field of fruit tree planting.

2 Preparation process of biochar-based fertilizer

The biochar-based fertilizer is compounded from biochar and fertilizer, taking biochar as the matrix, adding one or more of nitrogen, phosphorus, potassium and other nutrients, and using

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chemical/physical methods to prepare the fertilizer biochar as a soil improver. Its principle of action is mainly due to the nature of biochar, which can carry a large amount of fertilizer^[7]. The preparation of biochar mostly comes from organic wastes in daily life, including agricultural and forestry wastes, domestic wastes and industrial wastes^[8]. The raw materials for biochar preparation are widely available, and the biochar prepared from different raw materials has different physical properties, but at present, the biochar raw materials used to prepare biochar-based fertilizer are still mainly agricultural and forestry wastes. At present, there are mainly four kinds of biochar-based fertilizer production processes in China, namely, bulk blending fertilizer production, coating fertilizer production, granulation fertilizer production and adsorption fertilizer production.

2.1 Bulk blending method The bulk blending method is a common method in the early preparation process of biochar-based fertilizer. The method comprises the following steps: blending biochar, an adhesive and a fertilizer according to a certain proportion to obtain the biochar-based fertilizer. For example, Cao *et al.*^[9] applied biochar-based fertilizer blended with biochar and N, P, K in the 5-year continuous cropping of maize, and Yang^[10] used biochar and chemical fertilizer in the acid tea garden, which effectively increased the yield and improved the physical and chemical properties of the soil. Although the bulk blending method has the advantages of simplicity, strong operability and low cost, and can significantly improve the contents of N, P, K and other elements, the disadvantages of low molding rate and low fertilizer slow-release rate should not be ignored. Therefore, in recent years, this method has been gradually replaced by other methods and less adopted^[11].

2.2 Coating method The core of coating method is to use fertilizer as the core component, through the role of adhesive, the fine powder of biochar is evenly wrapped in the outer layer, so as to prepare biochar-based fertilizer. This kind of fertilizer can effectively reduce the nutrient loss caused by volatilization, decomposition, erosion and other reasons, thereby improving the efficiency of fertilizer use. Using rice husk charcoal as matrix, modified corn starch as binder, and extrusion granulation technology, Ma Qian *et al.*^[12] successfully prepared spherical biomass char-based slow-release fertilizer with excellent compressive strength and molding rate. Lu Juan *et al.*^[13] used pine nut shell biomass carbon as matrix, acetate starch as binder, and prepared granular carbon-based fertilizer through disc granulation technology. The biochar-based fertilizer prepared by the coating method has a good slow-release effect, and the thicker the carbon shell and the stronger the water repellency of the film-forming agent after drying, the better the slow-release effect. However, this preparation process is complex and costly, which limits the wide application of biochar-based fertilizers in the market to a certain extent.

2.3 Granulation method The granulation method involves mixing biochar with fertilizer and granulating by disc granulation or mechanical extrusion^[11]. In this process, binders are usually

added, the main purpose of which is to enhance the mechanical strength of biochar-based fertilizers and their ability to resist various external forces under different environmental conditions. In the experiment, Gwenzi and his team^[14] combined mixed fertilizer and biochar with starch/PVA (polyvinyl alcohol) binder, and prepared biochar-based fertilizer by mechanical extrusion granulation technology. This fertilizer can increase the pH, nutrient utilization and water retention of sandy soil. Because the granular biochar-based fertilizer can increase resistance and effectively slow down the release of nutrients, the biochar-based fertilizer prepared by the technology has superior slow-release performance. At present, this method has become the preferred method and main technical direction in the production of biochar-based fertilizers in China^[11].

2.4 Adsorption method Adsorption method is a fertilization technology that uses the porosity and adsorption of biochar to immerse it in a nutrient-rich liquid, thus providing a storage place for nutrients. Compared with ordinary fertilizers, the adsorption method can first adsorb nutrients in biochar and then release them slowly, thus effectively reducing the loss of nutrients. The experimental results of Dominguez *et al.*^[15] showed that the nutrient retention of oil palm kernel shell biochar-based fertilizer was significantly better than that of ordinary fertilizer. This method has the advantages of low cost and convenience, but the adsorption capacity of biochar limits its effect to a certain extent. In order to solve this problem, researchers started to modify the biochar by metal, acid-base and modifier to further enhance its adsorption performance, so as to improve the fertilization effect of biochar-based fertilizer^[11].

3 Types of biochar-based fertilizer

There are many kinds of biochar-based fertilizer products, which can be divided into three basic categories according to the nutrient characteristics of the fertilizer: carbon-based inorganic fertilizer, carbon-based organic fertilizer and carbon-based organic-inorganic compound fertilizer^[1]. Carbon-based inorganic fertilizers involve mixing biochar with chemical fertilizers such as ammonium nitrate ($\text{H}_4\text{N}_2\text{O}_3$), urea, potassium sulfate ($\text{K}_2\text{O}_4\text{S}$), monoammonium phosphate ($\text{NH}_4\text{H}_2\text{PO}_4$), and potassium chloride (KCl). Carbon-based organic fertilizer combines biochar with organic fertilizer, including organic raw materials from animal and plant sources such as livestock and poultry manure, peanut bran and mushroom residue. In terms of preparation process, it can be further divided into direct mixing type and fermentation type. Direct mixing type is to mix biochar with organic materials directly for mineralization and decomposition, while fermentation type is to mix fermented organic fertilizer with biochar^[1]. Carbon-based organic-inorganic compound fertilizer is a kind of compound fertilizer, which combines biochar, organic matter and fertilizer to improve the overall effect of fertilizer^[1]. According to the different components of compound fertilizers, biochar-based fertilizers can also be subdivided into carbon-based phosphate fertilizers, carbon-

based nitrogen fertilizers, carbon-based potassium fertilizers and carbon-based compound fertilizers. Carbon-based compound fertilizer refers to the fertilizer compounded by biochar and two or more nutrients such as nitrogen, phosphorus and potassium^[1].

4 Fertilization methods of biochar-based fertilizer on fruit trees

The type, proportion and application method of biochar-based fertilizer have a significant impact on the application effect of crops. When applying biochar-based fertilizer to different crops, it is necessary to consider the differences in application methods and time. As shown in Table 1, the methods of applying biochar-based fertilizer on perennial fruit trees generally include soil mixing application, surface mulching application, irrigation water applica-

tion and hole application. Among them, the most common fertilization methods are hole application or mixed application with soil. The application time can be one-time application or multiple application. Findings of Yang Wujuan *et al.*^[16] showed that compared with one-time basal application, basal application combined with topdressing of carbon-based fertilizer had a better effect on increasing the yield of sweet potato, with an increase of 7.84%. However, the comparative test data of different application methods and application time on fruit trees are relatively scarce, and a relatively fixed application mode has not yet been formed. Therefore, before applying biochar-based fertilizer, it is necessary to fully understand the factors such as soil type, crop demand characteristics and labor costs, and adjust and optimize them according to the actual situation in order to achieve the optimal application effect.

Table 1 Fertilization methods of biochar-based fertilizer on different perennial fruit trees

Crop name	Type of biochar-based fertilizer	Fertilization methods	Reference
Honey pomelo	Biochar-based fertilizer with reduced nitrogen	Hole application is carried out on the east side and the west side of the fruit tree, the chemical fertilizer is applied for four times according to different proportions, and water and fertilizer are integrated or sprayed at the same time interval.	[17]
Apple	Biochar-based fertilizer	Base fertilizer ditch application, fruit preservation fertilizer, fruit expanding fertilizer hole application.	[7]
Red bayberry	Biochar-based fertilizer	A circular ditch is dug at a distance of about 1m from the tree trunk to the drip line of the tree crown, and the tree crown is covered with soil after being fertilized and mixed with the soil.	[18]
Citrus	Biochar-based fertilizer	On both sides of the canopy, ditch along the canopy drip line, mix the fertilizer with the soil and apply it into the ditch. Fruit-preserving fertilizer and fruit expanding fertilizer are applied in holes.	[19]
Chinese chestnut	Biochar-based fertilizer	The fertilizing method is hole application, and the soil is covered after the hole application.	[20]
Banana	Biochar-based fertilizer	Hole application is carried out on both sides of the fruit tree, and water and fertilizer are integrated or sprayed at the same time interval.	[21]
Huangguan pear	Biomass charcoal	The biochar was spread evenly on the soil surface and then rotary tilled for 10 cm to mix with the topsoil.	[22]

5 Application effects of biochar-based fertilizer on fruit trees

5.1 Effects of biochar-based fertilizer on soil physical and chemical properties of different perennial fruit trees

The soil improvement performance of biochar-based fertilizer is outstanding, and the application of biochar-based fertilizer to perennial fruit trees has a series of effects on soil physical and chemical properties. As shown in Table 2, Wang Chong *et al.*^[7] found that after applying biochar-based fertilizer to apples, the soil volume and available phosphorus decreased, and the soil water content, pH, total nitrogen content, organic matter and available potassium increased. Wu Qiangjian *et al.*^[17] also found that after applying biochar-based fertilizer with reduced nitrogen to honey pomelo, the soil volume and bulk density decreased, the total soil porosity and maximum water content increased, the soil aeration and water permeability increased, the soil environment improved, and the soil pH increased first and then decreased, the contents of soil organic matter, available nitrogen, available phosphorus, available potassium, total nitrogen cation exchange capacity and exchangeable magnesium increased significantly, and the soil enzyme activity increased. The research of Yi Xiaotong^[23] shows that after citrus is applied with bio-

char-based fertilizer, the soil hardness and bulk density are reduced, the soil porosity is increased, the soil aeration and water permeability and the ability of drought resistance and soil moisture conservation are increased, the soil water content is increased, the soil structure is more stable, the organic carbon content is increased, the soil pH is significantly increased, the overall soil acidification is improved, and the soil fertility is improved, the content of soil mineral nutrients was increased, and the degree of soil aggregation in citrus orchards was increased^[19]. The application of biochar-based fertilizer to Chinese chestnut also has the same effect^[20]. The application of biochar-based fertilizer to banana can promote the fixation of carbon in soil and significantly improve the utilization rate of nitrogen fertilizer^[21]. After the application of biomass charcoal to pear, the content of nitrate nitrogen in soil was significantly reduced, and the content of available phosphorus and potassium in soil was gradually increased, which could increase the soil pH^[22]. Therefore, biochar-based fertilizer has a significant effect on improving soil fertility and improvement in perennial orchards.

5.2 Effects of biochar-based fertilizer on yield and fruit quality of different perennial fruit trees

The application of biochar-based fertilizer to perennial fruit trees has a series of

effects on fruit yield and quality. As shown in Table 3, You Jianlin *et al.*^[18] found that different types of *Myrica rubra* trees with biochar-based fertilizer had different effects on the yield and fruit quality of *M. rubra* trees. The longitudinal and transverse diameters of fruits of Dongkui and Zaotanmei 8801 decreased on the whole, while those of Biqi *M. rubra* trees increased with the increase of biochar-based fertilizer. The fruit soluble solids content of Dongkui *M. rubra* tree decreased in general, and the fruit color difference L value did not change significantly, the fruit soluble solids content of Zaotanmei 8801 *M. rubra* tree increased and decreased, the Biqi *M. rubra* trees soluble solids content increased in general, the fruit color difference L value decreased, and the fruit Vc content increased. Li Hui *et al.*^[7] also found that after biochar-based fertilizer was applied to apples, the yield was increased, the soluble solids of fruits were increased, the Vc content

of fruits was increased, and the fruit quality was improved. After citrus was applied with biochar-based fertilizer, the mineral nutrient content of fruit increased, and the single fruit weight, fruit shape index, Vc soluble solids, titratable acid and solid acid ratio increased^[19]. After the application of biochar-based fertilizer, the content of starch and soluble sugar and the fruit setting rate were increased^[20]. After the bananas were applied with biochar-based fertilizer, the growth and development of bananas were promoted, and the yield and quality of bananas were significantly improved^[21]. The nitrate content in the fruit was gradually reduced after the application of biochar to the pear, the soluble solids content of the fruit quality of Huangguan pear was generally increased, and the titratable acid was generally dropped^[22]. These indicate that the biochar-based fertilizer can significantly improve the yield and fruit quality of fruit trees.

Table 2 Application effects of biochar-based fertilizer on soil physical and chemical properties of different perennial fruit trees

Crop name	Type of biochar-based fertilizer	Application effects	Reference
Honey pomelo	Biochar-based fertilizer with reduced nitrogen	The soil environment is effectively improved, the pH of the soil is increased first and then decreased, the content of the organic matter of the soil is increased, the activity of the soil enzyme is increased, the contents of the total nitrogen cation exchange weight, the exchangeable magnesium and the like of the soil are increased, the fertilizing capacity of the soil is improved, and the aeration and water permeability capacity of the soil and the content of the soil macroaggregate are improved.	[17]
Apple	Biochar-based fertilizer	The soil bulk density is effectively reduced, the soil water content is improved, the soil pH is improved, the soil fertilizer efficiency is improved, the water and fertilizer retention capacity of the soil is improved, the in-season utilization rate of the fertilizer by the crops is improved, the soil ecology is improved, and the pollution is reduced.	[7]
Citrus	Biochar-based fertilizer	The soil aeration and water permeability, drought resistance and soil moisture conservation capacity can be increased, soil bulk density can be reduced, soil moisture content can be increased, soil structure can be more stable, organic carbon content can be increased, soil pH can be significantly increased, soil fertility can be improved, and the degree of soil aggregation in citrus orchards can be increased.	[19]
Chinese chestnut	Biochar-based fertilizer	This method can reduce soil hardness, improve soil porosity, increase soil aeration and permeability, improve soil water content, significantly improve soil pH, improve soil fertility, and improve soil mineral nutrient content.	[20]
Banana	Biochar-based fertilizer	This method has a strong retention function on nutrients, can promote the fixation of carbon in the soil, significantly improve the utilization rate of nitrogen fertilizer, and reduce the loss of soil nutrients.	[21]
Huangguan Pear	Biomass charcoal	The content of nitrate nitrogen in soil can be significantly reduced, the content of available phosphorus and potassium in soil is gradually increased, and the pH of soil is increased.	[22]
Honey pomelo	Biochar-based fertilizer	This method can reduce the soil bulk density and increase the soil total porosity and soil water content, and also increase the contents of soil available phosphorus and potassium.	[23]

Table 3 Application effects of biochar-based fertilizer on yield and fruit quality of different perennial fruit trees

Crop name	Type of biochar-based fertilizer	Application effects	Reference
Dongkui <i>M. rubra</i> tree	Biochar-based fertilizer	The longitudinal and transverse diameters of the fruit are decreased, the single fruit weight is decreased, the soluble solids content of the fruit is decreased, the L value of the fruit color difference does change significantly, and the Vc content of the fruit is increased.	[18]
Zotanmei 8801 <i>M. rubra</i> tree	Biochar-based fertilizer	The longitudinal and transverse diameters of the fruit generally show a downward trend, the fruit weight increases with the increase of biochar-based fertilizer, the soluble solids content of the fruit is increased and decreased, and the Vc content of the fruit is increased.	[18]
Biqi <i>M. rubra</i> tree	Biochar-based fertilizer	The longitudinal and transverse diameters of fruit increase with the increase of biochar-based fertilizer dosage, the fruit weight increases with the increase of biochar-based fertilizer application, the soluble solid content of fruit is increased, the L value of fruit color difference is decreased, and the Vc content of fruit is increased.	[18]

(To be continued)

(Continued)

Crop name	Type of biochar-based fertilizer	Fertilization methods	Reference
Apple	Biochar-based fertilizer	This application can increase the fruit yield, reduce the fruit hardness, improve the fruit soluble solid content, significantly improve the fruit sugar-acid ratio, increase the fruit Vc content, increase the soluble sugar content, reduce the titratable acid content, increase the fruit Vc content, and improve the fruit flavor.	[7]
Citrus	Biochar-based fertilizer	Fruit mineral nutrient content, single fruit weight, fruit shape index, Vc, soluble solids, titratable acid and solid acid ratio are increased, and fruit quality is improved.	[19]
Chinese chestnut	Biochar-based fertilizer	This application can increase the fruit setting rate and the yield of a single plant, ensures stable yield, high yield and high quality of the Chinese chestnut, increase the content of starch and soluble sugar, promote the growth and development of the Chinese chestnut, and improve the yield and the quality of the Chinese chestnut.	[20]
Banana	Biochar-based fertilizer	This application can promote the growth and development of the banana and obviously improve the yield and quality of the banana.	[21]
Huangguan Pear	Biomass charcoal	The content of nitrate in pear fruit is decreased gradually, the content of soluble solids in Huangguan pear fruit is increased, and the content of titratable acid is decreased.	[22]

5.3 Effects of biochar-based fertilizer on different perennial fruit trees As shown in Table 4, previous studies have found that the application of biochar-based fertilizer to perennial fruit trees will also have a series of effects on the tree body. Wang Chong *et al.* [7] found that the length of new shoots, SPAD value, 100-leaf thickness, 100-leaf weight and water content of leaves increased after biochar-based fertilizer was applied to apples, and the content of nitrogen, phosphorus and potassium in leaves decreased with the increase of the content of biochar-based fertilizer. Cao Sheng [19] found that the content of mineral nutrients (N, P,

K) in citrus leaves increased with the increase of certain nutrients in soil after biochar-based fertilizer was applied. Wang Wensheng [21] also found that the SPAD value, leaf transpiration rate and stomatal conductance of banana increased first and then decreased with the increase of biochar-based fertilizer application, which could increase chlorophyll content and photosynthetic parameters. Biochar-based fertilizer not only inherits many advantages of biochar, but also changes the soil environment. Loading biochar with fertilizer can also improve the effect of fertilizer, improve soil quality, and have a very positive impact on plant growth and development.

Table 4 Application effects of biochar-based fertilizer on different perennial fruit trees

Crop name	Type of biochar-based fertilizer	Application effects	Reference
Apple	Biochar-based fertilizer	The content of N, P and K in leaves decreased with the increase of biochar-based fertilizer content, while the length of new shoots, SPAD value, 100-leaf thickness, 100-leaf weight and leaf water content increased. The application of biochar-based fertilizer is beneficial to the growth of fruit trees.	[7]
Citrus	Biochar-based fertilizer	The content of mineral nutrients (N, P, K) in leaves increases with the increase of certain nutrients in soil, which promoted the growth of fruit trees.	[19]
Banana	Biochar-based fertilizer	The SPAD value, leaf transpiration rate and stomatal conductance increase first and then decrease with the increase of biochar-based fertilizer application, and the effect of biochar-based fertilizer on net photosynthetic rate increases first and then decreases. It can increase chlorophyll content and photosynthetic parameters.	[21]

6 Prospects of application of biochar-based fertilizer in fruit trees

Through the research on the application of the biochar-based fertilizer material to the fruit trees, we found that the biochar-based fertilizer material which uses the biochar as a slow-release carrier can effectively repair and improve the soil and enhance the absorption and utilization efficiency of the fruit trees to nutrient components, thereby promoting the growth of plants, and both the yield and the quality of the fruit are improved. Therefore, biochar-based fertilizer has become a key technology in the field of fruit trees, showing a huge market potential and development prospects.

With the country's increasing attention to environmental pro-

tection and the introduction of a series of related environmental protection policies, the popularity of domestic environmental protection policies continues to rise. In this context, with the advantages of biochar and bio-based fertilizer, the research and application of biochar-based fertilizer has entered an accelerated development stage. Biochar-based fertilizer is rich in high carbon, and has the benefits of reducing weight, increasing efficiency, and sustainable supply of nutrients, which shows broad application prospects in improving soil physical and chemical properties, reducing fertilizer use, and promoting crop growth. Extensive studies have shown that biochar-based fertilizer has been widely used in green pepper [24], wheat [25], cabbage [26], rice [27], cotton [28], tea [29] and other crops, significantly improving the quality of crops. Although

some achievements have been made in the field of fruit trees in recent years^[30], as a new green fertilizer, biochar-based fertilizer still faces the problems of high transportation cost of raw materials, immature production technology and difficult application on perennial fruit trees^[31]. In particular, its application in citrus, apple and other fruit trees is limited^[32]. In addition, the high price of biochar-based fertilizer in the fertilizer market is a main factor limiting its promotion^[33]. Furthermore, there are many kinds of biochar-based fertilizer products, but the intellectual property system is not perfect, and the product quality is difficult to guarantee.

In the future, the development of biochar-based fertilizer industry should focus on the following aspects. (i) It is recommended to build a more perfect technical platform for carbon-based fertilizer performance and product quality testing, realize standardized operation, and establish a testing institution with certification qualification. (ii) It is necessary to issue relevant supporting policies, make use of superior resources to form complementary synergy with enterprises, and promote the high-value utilization of carbon-based fertilizer. (iii) It is recommended to strengthen the research and development of new materials, new technologies and new products, improve the preparation technology of biochar-based fertilizers, optimize the proportion of biochar and chemical fertilizers, expand the types of biochar-based fertilizers and increase the yield. (iv) It is recommended to formulate supporting technical regulations for the application of biochar-based fertilizer in fruit trees through the construction of long-term location test and demonstration base, accelerate the transformation of technical achievements, promote the rapid development of biochar-based fertilizer in fruit industry, strengthen the promotion efforts, and enhance the public awareness of biochar-based fertilizer and continuously expand its application fields.

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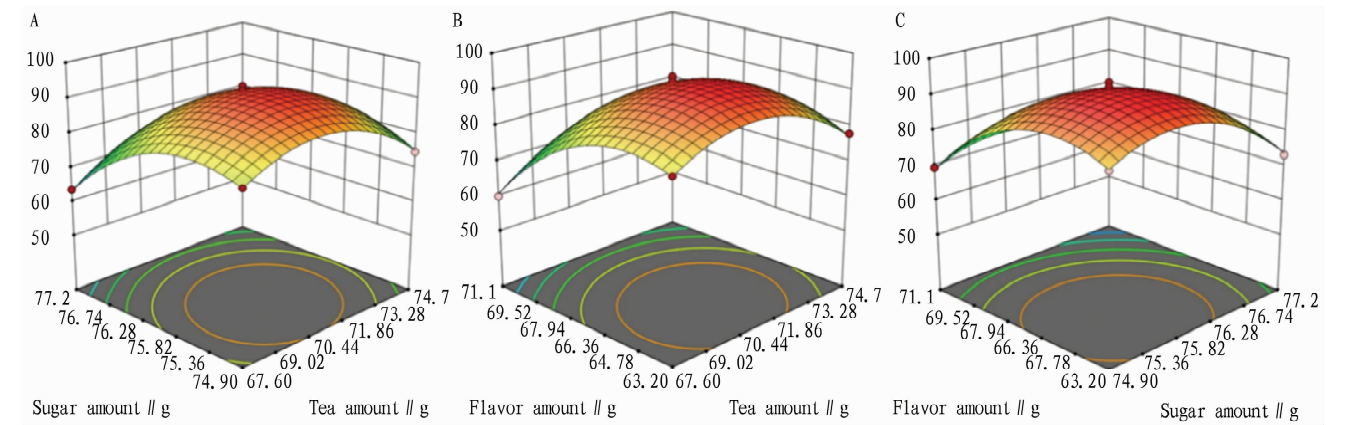


Fig.6 Response surface of Box-Behnken design by plotting

4 Conclusions

This study developed an optimal formulation of peanuts with Yingshan Yunwu tea flavor. Firstly, the single-factor experiment was performed to study all factors on the sensory score of the peanut, including tea amount, salt amount, sugar amount, flavor amount and cooking time. Then, response surface methodology with the Box-Behnken design were carried out, and the optimal formulation composition was 100 g peanuts, 500 mL of water, 25 g tea, 5 g salt, 8 g sugar and 1 g tea flavor with a sensory score of 94.3 points. In conclusion, the peanuts with Yingshan Yunwu tea flavor were generally acceptable by consumers.

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