Research on Intelligent Blending Method of Matcha Based on Improved PID Control Algorithm

Kai Chen¹, Jie Yu¹, Miao Hao¹, Chengmei Zhang¹, Bing Yang¹, Hong Tan² and Yajie Wang*¹
¹ Guizhou Academy of Testing and Analysis, Guiyang, Guizhou, 550000, China
² Guizhou Academy of Sciences, Guiyang, Guizhou, 550000, China
*Corresponding author’s e-mail: wangyajie@gzbdi.com

Abstract. Most of the existing Matcha blending is done manually, which is inefficient and leads to uneven tea products. To solve this problem, this paper proposes an intelligent blending method based on improved PID control algorithm. In this paper, considering the various factors that affect the quality of tea, without affecting the quality of the product, taking the lowest cost of the enterprise as the constraint goal, the basic combination model is constructed by using PID control algorithm. Since the selection of PID parameters will affect the output of the model, this paper introduces particle swarm optimization algorithm to optimize the PID controller parameters globally, so that the PID controller can achieve the ideal control index, and finally determine the optimal combination of Matcha. The experimental results show that the method proposed in this paper can effectively realize the intelligent blending of Matcha, and maximize the cost of tea factory, effectively improve the income of Matcha products, which is conducive to the further development of tea companies.

1. Introduction

Tea is popular among consumers because of its many beneficial nutrients and ingredients. Matcha is a traditional way of drinking tea in China. High quality tea can effectively improve the drinking effect of Matcha and bring high-quality sales to consumers. The quality of tea not only depends on the variety of tea, but also closely related to blending technology. In the production of Matcha tea, blending is one of the most important processes. Tea blending refers to the combination of a variety of tea with different shapes and qualities but similar products. It is a method that can fully improve and stabilize the quality of tea and ensure the yield, and can effectively improve the economic benefits brought by tea planting. Therefore, in order to give full play to the economic value of tea, tea must be reasonably and efficiently blended.

There are few studies and reports on the control of tea blending degree. At present, tea blending mainly adopts the traditional manual blending method, which requires the blending personnel to have a higher technical level. At the same time, many tea processing enterprises receive tea varieties, quantity and the quality of finished products required for shipment are uneven, which leads to the need to develop a highly targeted blending scheme in the process of tea blending, and also need to make dynamic adjustment according to the market fluctuations, which leads to the extremely low efficiency of traditional blending methods. With the outbreak of COVID-19 and the global economy showing a significant downward trend, the pressure of financial pressure on tea enterprises has increased...
dramatically. Therefore, an intelligent blending method is urgently needed to replace the traditional artificial blending method, which reduces processing costs and improves economic returns.

In recent years, the manufacturing industry has gradually realized the intelligent technology. The application of intelligent technology in tea blending will greatly improve the blending efficiency and reduce the production cost. In this paper, the PID control algorithm is applied to tea blending technology, and the parameters of PID control are optimized by particle swarm optimization algorithm. Finally, the optimal tea blending scheme is solved with the enterprise cost as the constraint. The method proposed in this paper can help tea enterprises to develop intelligent tea blending scheme, promote tea enterprises to complete technological upgrading, and then expand profits to achieve industrial upgrading.

2. Tea Blending Technology

2.1. Basic Principles
Tea blending is an important process in tea processing, and it is also an important method to maintain the quality of tea. Tea blending is based on the finished tea, the sifted tea from different raw materials, according to the blending ratio, finally combined into a specific grade of finished tea. In the process of tea blending, we should not only consider the economic interests of enterprises, but also ensure the quality of tea. Therefore, blending is a complex technology. Accurately controlling the quality of blending is the key to adjust the quality of tea, stabilize the quality of tea, give play to the economic value of tea and improve the economic benefits. At present, the tea blending is usually carried out by the blending personnel. First, the sensory evaluation of each raw material tea is carried out. Then, based on their own experience, they try to make a small sample and make appropriate adjustments, and finally determine the blending scheme. Therefore, the results of different batches are accidental, which is not conducive to the standardization of tea production.

2.2. Quality Factors and Rating Standards of Tea
In the evaluation of tea blending degree, single identification method can not fully reflect the quality of tea. Therefore, in the process of tea blending, the blending personnel should consider multi index information and use intelligent methods to realize tea blending, which is the development trend of tea blending technology in the future.

Taking a tea factory as an example, this paper expounds the quality factors and rating standards of tea. The intelligent blending method analyzed in this paper mainly takes the initial sensory quality of tea evaluators, that is, the conclusion from the "eight factor tea evaluation method", as the reference standard of tea rating. The evaluation content includes "dry evaluation of appearance" and "wet evaluation of internal quality". "Dry evaluation appearance" includes "Granule", "fragmentation", "clarity", "color", and "wet evaluation endoplasm" includes "soup color", "aroma", "taste" and "leaf bottom". The sensory quality standard of Matcha from a tea factory is shown in Table 1.

| Grade     | Appearance                                      | Soup color          | Aroma               | Taste             | Leaf                          |
|-----------|------------------------------------------------|---------------------|---------------------|-------------------|-------------------------------|
| Superior  | Disc flower like particles, uniform and heavy, green and moist, with a trace | Bright yellow and green | Rich chestnut fragrance | Thick and fresh | Soft, bright yellow and green, complete buds and leaves |
| superfine | Flower like particles, more uniform, green, more moist, hidden hair | yellow and green, bright | Relatively rich with chestnut fragrance | Mellow | Soft, bright green, complete buds and leaves |
3. Improved PID Control Algorithm

3.1. The Basic Principle of the Algorithm

PID control algorithm constructs the control deviation according to the difference between the given value \( g \) and the actual output value \( g(t) \)

\[
e(t) = g - g(t)
\]

(1)

Then, the linear control output \( y(t) \) is formed by the deviation \( e(t) \) through proportional link (P), integral link (I) and differential link (D), and the controlled object is regulated.

The continuous form of the algorithm is as follows

\[
y(t) = K_p e(t) + K_i \int_0^t e(t) dt + K_d \frac{de(t)}{dt}
\]

(2)

Where \( K_p \) is the proportional coefficient, \( K_i \) is the integral coefficient, \( K_d \) is the differential coefficient, \( y(t) \) is the control output, \( e(t) \) is the deviation term.

The functions of each link of PID control algorithm are as follows [1-3]

1. Proportional link: once the deviation is generated in the system, the deviation amount will be proportionally reflected, and the control algorithm will immediately play a role, so as to reduce the deviation.

2. Integral link: its function is to reduce the static error of the system and improve the control level of the system. The size of the integral constant determines the strength of the integral effect. The larger the integral constant, the stronger the integral effect. The smaller the integral constant, the weaker the integral effect.

3. Differential link: the change trend of system deviation can be reflected in this link, and an effective correction signal can be introduced into the system in advance before the deviation signal value becomes too large, so that the action speed of the system can be accelerated, and the control time will be reduced.

The variables analysed in this paper are all discrete factor variables, so the discrete form of PID is as follows:

\[
y(n) = K_p \varepsilon(n) + K_i \sum_{m=0}^n \varepsilon(m) + K_d [\varepsilon(n) - \varepsilon(n-1)]
\]

(3)

Figure 1. The principle of PID control process
The principle of PID control process is shown in Figure 1. Figure 1 is the process diagram of dynamic processing of the error between the given value and the output value. When the PID control algorithm works, if the given value is different from the controlled object value, there will be an error. The error $\epsilon(t)$ forms the output value $y(t)$ through the proportional link, the integral link and the differential link, and reacts on the control object through $y(t)$ to make the output value of the controlled object close to the given value and reduce the error.

3.2. Improvement of PID Control Based on PSO

3.2.1. Selection of evaluation index

The ideal PID control system can fully meet the control performance requirements of the controlled object. But in practical application, due to the influence of various interference factors, the actual control effect cannot fully meet all the requirements, so we can only seek a balance among various control requirements to achieve the best control effect. The control effect is decided by the performance index of the control system. However, there are some characteristics between the performance indexes, such as mutual coupling and mutual constraint. The optimization of a single index may cause the deterioration of other performance indexes, resulting in the reduction of control performance. In the parameter tuning of PID controller optimized by swarm intelligence algorithm, the performance index function, as the fitness function of the algorithm, determines the judgment method of the optimal value of the algorithm. In the algorithm, all individuals are the parameter combination of PID controller. The fitness values of all individuals are calculated by using the performance index function. The advantages and disadvantages of PID controller parameter combination are judged by comparing the fitness values, and then the individual with the optimal fitness value is selected as the global optimal parameter combination at the current iteration number. Integrated time absolute error (ITAE) evaluation index can identify the change of PID control parameters, and can accurately judge the pros and cons of individuals in the intelligent algorithm. Therefore, this paper uses ITAE evaluation index as the fitness function of the algorithm, the calculation formula is as follows:

$$ITAE = \int_0^T t|\epsilon(t)|dt$$  (4)

The evaluation standard is to integrate the product of the absolute value of steady-state error and time, so that PID control has strong stability and short dynamic response time, and can identify the control system with different parameters.

3.2.2. PID parameter optimization based on PSO

The central idea of particle swarm optimization (PSO) is to use the cooperation and sharing of the global optimal position among particles to search the global optimal solution of the optimization problem. In the algorithm, the position of all individual particles is the solution of the problem to be optimized. The fitness function is used to calculate the fitness value of particles, and the position of particles is judged by comparing the fitness values of all individuals. When all the individuals move in the space of the solution of the problem to be optimized, the direction and distance of the particles in each iteration depend on a velocity variable. In the algorithm, all individuals update their positions with the current global optimal particle position and the individual historical optimal position as the goal. Through the continuous update of the individual position and the optimal position, the particles gradually approach the optimal position in the search space [4-6].

In the process of optimizing PID parameters by PSO, each particle is used as the parameter combination of PID controller. The position component of particle in different dimensions is changed continuously through the update formula of speed and position, that is, the three parameter values of PID controller. The fitness value of each particle is judged by the control system evaluation index function, and the particle with the optimal fitness value is retained. The global optimal value is updated through continuous iteration. The particle with optimal fitness converges optimally and outputs the optimal particle, that is, a group of PID parameters with the best control performance.
4. Application Model of Improved PID Control Algorithm in Matcha Blending

The process of constructing Matcha blending with improved PID control algorithm is as follows:

(1) The initial weight of tea combination was determined. Assuming that the eight quality data of the selected tea samples conform to the Markowitz hypothesis, the initial weight of the combination is determined by the mean variance model.

(2) Establishing the cost expenditure model of the tea blending combination.

\[ C_{NQ} = \sum_{q=1}^{8} X_{Nq} C_{Nq} \]  

Where \( X_{Nq} \) is the weight of quality, \( C_{Nq} \) R is the combination cost of different teas, and \( C_{Nq} \) ran is the cost of each combination.

(3) The difference between the cost \( C \) of the combination and the expected cost \( C_{NQ} \) is as follows:

\[ \epsilon(t) = C - C_{NQ} \]  

(4) After the generated deviation \( \epsilon(t) \) acted by PID control algorithm, a control output \( y(N) \) is generated

\[ y(N) = K_p \epsilon(n) + K_i \sum_{j=0}^{N} \epsilon(j) + K_d [\epsilon(N) - \epsilon(N-1)] \]  

(5) According to the value of control output \( y(N) \), the weight \( X_{Nq} \) of tea quality in blending combination was adjusted to realize the rebalancing of blending weight.

\[ k_{Nq} = \frac{X_{Nq(N-1)}}{N} \]  
\[ X_{Nq} = k_{Nq} y(N) + X_{Nq(N-1)} \]

5. Experimental Results

In this paper, according to the actual situation of tea blending, a comparative experiment is designed.

![Figure 2. The experimental results](image-url)
The proposed method is compared with the traditional manual blending method and a single PID control algorithm. The time and final blending cost are observed respectively. The purpose of the experiment is to compare the differences of the three methods and the influence of the change of the number of samples on the efficiency of the algorithm. The experimental results can be seen in Figure 2.

As can be seen from Figure 2, with the increase of data samples, the time and cost of manual operation also increase linearly. After the PID control algorithm is applied to tea blending, the time consumption is significantly reduced, and it does not change much with the increase of data, and the cost is also slightly reduced. When the improved PID control algorithm is used for tea blending, the time is the least and the cost is the least. Therefore, it can be concluded that, in general, the improved PID control algorithm proposed in this paper has higher efficiency and less cost than the manual matching method, and overcomes the problem that the parameters of the original PID algorithm are difficult to select. The method proposed in this paper can effectively improve the efficiency of tea blending, reduce the working time and reduce the cost of enterprises.

6. Conclusion

In view of the shortcomings of traditional tea blending, this paper introduces PID control algorithm to realize intelligent tea blending, and uses particle swarm optimization algorithm to optimize the parameters of PID control algorithm. The tea blending work is solved by intelligent data processing method, which is more efficient and accurate than traditional manual method in the actual production of tea enterprises, and also provides efficient tea blending service for tea enterprises. The blending method has good economic benefits and is conducive to promoting the long-term development of tea enterprises. In the next step, we can consider the combination of market fluctuations and consumer psychology to deeply explore the existing tea blending methods, and further study the processing scheme of tea blending for different volume enterprises.

Acknowledgments

This work was supported by Scientific and Technological Project of Guizhou Province (20201Y147) and National Key Research and Development Program of China (2017YFC1601806)

References

[1] Juang, J., Huang, M. and Liu, W. (2008) PID Control Using Presearched Genetic Algorithms for a MIMO System. IEEE Transactions on Systems, Man, and Cybernetics, Part C (Applications and Reviews), 38(5): 716-727.
[2] Meng, F., Liu, S. and Liu, K. (2020) Design of an Optimal Fractional Order PID for Constant Tension Control System. IEEE Access, 8: 58933-58939.
[3] He, Y. and Wang, Q. (2006) An Improved ILMI Method for Static Output Feedback Control With Application to Multivariable PID Control. IEEE Transactions on Automatic Control, 51: 1678-1683.
[4] Jia, L. and Zhao, X. (2019) An Improved Particle Swarm Optimization (PSO) Optimized Integral Separation PID and its Application on Central Position Control System. IEEE Sensors Journal. 19(16): 7064-7071.
[5] Puchta, E. D. P., Siqueira, H. V. and Kaster, M. d. S. (2020) Optimization Tools Based on Metaheuristics for Performance Enhancement in a Gaussian Adaptive PID Controller. IEEE Transactions on Cybernetics, 50(3): 1185-1194.
[6] Qi, Z., Shi, Q. and Zhang, H. (2020) Tuning of Digital PID Controllers Using Particle Swarm Optimization Algorithm for a CAN-Based DC Motor Subject to Stochastic Delays. IEEE Transactions on Industrial Electronics, 67(7): 5637-5646.