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Research Article

Established Digital Model of Fruit Body Growth of *Agrocybe cylindracea* Based on Network Programming

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Agricultural information technology is an emerging technology based on the cross-fertilization of information technology and agricultural science, which has caused the rapid development of digital agriculture and smart agriculture. Crop growth models, as one of their core components, can dynamically simulate the crop growth and development process and its relationship with climate factors, soil properties, and management techniques, thus effectively overcoming the strong spatial and temporal limitations in traditional agricultural production management research and providing quantitative tools for early warning and effect assessment of crop productivity prediction under different conditions. This study focuses on the general technical approach, the latest research progress, and future development thinking developed by the authors in the construction and application of the tea mushroom growth model. Based on the fitting method of the data model curve of the Internet laboratory, this study is proposed to use network programming technology to digitally fit the growth curve of cap diameter and stalk diameter of the fruiting body in the process of *Agrocybe cylindracea* growth. The fitting system adopted the development mode of PHP + MYSQL and took the MYSQL database as the core, which made the curve fitting of the final experimental data fast, convenient, and more intelligent. This study laid a preliminary foundation for the effective establishment and improvement of laboratory *Agrocybe cylindracea,* fruiting body growth data statistics and analysis, and graphical output network sharing.

1. Introduction

With the deepening of agricultural and rural reform, China has become a major producer of edible mushrooms in the world, and the scale and speed of development have soared. The development of the edible mushroom industry has not only promoted the improvement of agricultural resource utilization but also has driven the development of logistics and distribution, storage and processing, and other related industries, realizing a circular economy [1, 2]. At present, the edible mushroom industry has become a sunrise industry comparable to the farming and cultivation industries, and the 2017 Central Government Document No. 1 even listed it as one of the "advantageous characteristic industries" to be vigorously developed [3, 4].

Currently, the World Edible Mushroom Center is shifting to China. To summarize, China's edible mushroom industry and technology have six comprehensive advantages. First is the availability of abundant resources. Among more than 2000 species of edible mushrooms in the world, there are 981 species in China, and more than 30 species have been put into commercial cultivation. Second is abundant labor. China has the advantage of both better labor costs than developed countries and higher cultivation technology than developing countries. Third, the technology level is relatively advanced. China is a world leader in edible mushroom cultivation, strain preservation, deep processing, medical and health products, and molecular biology. Fourth is good foundation for industrial development. In China, the north-south migration of mushrooms and the west-east advancement of mushrooms have been launched with great enthusiasm, and the edible mushroom cultivation industry is found everywhere in China. Fifth is that the market is vast. With the decline of the overall unit price of edible mushrooms and the continuous improvement of people's living standards, edible mushrooms will further become daily dishes and common nutritional health food for ordinary families in China, and the total market is extremely large; in the overseas market, 34 export codes of edible mushroom products of the national customs, the trade volume is 1.622 billion dollars, and the international market is a momentum of the international market is very good. Sixth is the deep cultural heritage. The development of China's edible mushroom industry is rooted in the Chinese food culture, which emphasizes longevity and health, high protein, low fat, and vegetarianism, making edible mushrooms increasingly popular among modern people [5–8].

To achieve better and faster development of the edible mushroom industry in China, domestic scholars have conducted a lot of research. At the macrolevel, research on the edible mushroom industry has mainly focused on edible mushroom cultivation and production, market development, and mushroom recycling. Topics such as e-commerce and edible mushroom industry development, edible mushroom brand building and product competitiveness, mushroom residue, and agricultural circular economy have emerged, and poverty alleviation in the edible mushroom industry has been a hot topic in recent years [9–13]. At the microlevel, scholars have researched the adoption of cultivation techniques and cost benefits for mushroom farmers. With the development of the edible mushroom industry, edible mushroom factory production has become an increasing trend, and the demand of mushroom farmers for the quality of strains, light cultivation techniques, pest control, and other technologies has climbed [14–18].

Agrocybe cylindracea has been consumed by a significantly increased number of consumers recently due to their high value of nutrition and delicious taste [19]. As an edible and medicinal fungus that belongs to basidiomycete, *A. cylindracea*, belonging to *Agrocybe* genus, is an edible mushroom that is very popular for the unique flavor and high nutritional content of its fruiting body [20]. *A. cylindracea* is also regarded as a multipurpose food supplement due to the high levels of nutrients and bioactive compounds present in this species. Some studies [21–23] have shown that active extracts of *A. cylindracea* have effects on various human diseases. In the early 1990s, after the successful experiment of artificial cultivation of *Agrocybe cylindracea* in China, there is an annual output of about 10,000 tons of fresh mushrooms of *Agrocybe cylindracea* in Lichuan County, Jiangxi Province, and the product was mainly sold as fresh, partly processed into dried products, and sold to major cities, which was regarded as a fashionable and rare mushroom. The development is rapid. Fujian, Guangdong, Guangxi, Hunan, Yunnan, Jiangsu, Anhui, and other province (region) governments have listed *Agrocybe cylindracea* as a target species for agricultural industrialization structural adjustment projects, strengthening technical guidance and financial support to facilitate industrial development [24, 25]. In Gutian County of Fujian Province, which is adjacent to Jiangxi Province, *Agrocybe cylindracea* has developed rapidly in recent years and has become one of the leading products in the local edible mushroom industry, with an annual cultivation scale of more than 1 billion bags and an output of 193,000 tons (fresh products) and an output value of 1 billion yuan, far exceeding the output of shiitake mushrooms in the county [26].

The rapid development and cross-fertilization of information technology and agricultural science have formed agricultural information technology, which has further given rise to the rapid development of digital agriculture and intelligent agriculture, providing quantitative technical support and comprehensive information services for modern agriculture and injecting technological transformation and upgrading of the agricultural industry. It has brought new vitality and significant social, economic, and ecological benefits [27–29]. The emergence of agricultural information technology in the world of agriculture began in the late 1970s, with the successful development and application of the crop growth model as a prominent representative. The crop production system is a complex and unique dynamic system, which is influenced by climate conditions, soil characteristics, variety characteristics, technical measures, and other factors and has significant spatial and temporal variabilities [30]. The crop growth model, on the other hand, is based on the intrinsic laws of crop growth and development and integrates the causal relationships among crop genetic potential, environmental effects, and regulatory technologies, which can quantitatively describe and predict the crop growth and development process and its dynamic relationships with the environment and technologies [31]. Therefore, the construction of a mechanistic and widely applicable crop growth model can provide an effective quantitative tool for crop productivity prediction and effect assessment under different conditions.

In the 1950s and 1960s, De Wit and Duncan et al. successively published models of plant canopy light energy interception and population photosynthesis, marking the advent of crop physiological and ecological process simulation [32, 33]. At present, the better foreign crop growth models include DSSAT in the USA, APSIM in Australia, STICS in France, GECROS in the Netherlands, and ORYZA in the International Rice Research Institute of the Philippines [34, 35]. Although the research on crop models in China started late, it has developed relatively fast. Based on tracking and learning from foreign research results, early research constructed relevant simulation models for the characteristics of crop production in China [36]. Since 2000, research institutions such as Nanjing Agricultural University, China Agricultural University, Northwest Agricultural and Forestry University, Chinese Academy of Sciences, and Jiangsu Academy of Agricultural Sciences have carried out more systematic research works in crop simulation algorithm construction, simulation platform construction, model regional application, and scenario effect evaluation and have made a positive impact in the international crop simulation field [37, 38].

Since 2010, the International Organization of Agricultural Systems Modeling Experts (IOSMA) has launched the Agricultural Model Intercomparison and Improvement

Project (AgMIP) to compare and improve different existing crop growth models, livestock growth models, and agro-economic models around the world and to couple future climate models and scenarios to quantitatively assess agricultural production and food security at different scales [39]. The project aims to quantitatively assess agricultural production and food security at different scales, sites, regional, national, and global by comparing and improving different crop growth models, livestock growth models, and agro-economic models around the world, coupled with future climate models and scenario simulation methods (https://agmip.org) [40, 41]. In the field of crop growth models, the collaborative group has formed several international research teams for different crops, such as rice, wheat, maize, and edible mushrooms, to collaborate on the comparison and improvement of crop growth models and to enhance the simulation and application capabilities of the models under different conditions. However, due to the combination of poor sharing of experimental data, limited controlled experimental conditions, slow development of regional simulation technology, and lack of model researchers, the existing crop growth models still need further improvement and refinement, and there is an urgent need to propose a comprehensive crop growth model and decision support system that is both mechanistic and predictive. Because of the above, the application of network programming technology to the growth and development of edible fungi to design a set of convenient and intuitive univariate or multivariate statistical data and curve fitting network sharing systems is one aspect of the current development of edible fungus bioinformatics [42]. At present, some researchers have proposed to use PHP to compile network-shared statistical analysis of biological growth and development, but have not made a more mature curve fitting system. Through the recent research, the authors realized the statistical analysis of the growth and development of *A. cylindracea* by PHP programming and established a set of data processing centers which can meet the laboratory data processing and analysis and growth curve fitting.

2. Materials and Methods

2.1. Logical Structure of the Curve Fitting System. The correlation coefficient formulas and model parameters commonly used in the four statistical models are selected to test the hypothesis of a correlation coefficient [43, 44].

2.1.1. Linear Regression Model.

$$\hat{y} = a + bx, \tag{1}$$

in which $r_{\text{correlation coefficient}} = \left(\sum (x-\overline{x})(y-\overline{y})/\sqrt{\sum (x-\overline{x})^2 \sum (y-\overline{y})^2}\right)$

2.1.2. Exponential Curve Model.

$$\hat{y} = ae^{bx}. \tag{2}$$

Take the logarithm on both sides of the equation, if defined $\hat{y}' = \ln y$, the linear equation was $\hat{y}' = \ln a + bx$, in which

$$r_{\text{correlation coefficient}} = \frac{\sum (x-\overline{x})(\ln y - \overline{\ln y})}{\sqrt{\sum (x-\overline{x})^2 \sum (\ln y - \overline{\ln y})^2}}. \tag{3}$$

2.1.3. Power Function Curve Model.

$$\hat{y} = ax^b, \tag{4}$$

in which

$$r_{\text{correlation coefficient}} = \frac{\sum (\ln x - \overline{\ln x})(\ln y - \overline{\ln y})}{\sqrt{\sum (\ln x - \overline{\ln x})^2 \sum (\ln y - \overline{\ln y})^2}}. \tag{5}$$

2.1.4. Logistic Curve Model.

$$\hat{y} = \frac{k}{1 + ae^{-bx}} \quad (a, b, k > 0). \tag{6}$$

$k = (y_2^2(y_1 + y_3) - 2y_1y_2y_3)/(y_2^2 - y_1y_3)$ $(y_1, y_2, y_3$ were the observed values).

Shift the term in the curve equation and take the natural logarithm to get $\ln(k - \hat{y}/\hat{y}) = \ln a - bx$.

If defined $y' = \ln(k - \hat{y}/\hat{y})$, the regression linear equation is obtained $\hat{y}' = \ln a - bx$, $-b = \sum (x-\overline{x})(y' - \overline{y}')/\sum (x-\overline{x})^2$, $\ln a = \overline{y}' + b\overline{x}a = e^{\ln a}$.

$$r_{\text{Correlation coefficient}} = \frac{\sum (x-\overline{x})(y' - \overline{y}')}{\sqrt{\sum (x-\overline{x})^2 \sum (y' - \overline{y}')^2}}. \tag{7}$$

2.2. Programming Principle

2.2.1. Workflow of the Curve Fitting System. The best fit model is determined according to the correlation coefficient of different curve models and the experimental data. The workflow is detailed in Figure 1.

2.2.2. Network Structure of the Curve Fitting System. PHP is used as the development environment, APACHE as the Web server, MySQL as the background database, and IE browser as the client [45–47]. Since the combination of PHP, APACHE, and MySQL can run across platforms, this means that the three can be developed simultaneously on Windows and run smoothly on the Unix/Linux platform [48, 49].

2.2.3. Program Modules and Their Operational Relationships. This program includes four major modules, namely, the EXCEL table processing module, a statistical data processing module, a curve fitting module, and a graphical output module.

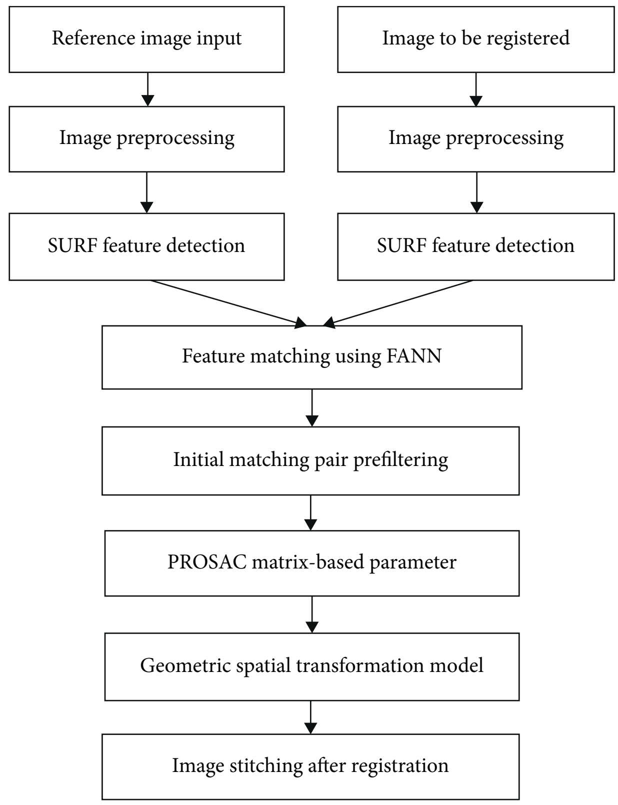

Figure 1: The work flowchart of the curve fitting system.

(1) EXCEL table processing module: enter the stalk diameter and cap diameter data of *A. cylindracea* into the EXCEL table template. Columns A, B, and C in the table are written into three groups of data, and group A is the data identifier ID, group B is the cap diameter (total coordinates), and group C is the stalk diameter (abscissa). When the program reads data, the first line is the field name, and the second line of data text data is the identification. The program reads the processed data from the EXCEL table and sends them all to the MYSQL database for the statistical data processing module to extract.

(2) Statistical data processing module: this module extracts data from the MYSQL database and does high-precision operations according to the needs of the statistical model, stores the results in the specified result variables, and calculates the correlation coefficient. The model with the largest correlation coefficient is the best fit model, and the correlation coefficient is tested by the t-test.

(3) Curve fitting and graphical output module: the function provided by the GD library of PHP program is used to graphically output experimental data points and curve fitting. The normal operation of the program needs the support of the following environments: the support of the GD graphics library and PHP2.X version or higher interpreter.

3. Results and Analysis

Through the test results of four kinds of digital models, we can see the graphical output of curve fitting, and the best fitting curve of scattered points in each model can be detected (Figure 2).

The determination coefficient of the exponential function is 0.953 and that of the power function is 0.955, while the determination coefficient of the LOGISTIC model is unreasonable. The greater the determination coefficient, the greater the absolute value of the correlation coefficient, indicating that the power function model fits the data best, and the correlation value of the power function is 0.964. According to the degree of freedom and the test level value, the program reads the data from the text of the t distribution table and makes a double-tailed t-test when the significant level is 0.01. The result is 0.000, which indicates that the hypothesis that the two variables are not related is not valid, indicating that there is a very significant positive correlation between the diameter of the cap and the diameter of the

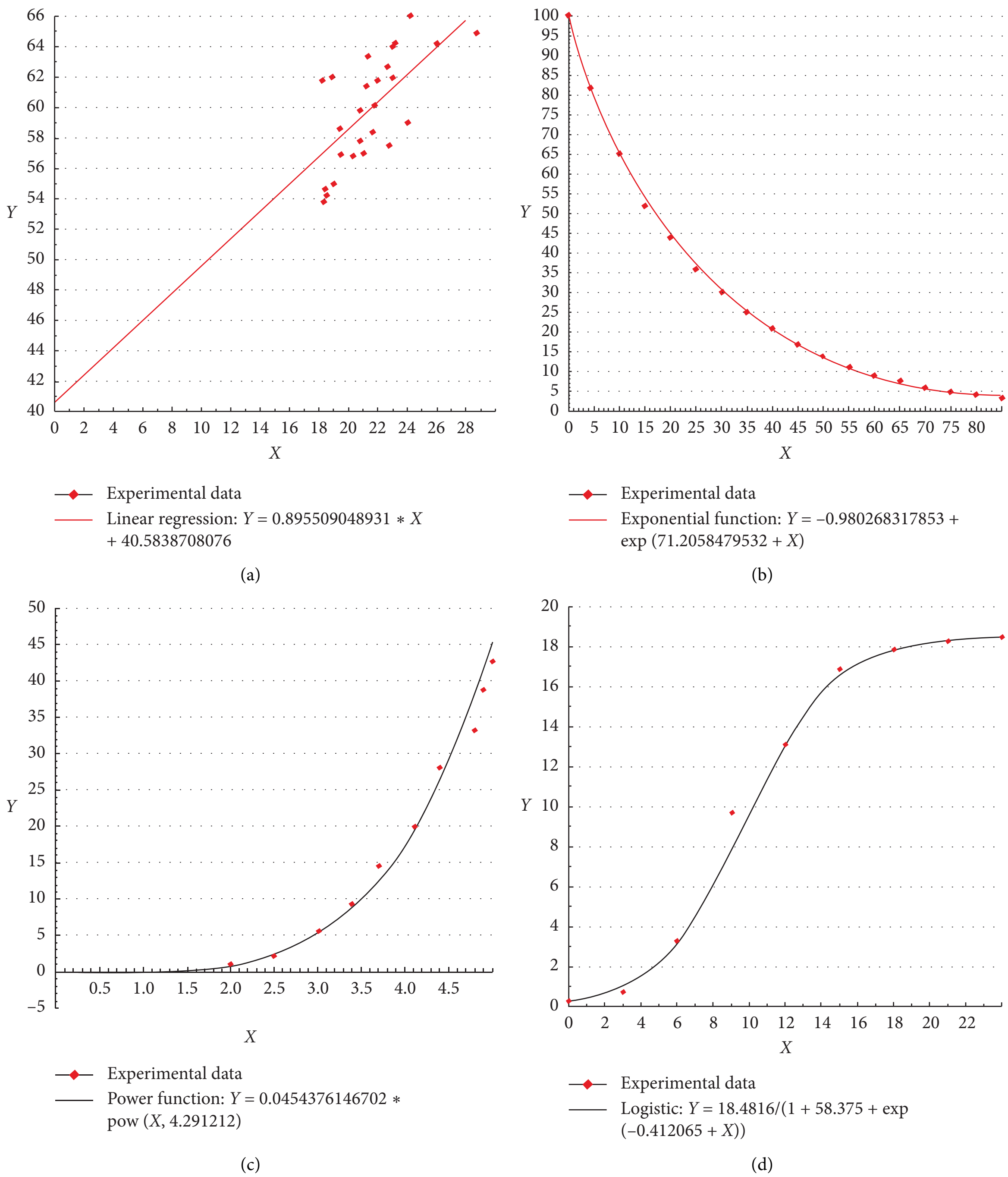

Figure 2: Fitting curve of four statistical models. (a) Linear regression model. (b) Exponential function model. (c) Power function model. (d) LOGISTIC model.

stalk. The program transfers the results of high-precision operation into the graphical output module to make the fitting curve of the diameter of the cap and the diameter of the stalk (Figure 3).

The fitting curve model equation of stipe diameter and pileus diameter of *A. cylindracea* is $\widehat{y} = 8.992681x^{0.612322}$ (in which $0 < x < x_{\max}$, $x_{\max}$ is the maximum diameter of the stalk).

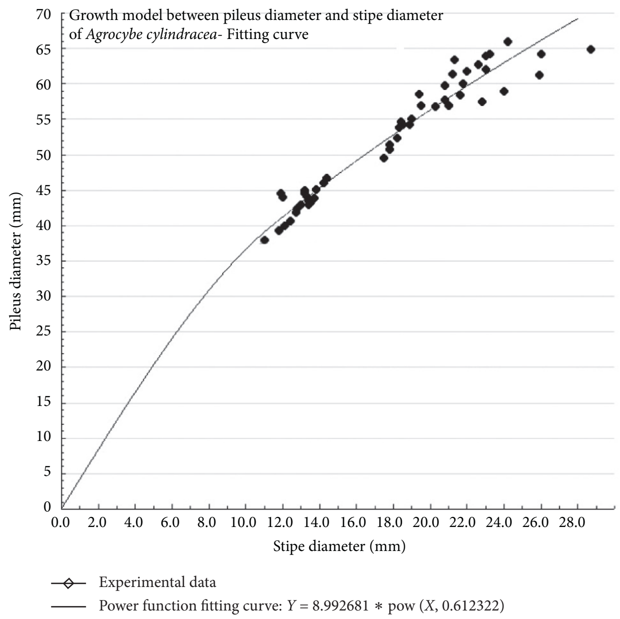

Figure 3: The best fitting curve of the growth model between pileus diameter and stipe diameter of *A. cylindracea*.

4. Conclusion

A large amount of research in the field of the edible mushroom industry has been carried out in the overall context of the rise of the general trend of industrial development. On the one hand, the introduction of guidelines and policies has led to a focus on the development of edible mushroom factory cultivation technology, promoting the transformation of traditional farmer production methods to factory production methods, while a series of initiatives such as promoting the development of the mushroom cycle have also promoted the transformation and upgrading of the edible mushroom industry, and research hotspots have been emerging. On the other hand, the factory production mode of China's edible mushroom industry is emerging, the market demand and market capacity are gradually increasing, the competitive advantages of the products are highlighted, the industry has broad development prospects, and there are many future research contents [50, 51]. At this stage, research in the global edible mushroom industry mainly presents hot spots in the following aspects. First is the research on edible mushroom production methods, focusing on factory production. Factory production is the most modernized agricultural industry and is an important direction for the industrial development of edible mushrooms. Various aspects of factory production, such as the research and development of factory cultivation technology and factory management, need to be improved through research. Second is the research on the market-oriented development of edible mushrooms. Research results about product competitiveness, especially export trade, are abundant. With the introduction of policies such as "One Belt, One Road," and "Rural Revitalization," fine research on edible mushroom brand construction and integration with e-commerce is promoted. Third is the research on the circular economy of the edible mushroom industry. The flourishing of low-carbon agriculture and the development of agricultural circular economy make the research on the circular economy of mushroom industry promising, and the standard paradigm of mushroom recycling technology, system, laws, and regulations need to be developed and formed [52, 53].

At present, although crop growth models have made great progress, some physiological and ecological mechanisms still need to be studied in depth and further improved [54, 55]. Many parts of the existing models are still more empirical, and in the application of the model, due to the complexity of the model, more parameters are included in the model, and the acquisition and reliability of the parameters are the key issues affecting the application of the model. There are still many aspects that need to be explored and researched in depth [56].

In this study, the curve model of the growth trend of cap and stalk in the process of growth and development of *Pleurotus ostreatus* was fitted by using the research methods of biology and statistics. The final fitting curve model equation is as follows: $\hat{y} = 8.992681x^{0.612322}$ (in which $0 < x < x_{\max}$, $x_{\max}$is the maximum diameter of the stalk). The results show that the fitting equation is feasible and efficient. If the program is further improved and used, the data model of liquid fermentation growth of related edible fungi can be established in the future, and the shared network of data fitting and curve output can be established at the same time.

In the process of research, it is found that the statistical data processing module is the core module of the program, and the biggest difficulty in compiling lies is whether the operation accuracy meets the requirements, while PHP provides a binary calculator for any precision mathematical calculation, which supports numbers of any size and precision, describes the addition of a string bcadd (string left_operand, string right_operand [, int scale])//floating-point numbers in the form of a string, and retains' scale' decimal places after the decimal point. This study uses a high-precision algorithm with a decimal accuracy of 6 and ensures the least number of iterations (the less the number of iterations, the smaller the error), which can meet the needs of statistical parameters. Finally, the results of these high-precision operations are stored in the corresponding curve model variables to provide initial data for graphics [57]. At the same time, there are four evaluation indexes in the test of the curve fitting effect: the average value of residual standard deviation (RSE), correlation coefficient (CRI), absolute deviation (AAD), and the average value of relative deviation absolute value (AARD). Among them, the smaller the average (AAD) of the absolute deviation of the residual standard deviation (RSE) and the average (AARD) of the absolute value of the relative deviation, the larger the correlation coefficient (CRI) and the better the fitting effect of the surface test [58–60]. Besides, in the establishment of the digital model, there are some problems in the graphical output and fitting curve, such as the output curve is not smooth. To solve this problem, the abscissa variable is divided into tiny units, and an array of 10000 variables is obtained. so that the graphical output can get a smooth fitting curve [61–63]. In this study, it is feasible, convenient, and efficient to use biology, statistics, and PHP programming methods to fit the growth curve of cap diameter and stalk diameter of *Pleurotus ostreatus*. With the continuous improvement of this program, the shared network center of data model fitting and curve output can be established in the laboratory, which provides a reference basis for the graphic data of the laboratory.

As an emerging discipline, the role of crop growth modeling in education and research is indelible and will continue to have great vitality [64]. With the further integration of theoretical research with production practice and the deepening of systematic scientific research, there will be a new progress in the study of the quantitative effect of environmental conditions on crop growth and development, and the visualization of crop growth and virtual crop growth will be the focus of a new round of research on crop growth simulation models.

Data Availability

All data, models, and code generated or used during this study are included within the article.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Authors' Contributions

Long Wang performed the experiment investigations, data analysis, and wrote the original manuscript. Lingli Li provided parts of resources and materials. Qingping Zhou conceived and designed the experiments, contributed reagents/materials/analysis tools, and wrote the manuscript. All authors reviewed the manuscript.

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References

[1] J. B. Zhang, "China edible mushroom industry economic research report," National Edible Mushroom Industry Technology System Industrial Economy Research Office Beijing, China, 2016.

[2] P. Li, C. X. Yang, and J. B. Zhang, "Analysis of farmers' technology needs in China's edible mushroom industry," *China Science and Technology Forum*, vol. 142, no. 6, pp. 132–136, 2010, (in Chinese).

[3] M. Lu, Y. Li, and J. B. Zhang, "Analysis of information acquisition and related decision-making behavior of edible mushroom production from farmers' perspective," *Agricultural Technology Economics*, vol. 29, no. 4, pp. 107–113, 2010, (in Chinese).

[4] J. Dong, L. Zhang, L. M. Tai et al., "Analysis of the current situation of edible mushroom strain standards and cultivation standards in China," *Chinese Edible Mushrooms*, vol. 38, no. 11, pp. 98–101, 2019, (in Chinese).

[5] J. Ma, Y. Li, and Z. Wang, "Analysis of pricing and services effort in dual-ChannelSupply chains with showrooming effect," *International Journal of Bifurcation and Chaos*, vol. 30, no. 16, p. 21, Article ID 2050241, 2020.

[6] Y. Zeng, J. Zhang, L. Cheng et al., "Analysis of the export competitiveness and trade potential of Chinese edible mushroom products," *Journal of Huazhong Agricultural University (Social Science Edition)*, vol. 142, no. 6, pp. 8–16, 2016, (in Chinese).

[7] Q. Hu and R. Zhang, "Fungal recycling model for efficient utilization of agricultural waste resources," *China Agricultural Resources and Zoning*, vol. 34, no. 6, pp. 113–119, 2013, (in Chinese).

[8] S. Y. Huang, H. W. Shen, H. D. Han et al., "Research progress and countermeasure suggestions on resourceful recycling model of edible mushroom industry by-products," *China Agricultural Science and Technology Herald*, vol. 21, no. 10, pp. 125–132, 2019, (in Chinese).

[9] M. Dong, "Exploration on the application of new mode of offline experience and online sales of edible mushroom product line," *Anhui Agricultural Science*, vol. 44, no. 17, pp. 275–278+282, 2016, (in Chinese).

[10] J. H. Ma, Y. M. Hou, Z. X. Wang, and W. H. Yang, "Pricing strategy and coordination of automobile manufacturers based on government intervention and carbon emission reduction," *Energy Policy*, vol. 148, Article ID 111919, 2021.

[11] C. Wang, Y. Zhou, and K. Zhao, "Internet+" sales channels of edible mushrooms combined online and offline," *Edible Mushrooms*, vol. 42, no. 4, pp. 80-81, 2020, (in Chinese).

[12] J. Wang, "Research on the construction of marketing model of edible mushroom industry in the "Agriculture 4.0 era," *China Collective Economy*, vol. 36, no. 26, pp. 54-55, 2020, (in Chinese).

[13] J. H. Ma, Y. M. Hou, W. H. Yang, and Y. Tian, "A time-based pricing game in a competitive vehicle market regarding the intervention of carbon emission reduction," *Energy Policy*, vol. 142, Article ID 111440, 2020.

[14] F. Y. Han, J. B. Zhang, and Q. M. Tong, "Enhancing the international competitiveness of edible mushrooms in China through supply-side structural reform," *Edible Mushrooms*, vol. 25, no. 5, pp. 284–289, 2017, (in Chinese).

[15] L. Y. Chen, C. H. Xu, J. Chen et al., "Problems of industrialization of edible mushrooms in China and development countermeasures," *Journal of Microbiology*, vol. 36, no. 2, pp. 101–103, 2016, (in Chinese).

[16] J. Ma and Y. Liu, "Exact solutions for a generalized nonlinear fractional Fokker-Planck equation," *Nonlinear Analysis: Real World Applications*, vol. 11, no. 1, pp. 515–521, 2010.

[17] Y. Li, "Current situation, opportunities, and challenges in the development of the Chinese edible mushroom industry-taking the road of mushroom development with Chinese characteristics and realizing the dream of a strong edible mushroom industry," *Fungus Research*, vol. 16, no. 3, pp. 125–131, 2018, (in Chinese).

[18] J. Ma and H. Ren, "Influence of government regulation on the stability of dual-channel recycling model based on customer expectation," *Nonlinear Dynamics*, vol. 94, no. 3, pp. 1775–1790, 2018.

[19] Q. Liu, H. Song, R. Chen et al., "Species concept of the staple edible mushroom Chaetomium in China," *Journal of Mycology*, vol. 40, no. 5, pp. 981–991, 2021, (in Chinese).

[20] S. Yang, D. Cheng, S. Lai, X. Li, R. Chen, and K. Zhang, "New technology for high-yield and high-efficiency cultivation of tea mushroom in long-bag stacking style," *China Horticulture Digest*, vol. 34, no. 0, pp. 191-192, 2018, (in Chinese).

[21] Q. L. Liu, "Effect of polysaccharide of the tea-salmon mushroom on functional recovery from exercise muscle fatigue," *Chinese Edible Mushrooms*, vol. 39, no. 9, pp. 69–71+75, 2020, (in Chinese).

[22] W. Zhu, X. Miao, X. Zhang, T. Xu, and B. Zhang, "Research on ultrasound-high temperature-induced thick wall spore breeding of tea mushroom," *Northern Horticulture*, vol. 41, no. 4, pp. 132–136, 2017, (in Chinese).

[23] C. Xie, H. Guo, Z. Shi, Z. Wu, and GuZhenxin, "Effect of tea mushroom fermentation on dietary fiber quality and bioactivity of wheat bran," *Food Science*, vol. 34, no. 1, pp. 230–233, 2013, (in Chinese).

[24] Z. Liu, R. Yi, W. Zhang et al., "Research on the supporting cultivation technology of the new variety of "Gucha 2" tea salary mushroom," *Journal of Agronomy*, vol. 2, no. 8, pp. 53–55+73, 2012, (in Chinese).

[25] Y. Liu, H. J. Wang, and J. Li, "Research on marketing countermeasures and development of edible mushroom industry chain based on electric business as the main body," *National Circulation Economy*, vol. 35, no. 1, pp. 111-112, 2020, (in Chinese).

[26] W. Liu, Y. Zhao, S. Song et al., "Progress and prospects of domestic and international research on tea mushroom," *China Edible Mushroom*, vol. 31, no. 3, pp. 1–5, 2012, (in Chinese).

[27] G.P. Liao, C.Y. Guan, and J. Huang, "Overview of crop growth simulation modeling," *Crop Research*, vol. 15, no. 3, pp. 45–48, 1998, (in Chinese).

[28] J. Li, "Progress in the development and application of crop growth simulation models," *Journal of Northwest Agricultural University*, vol. 62, no. 8, pp. 102–107, 1997, (in Chinese).

[29] J. Ma and L. Sun, "Complexity analysis about nonlinear mixed oligopolies game based on production cooperation," *IEEE Transactions on Control Systems Technology*, vol. 26, no. 4, pp. 1532–1539, 2018.

[30] J. P. Yang and Z. Q. Wang, "Crop growth simulation models and their applications," *Journal of Applied Ecology*, vol. 10, no. 8, pp. 501–505, 1999, (in Chinese).

[31] G. F. Arkin, R. L. Vanderlip, and J. T. Ritchie, "The dynamic grain sorghum growth model," *Transactions of the American Society of Agricultural Engineer (ASAE)*, vol. 19, pp. 622–630, 1976.

[32] C. F. De Wit, "Photosynthesis of leaf canopies," Agricultural Research Reports 663, pp. 1–57, The Netherlands Pudoc, Wageningen, The Netherlands, 1965.

[33] W. G. Duncan, R. S. Loomis, W. A. Williams, and R. Hanau, "A model for simulating photosynthesis in plant communities," *Hilgardia*, vol. 38, no. 4, pp. 181–205, 1967.

[34] J. W. Jones, G. Hoogenboom, C. H. Porter et al., "The DSSAT cropping system model," *European Journal of Agronomy*, vol. 18, no. 3-4, pp. 235–265, 2003.

[35] J. Ma and L. Xie, "The comparison and complex analysis on dual-channel supply chain under different channel power structures and uncertain demand," *Nonlinear Dynamics*, vol. 83, no. 3, pp. 1379–1393, 2016.

[36] X. Yin and H. H. Van Laar, *Crop Systems Dynamics: An Ecophysiological Simulation Model for Genotype-By-Environment Interactions*, Wageningen Academic Publishers, Wageningen, The Netherlands, 2005.

[37] T. Li, O. Angeles, M. Marcaida et al., "From Oryza 2000 to Oryza (v3): an improved simulation model for rice in drought and nitrogen-deficient environments," *Agricultural and Forest Meteorology*, vol. 237-238, pp. 246–256, 2017.

[38] W. Lou and J. Ma, "Complexity of sales effort and carbon emission reduction effort in a two-parallel household appliance supply chain model," *Applied Mathematical Modelling*, vol. 64, pp. 398–425, 2018.

[39] L. Tang, Y. Zhu, D. Hannaway et al., "RiceGrow: a rice growth and productivity model," *NJAS: Wageningen Journal of Life Sciences*, vol. 57, no. 1, pp. 83–92, 2009.

[40] B. Liu, L. Liu, S. Asseng et al., "Modelling the effects of heat stress on post-heading durations in wheat: a comparison of temperature response routines," *Agricultural and Forest Meteorology*, vol. 222, pp. 45–58, 2016.

[41] J. Ma and W. Ren, "Complexity and hopf bifurcation analysis on a kind of fractional-order IS-LM macroeconomic system," *International Journal of Bifurcation and Chaos*, vol. 26, no. 11, Article ID 1650181, 2016.

[42] C. Rosenzweig, J. W. Jones, J. L. Hatfield et al., "The agricultural model intercomparison and improvement project (AgMIP): protocols and pilot studies," *Agricultural and Forest Meteorology*, vol. 170, pp. 166–182, 2013.

[43] E. Jason, *Sweat. PHP Architect's Guide to PHP Design Patterns*, pp. 36–40, Marco Tabini& Associates, Inc, Toronto, Canada, 2005.

[44] A. Leon and S. Zeev, *Prentice Core PHP Programming*, pp. 454–457, Prentice Hall PTR, New York, NY, USA, 3 edition, 2003.

[45] I. Navarro-González, V. García-Valverde, J. García-Alonso, and M. J. Periago, "Chemical profile, functional and antioxidant properties of tomato peel fiber," *Food Research International*, vol. 44, no. 5, pp. 1528–1535, 2011.

[46] C. Shiflett, *Essential PHP Security*, pp. 1170–1174, O'Reilly Media, Inc, New York, NY, USA, 2005.

[47] L. Xie, J. H. Ma, and M. Goh, "Supply chain coordination in the presence of uncertain yield and demand," *International Journal of Production Research*, vol. 59, no. 14, 2020.

[48] C. Zhang, S. Li, J. Zhang et al., "Antioxidant and hepatoprotective activities of intracellular polysaccharide from Pleurotus eryngii SI-04," *International Journal of Biological Macromolecules*, vol. 91, pp. 568–577, 2016.

[49] M. Y. Zhang, A. M. Liao, K. Thakur, J. H. Huang, J. G. Zhang, and Z. J. Wei, "Modification of wheat bran insoluble dietary fiber with carboxymethylation, complex enzymatic hydrolysis and ultrafine comminution," *Food Chemistry*, vol. 297, Article ID 124983, 2019.

[50] B. Bao, J. Ma, and M. Goh, "Short- and long-term repeated game behaviours of two parallel supply chains based on government subsidy in the vehicle market," *International Journal of Production Research*, vol. 58, no. 24, pp. 7507–7530, 2020.

[51] Y.-H. Shon and K.-S. Nam, "Inhibition of cytochrome P450 isozymes and ornithine decarboxylase activities by polysaccharides from soybeans fermented with Phellinus igniarius or Agrocybe cylindracea," *Biotechnology Letters*, vol. 26, no. 2, pp. 159–163, 2004.

[52] F. Wu and J. H. Ma, "The chaos dynamic of multiproduct cournot duopoly game with managerial delegation," *Discrete*

Dynamics in Nature and Society, vol. 2014, Article ID 206961, 10 pages, 2014.

[53] T. Xu and J. Ma, "Feed-in tariff or tax-rebate regulation? Dynamic decision model for the solar photovoltaic supply chain," *Applied Mathematical Modelling*, vol. 89, pp. 1106–1123, 2021.

[54] C. C. Wang, S. Ma, L. Li, X. L. Zheng, and X. X. Wang, "Effect of modified dietary fibre from wheat bran on the quality of noodle," *Quality Assurance and Safety of Crops & Foods*, vol. 10, no. 1, pp. 61–68, 2018.

[55] D. K. Gupta, M. Rühl, B. Mishra et al., "The genome sequence of the commercially cultivated mushroom Agrocybe aegerita reveals a conserved repertoire of fruiting-related genes and a versatile suite of biopolymer-degrading enzymes," *BMC Genomics*, vol. 19, no. 1, p. 48, 2018.

[56] E. Morin, A. Kohler, A. R. Baker et al., "Genome sequence of the button mushroom Agaricus bisporus reveals mechanisms governing adaptation to a humic-rich ecological niche," *Proceedings of the National Academy of Sciences*, vol. 109, no. 43, pp. 17501–17506, 2012.

[57] G. Qin and J. H. Ma, "Chaos and Hopf bifurcation of a finance system," *Nonlinear Dynamics*, vol. 58, no. 1, pp. 209–216, 2009.

[58] L. Xie, J. Ma, and H. Han, "Implications of stochastic demand and manufacturers' operational mode on retailer's mixed bundling strategy and its complexity analysis," *Applied Mathematical Modelling*, vol. 55, no. 3, pp. 484–501, 2018.

[59] X. Su, Y. Wang, S. Duan, and J. Ma, "Detecting chaos from agricultural product price time series," *Entropy*, vol. 16, no. 12, pp. 6415–6433, 2014.

[60] T. Yi, H. Jun, X. Lei et al., "Coordination and control of multichannel supply chain driven by consumers' channel preference and sales effort," *Chaos, Solitons and Fractals*, vol. 132, Article ID 109576, 2020.

[61] L. Liu, T. Wang, L. Xie, and X. Zhan, "Influencing factors analysis on land-lost farmers' happiness based on the rough DEMATEL method," *Discrete Dynamics in Nature and Society*, vol. 2020, Article ID 6439476, 10 pages, 2020.

[62] L. Liu and X. Zhan, "Analysis of financing efficiency of Chinese agricultural listed companies based on machine learning," *Complexity*, vol. 2019, Article ID 9190273, 11 pages, 2019.

[63] X. Su, H. L. Liu, and S. Q. Hou, "The trilateral evolutionary game of agri-food quality in farmer- supermarket direct purchase: a simulation approach," *Complexity*, vol. 2018, Article ID 5185497, 11 pages, 2018.

[64] X. Su, S. S. Duan, and H. L. Liu, "Evolutionary games in the agricultural product quality and safety information system: a multiagent simulation approach," *Complexity*, vol. 2018, Article ID 7684185, 18 pages, 2018.