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Research on the realization of food packaging design innovation and production efficiency improvement based on digital simulation technology

Yuehui Ye[1], Ziming Ye[2,✉], Lushan Guo[1], Huiqun Zhuo[1]

[1] *Horsh (Fujian) Food Co., Ltd., Zhangzhou, Fujian, 363000, China*

[2] *Academy of Arts, Minnan Normal University, Zhangzhou, Fujian, 363000, China*

ABSTRACT
Based on digital simulation technology, this paper proposes a food packaging design model and a food production efficiency improvement model with food production as the research entry point. Establish the overall structure of the virtual reality design environment, the parameters of the packaging design process is converted into basic parameters to describe the problem, and the data is fed back to the CAD system to realize the design work. Design the hybrid optimization genetic algorithm based on annealing principle, adjust and optimize the production process and initialize the operation, simulate the annealing genetic algorithm process, and complete the production and processing scheduling sequence. Take A Food Co., Ltd. as the research object to carry out food packaging design and production efficiency improvement practice. The egg cake product packaging design scheme constructed by using the packaging design method in this paper obtains the total attention time of the subjects to be 149.3s, and the subjective score value reaches 85 points, which is better than the original packaging design. And in the real simulation of production using the production efficiency improvement method of this paper, the total production process operating time percentage is reduced from 73.8% to 35.1%, and the food production capacity is steadily increased by about 6%.

Keywords: digital simulation technology, virtual reality technology, genetic algorithm, annealing principle, food production

1. Introduction

Packaging is a comprehensive reflection of the brand concept, product characteristics, consumer psychology, it directly affects the consumer's desire to buy, especially in people's consumer demand continues to improve today, and people's daily life is closely related to food packaging design, has become an important issue that the business community, designers have to pay attention to [1-4], food

✉ Corresponding author.
E-mail address: 13850405216@163.com (Z. Ye).
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packaging design is no longer just a previous In order to meet the easy to use, easy to transport, ensure hygiene, convey commodity information, promote sales and other simple functions [5-7], food packaging to meet the simple functional applications, but also need their own emotions to be respected, the personality to be manifested, the feelings to be communicated, so our food packaging design [8-10], we should also be Keep up with and adapt to the development of the times, innovation and personalization, and give the packaging design a different character and modern fashion consciousness [11-12].

Innovative and reasonable product packaging design can not only increase product sales and market share, but also effectively improve production efficiency. By reducing the use of packaging materials, selecting appropriate materials, standardizing packaging design, applying automated packaging equipment, optimizing the packaging process and rationally arranging the connection between packaging and production process [13-16], we can effectively improve the production speed and production efficiency of the enterprise, and give full play to the important role of packaging in the development of the enterprise. At the same time, through these measures, can also reduce packaging costs, improve product quality and meet environmental requirements, and further enhance the competitiveness of enterprises and market share [17-20].

In this paper, a food packaging design model based on virtual reality technology and a food production efficiency enhancement model based on digital simulation are respectively constructed to realize the innovation of food production related links. A new virtual reality-based food product appearance design method is proposed to build the overall structure of the virtual reality design environment, utilize the data mining method to realize the conversion of the designer's knowledge description, construct the parameter conversion matrix, and obtain the product appearance evaluation results through the evaluator to obtain the optimal food packaging design scheme. Hybrid optimization genetic algorithm based on annealing principle adopts the dual coding method based on processing process and based on processing machine, and solves the optimal production scheduling by annealing genetic algorithm calculation. After verifying the performance of the above model through experimental tests, the food packaging design and production efficiency improvement practice is carried out with A Food Co. Ltd. as the research object, and the newly designed food packaging is evaluated by combining eye movement experiment and subjective evaluation, and the production efficiency improvement effect is analyzed in terms of operation efficiency and production line capacity.

2. Food production based on digital simulation technology

Digital simulation technology is based on a variety of disciplines and theories, computer and software as a tool, through the establishment of mathematical models and algorithms, the real world systems, processes or phenomena for accurate modeling and efficient computational simulation, according to the actual needs of the selection of appropriate modeling methods and theories, to ensure the accuracy and completeness of the model in order to analyze and solve problems of a comprehensive technology. The core of digital simulation technology is mathematical models and computer algorithms, mathematical models are abstractions and descriptions of the real world, including physical equations, statistical models, optimization models.

Digital simulation technology includes CAD, CAE, numerical simulation, virtual reality, augmented reality, digital twin and so on.

This paper focuses on the application of digital simulation technology in food packaging design and production research ideas, dedicated to the realization of food packaging design innovation and food production efficiency.

1) Food packaging design based on virtual reality technology. A new collaborative food packaging design method based on virtual reality under human-computer interaction is proposed to give the overall structure of the virtual reality design environment, and the constraint-compliant solutions are

solved to obtain the best food packaging design solution.
2) Food production based on digital simulation. Design a hybrid optimization genetic algorithm based on the annealing principle to solve the food production scheduling scheme with the shortest maximum processing time, build up a food production line simulation system, realize the three-dimensional animation simulation of food production, and improve the efficiency of food production.

In the following chapters, the food packaging design based on virtual reality technology and the food production based on digital simulation will be explained and studied, and the food packaging design method and food production efficiency improvement method designed in this paper will be applied to the actual food production process.

3. Virtual reality-based food packaging design models

3.1. Overall architecture of virtual reality design environment

The key to product appearance design in a virtual reality environment is to shape the virtual environment in which the product model works. Based on virtual reality technology, the overall structure of the virtual reality environment designed in this section is depicted in Figure 1 [21].

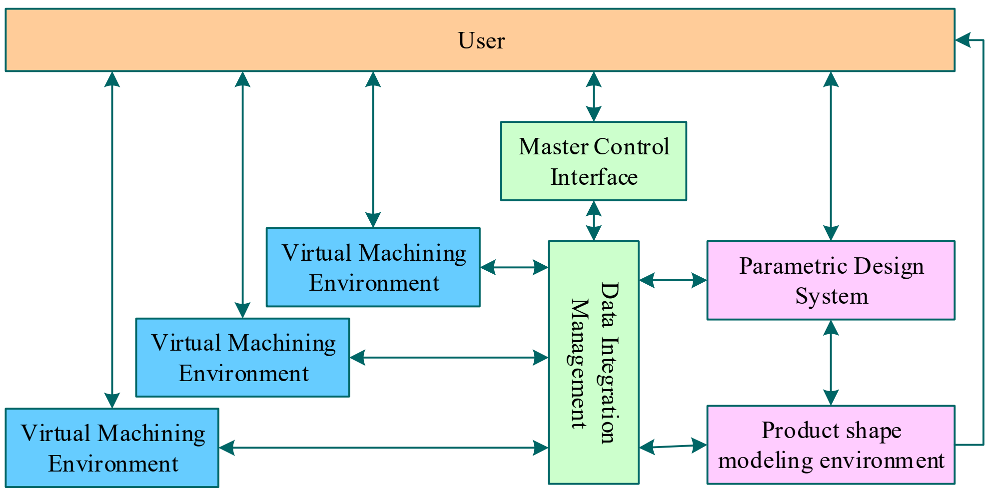

Fig. 1. Overall structure of virtual reality design environment

Virtual reality environment through virtual reality technology to shape the three-dimensional environment, in the design of product appearance through CAD technology, the design model can be imported into the virtual reality environment in order to adjust the parameters related to the appearance of the product, the designer to get satisfied with the design scheme, you can exit the virtual reality environment, will be the final design data feedback to the CAD system, so as to realize the appearance of the product design [22].

3.2. Collaborative product appearance design under human-computer interaction

In the virtual environment, when computers cannot effectively simulate human intelligence, it is necessary to combine man and machine together to collaboratively realize the design of product appearance. For this reason, this section proposes a collaborative product appearance design method under human-computer interaction, which regards the product appearance design process as a constraint judgment and solution process.

When designing the product appearance, the computer is mainly responsible for solving the solutions that meet the constraints, handing over the complicated computation work to the computer and the decision-making work to the designer, so that the two can collaborate to design the product

appearance and obtain the best design solution.
1) Description conversion of designer's knowledge. Assuming that the j nd technology is described by $e_{ij}\left(1<i<n,1<j<k\right)$ and that there exist a total of k technologies capable of converting the i th innovation element to a functional parameter, a collection of conversion technologies can be formed:

$$E=\left[E_1,E_2,\cdots,E_n\right]^{\mathrm{T}} \tag{1}$$

Eq. $E_i=\left[e_{i,i},e_{i2},\cdots,e_{ij},\cdots,e_{il}\right]$. Based on the designer's knowledge category, the data mining method is utilized to realize the designer's knowledge description conversion through various description conversion methods and rules.
2) Design parameter determination. The parameters involved in the process of product design can be transformed into basic parameter description problems, and the formula can be described as:

$$X=AX_0 \tag{2}$$

Where $X_0=\left(x_{10},x_{20},\cdots,x_{j0},\cdots,x_{n0}\right)^T$, $X_0\in R^n$, x_{j0} describe the functional parameters in the product design, and A describes the parameter conversion matrix, which is calculated by the following formula:

$$A=\left(a_{ij}\right)_{m\times n}=\begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{n2} \\ \vdots & \vdots & \ddots & \vdots \\ a_{m1} & a_{m2} & \cdots & a_{mn} \end{bmatrix} \tag{3}$$

Because there is a certain relationship between different product design parameters, so there is a contradiction between them, the product design process that is the process of resolving parameter conflicts. The whole solution process can be realized through the product design problem solving state space:

$$F\left(X\right)=\left[-x_i,x_j\right]=-\begin{bmatrix} x_1 & \cdots & x_1 \\ x_2 & \cdots & x_2 \\ \vdots & \ddots & \vdots \\ x_m & \cdots & x_m \end{bmatrix} \tag{4}$$

where $\left[-x_i,x_j\right]$ is used to describe the conflict resolution matrix between parameters x_i and x_i, and $F\left(X\right)$ is used to describe the operation that generates the conflict resolution and problem state transformation.

The above analysis leads to the following solution state space for the innovation design problem, which can be described by the following tuple, $P:X_s,X_r$, where X_s is used to describe the initial problem state vector:

$$X_s=\left[x_{1s},x_{2s},\cdots,x_{ms}\right]^T \tag{5}$$

That is, the designer's initial expectation of the product design solution. X_r represents the solution of the design problem through the TRIZ Contradiction Relationship Matrix with the following formula:

$$X_r=\left[x_{1r},x_{2r},\cdots,x_{mr}\right]^T \tag{6}$$

Based on the above analysis, the semantic model of the designer's knowledge can be described by the binary group $\left(X_s,X_r\right)$, and the best design solution can be obtained by the evaluator to obtain the evaluation results of the product appearance.

3.3. Experimental test analysis

In general, the market demand for food packaging design shows diversity. In this section, diversity will be used as an index to measure the design performance of the food packaging design methods in this paper, and the SPA algorithm-based design method and the FPGA-based design method are selected as comparison objects. The diversity performance of each method is specifically shown in Figure 2. As can be seen from the figure, the diversity of food packaging design of this paper's method fluctuates smoothly and is always greater than the level of 92%, and the diversity level is significantly better than that of the SPA method and the FPGA method.The diversity of the food packaging design of the SPA method and the FPGA method both show large fluctuations, with the diversity of the former reaching a maximum of 89.05% and the minimum of 66.38%, while the latter diversity highest is 78.04% while the lowest is only 57.51%.

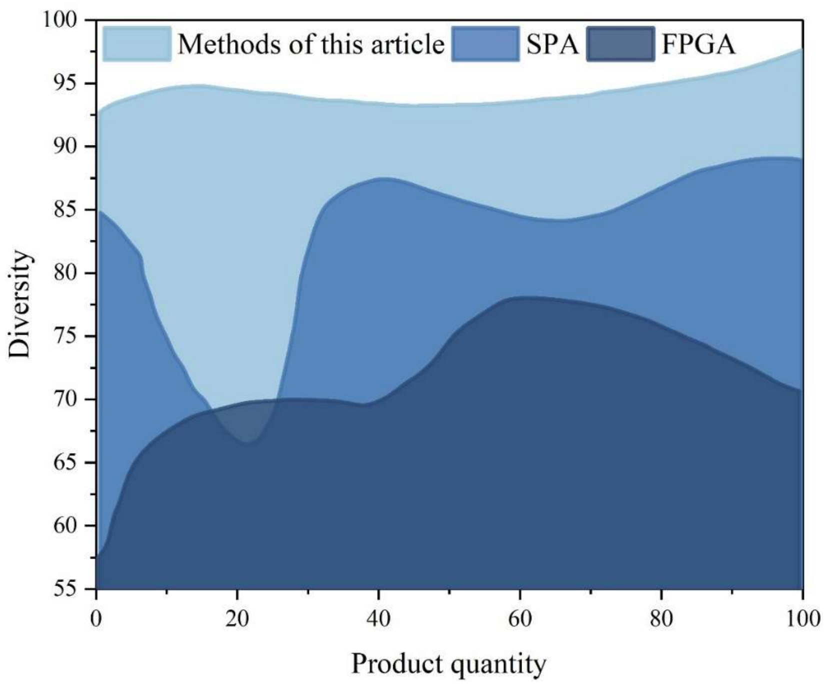

Fig. 2. Diversity

4. Digital simulation-based model for food production efficiency improvement

4.1. Production line scheduling and reconfiguration design

The workshop production line is described as follows, the production line needs to process n workpiece, the workpiece is denoted by J, and the set of workpieces is $J=\{J_1,J_2,\ldots,J_n\}$, the number of machining machines available in the workshop is m, and the machining machine is denoted by M, and the set of machines is $M=\{M_1,M_2,\ldots,M_m\}$, and the machining of each workpiece J needs to be done through a number of processes, O_{ij} denotes the jth process of workpiece i, and the set of processes is denoted by $O_{ij}=\{O_{i1},O_{i2},\ldots,O_{it}\}$, and t is the total number of machining processes of workpiece i, and the number of machining processes of a workpiece can be done by several machines, and the corresponding machining time on these machines is C_{ijk} known. A certain machining process of a workpiece can be completed by a number of machines and the corresponding machining time C_{ijk} on these machines is known, and k represents the jth process of workpiece i to be machined on machine k.

Optimizing the completion time can improve the efficiency of the production line, optimizing the delivery time can ensure that the order is completed on time, optimizing the machine idle time can avoid the phenomenon of wasteful machine waiting, and improve the utilization rate of machines and production resources. According to the actual production needs, the objective function needs to be set, and the objective function is also the evaluation standard of the algorithm calculation. In this paper, we use the most common evaluation index of the scheduling problem, the maximum processing time is the shortest. The objective function is:

$$F = Min\left(Max\left(F_1, F_2, \ldots, F_n\right)\right) \tag{7}$$

Let $C_{o_{i,j},k}$ denote the moment when the process j of the workpiece i leaves the processing machine k, t is the total number of processes for the workpiece i, and the workpiece processing process is $O_{ij} = \{O_{i1}, o_{i2}, \ldots, O_{it}\}$. $P_{O_{i,j},k}$ is the time required for the process O_{ij} of the workpiece i to be processed on the machine k, and is a fixed value. Z_{ij} is the set of machining machines available for the jth process of the ith workpiece. The total machining time of the production line is $C_{o_{i,j},k}$ the maximum value $(i = 1, 2, \ldots, n)$:

$$\sum_{k=1}^{m} Y_{ij,k} = 1 k \in Z_{ij} \tag{8}$$

$$C_{O_{ij},k} \le C_{\max} i = 1, 2, \ldots n \tag{9}$$

$$C_{O_{ij},k1} + P_{O_{i(j+1)},k_2} \le C_{O_{i(j+1)},k_2} \tag{10}$$

$$C_{O_{ij},k} \ge 0 i = 1, 2, \ldots n, k = 1, 2, \ldots m \tag{11}$$

$$C_{O_{ij},k} - P_{O_{ij},k} \ge 0 i = 1, 2, \ldots n, k = 1, 2, \ldots m \tag{12}$$

4.2. Simulated annealing genetic algorithm design

4.2.1. Coding Design and Initialization Operations. In this problem, two issues need to be addressed: workpiece process selection and machine selection. Process selection determines the sequence of all the processes of all the workpieces, and machine selection determines on which machine a particular process of a particular workpiece is processed. Therefore, in this thesis, process and machine are coded separately, and the coded chromosome is divided into two parts, process selection part and machine selection part.

1) Process-based coding. The contents of the processes are stored in a primitive matrix, where each row corresponds to an artifact and each column corresponds to the process of that artifact, so that element O_{ij} of row i and column j corresponds to the jth process of artifact i. Raw matrix E is represented as follows:

$$E = \begin{bmatrix} O_{11} & O_{12} & \cdots & O_{1t} \\ O_{21} & O_{22} & \cdots & O_{2t} \\ \vdots & \vdots & & \vdots \\ O_{n1} & O_{n2} & \cdots & O_{nt} \end{bmatrix} \tag{13}$$

The genes for the arrangement of the processes are also stored in a matrix X of the same latitude as E. The numbers in matrix X and in the corresponding positions of matrix E represent the order of the process throughout the machining process, as an example.

$$E_1 = \begin{bmatrix} O_{11} & O_{12} \\ O_{21} & O_{22} \end{bmatrix}; X_1 = \begin{bmatrix} 1 & 3 \\ 2 & 4 \end{bmatrix} \tag{14}$$

2) Processing machine-based coding. The contents of the processing machine are stored in a raw matrix, the rows correspond to the processes (processes are strictly corresponding, i.e., according to

the process arrangement matrix X, the first row corresponds to the first process, and so on, the total number of processes is h), the columns correspond to the processing machine, then the h rows of k columns of the element $P_{o_{i,j,k}}$ corresponds to the processing time of process O_{ij} in the kth machine, the raw matrix of machine processing P is expressed as follows, where a process cannot be processed by a certain processing machine, then the corresponding $P_{o_{i,j,k}}$ is 0:

$$P = \begin{bmatrix} P_{O_{i1,j1},1} & P_{O_{i1,j1},2} & \cdots & P_{O_{i1,j1},k} \\ P_{O_{i2,j2},1} & P_{O_{i2,j2},2} & \cdots & P_{O_{i2,j2},k} \\ \vdots & \vdots & & \vdots \\ P_{O_{ih,jh},1} & P_{O_{ih,jh},2} & \cdots & P_{O_{ih,jh},k} \end{bmatrix} \tag{15}$$

The arrangement genes of the processing machines are stored in a processing machine selection matrix Y of the same latitude as P. When the number of corresponding positions in matrix Y and matrix P is 1, the corresponding processing machine is selected for that corresponding process, and when it is 0, it means that the processing machine is not selected, as an example, selections E_1 and X_1 are the original process matrix and the process arrangement matrix.

$$P_1 = \begin{bmatrix} a_1 & b_1 & 0 & 0 \\ 0 & a_2 & b_2 & 0 \\ a_3 & 0 & b_3 & 0 \\ 0 & 0 & a_4 & b_4 \end{bmatrix}; Y_1 = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \tag{16}$$

Initialization of the genetic code is performed separately for process selection and machine selection.

(1) Initialization of process alignment matrix X

The number of all processing processes is h, and h consecutive integers are randomly generated $1 \sim h$, and then these h integers are randomly assigned to a corresponding position in matrix X with the same latitude as the original process matrix E.

Randomly initialize the process arrangement matrix to X'_a, analysis shows that process O_{12} can not be in front of O_{11}, so after bubble sorting to get the legal processing process arrangement, after replacement to get the matrix X_a:

$$X'_a = \begin{bmatrix} 3 & 1 \\ 4 & 2 \end{bmatrix} \rightarrow X_a = \begin{bmatrix} 1 & 3 \\ 2 & 4 \end{bmatrix} \tag{17}$$

The bubble sorting algorithm is as follows, t represents the number of work processes of a certain workpiece, due to the strict determinism of the process order, it is possible to destroy the legitimacy of the process matrix after each transformation operation, so after each crossover and mutation transformations, each row of the process arrangement matrix should be bubbled sorted to restore the legitimacy of the process matrix X.

(2) Initialization of processing machine selection matrix Y

Set the workpiece a of the ith process on the machine k start time is T_{ai}, processing time is $P_{o_{ai,k}}$, the completion of the moment is $C_{o_{ai,k}}$. Processing time matrix T, can be obtained through the machine selection matrix Y and machine processing time matrix P:

$$T = P.Y^T \tag{18}$$

The data on the main diagonal of the machining time matrix T is the machining time for each process. Finally, according to the process selection matrix x, each process is arranged to the corresponding processing machine, and the total time for processing each workpiece can be calculated by analysis F_i.

4.2.2. Simulated annealing genetic algorithm process. In this paper, genetic algorithm and simulated annealing algorithm are combined to solve the production line scheduling problem using hybrid optimization strategy [23-24].

Calculate the fitness of the newly generated offspring, which is recorded as f, and the fitness of the parent generation is recorded as $\tilde{f}$. Accept the new individual when $f > \tilde{f}$, otherwise accept the new individual with a certain probability, the probability formula is:

$$p = \exp\left(\left(f - \tilde{f}\right)/T\right) \tag{19}$$

Where T is the control parameter, equivalent to temperature in thermodynamics, which decreases by a fixed decay factor. Exp denotes the natural exponent. The formula shows that as the temperature T decreases, p decreases gradually, and since $f - \tilde{f}$ is always less than 0, the natural exponent takes a value in the range of $(0,1)$.

By using genetic algorithm and simulated annealing algorithm, both of them are combined, genetic algorithm searches globally and simulated annealing algorithm enhances its local searching ability, which enables to obtain a better solution. Therefore, by hybrid optimization algorithm to solve the production line processing scheduling problem, the steps are represented as follows.

Step 1, initialize parameters such as temperature, crossover probability, mutation probability, coefficient of desuperheating, number of initial populations, and number of iteration generations.

Step 2, according to the set process-based coding and processing machine-based coding, initialization operations are performed on the primordial genes, respectively, to randomly generate the initial population for the processing line scheduling problem.

Step 3, selection, crossover, and mutation operations are performed on the chromosomes of the parent to calculate the fitness f of the process-coded and machine-coded genes of the offspring individuals.

Step 4, for the fitness of the offspring individual, compare it with the fitness $\tilde{f}$ of the parent individual, $f > \tilde{f}$ then accept the individual to form a new population, $f < \tilde{f}$, then analyze it by simulated annealing algorithm and accept the individual to form a new population with probability $p = e^{\left(f-\tilde{f}\right)/T}$.

Step 5, determine whether the maximum number of iterations is reached, if satisfied, end the program, otherwise carry out the cooling operation, $T_{new} = \alpha T$, where α is the attenuation coefficient, return to step 3.

Step 6, the program ends and outputs the approximate optimal solution.

4.3. *Experimental test analysis*

It is known that the food production efficiency improvement model based on digital simulation proposed in this paper incorporates simulated annealing genetic algorithm, in order to further verify its specific effect of improving food production efficiency, this section selects the standard genetic algorithm as a comparison, and sets the relevant parameters, and no longer performs the annealing operation. The iteration of this paper's method and the standard genetic algorithm is shown in Figure 3. As can be seen from the figure, the processing time of this paper's method is below 100 min during the iteration process, while the standard genetic algorithm does not start to stabilize the processing time within 100 min until 104 iterations. In addition, the method in this paper in the iteration to 85 times, the processing time will show a stable performance, basically stable at about 55min, while the standard genetic algorithm to 130 iterations to stabilize, and the processing time stabilized at about 87min. Through the analysis, it can be seen that due to the introduction of the annealing principle, the method in this paper can have a better solving ability under the same number of iterations, and the performance is better than the standard genetic algorithm.

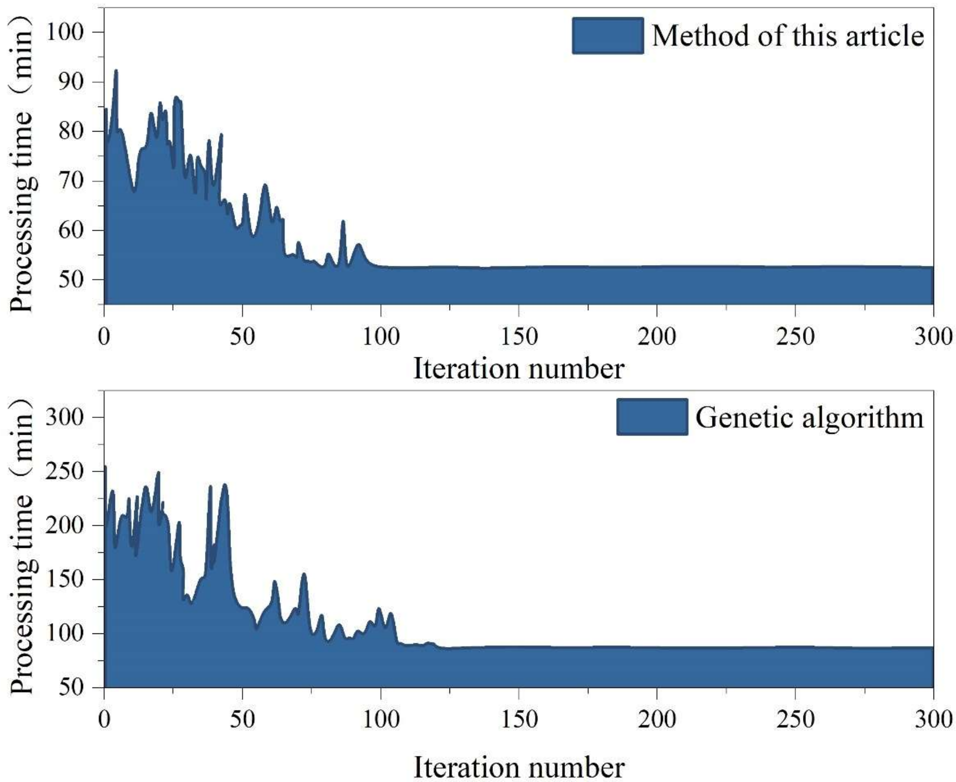

Fig. 3. Iteration

5. Food packaging design and productivity improvement practices

Company A is a 100-year-old manufacturer of confectionery products with more than 400 types of products. However, with the increasingly fierce market competition in the food industry, Company A's confectionery products are facing problems such as outdated packaging design, inability to attract young consumers and low production efficiency due to irrational production processes. The research of this topic is to take A Food Co., Ltd. as the research object, using the food packaging design model and food production efficiency model proposed in this paper, respectively, to carry out packaging design innovation for the confectionary products of A Company, and improve and optimize its food production efficiency.

5.1. Evaluation of food packaging design

Using the food packaging design methodology in this paper, a food packaging design for an egg cake product of A Foods Co., Ltd. was developed, and the design solution was named “Option 1”, while the original packaging design solution for the product was named “Option 2”. The method of eye-tracking experiment was used to analyze the subjects' attention to each food design solution by accurately capturing their gaze trajectories when observing the food design solutions and combining them with subjective evaluation.

1) Subject population. The total number of subjects was 12 people, aged between 18-40 years old. The 12 people were divided into two groups: school students with art skills and the general population without art skills. In each category, 6 subjects were selected to be tested, and all the participants in the evaluation experiment had normal visual acuity or corrected visual acuity.

2) Experimental equipment. In the screening program, the main equipment used is a combination of hardware equipment wearable TOBII eye movement device and software equipment ErgoLAB human-computer environment synchronization platform.

3) Experimental objects. The experimental object to A company of an egg cake product of the original

food packaging design “program two”, and the application of this paper's food packaging design method designed by the food packaging “program one”.

4) Analysis of evaluation results. The eye movement experimental data of 12 subjects were counted, and their gaze lengths when gazing at different food design solutions were recorded, and immediately after the subjects' eye movement was in the test, a subjective questionnaire was administered to the subjects, so that they could score the experimental different food packaging design solutions out of 10 points respectively. The subjects' gaze market and subjective scores for the different food packaging design schemes are shown specifically in Table 1. Calculated according to the total attention time of each scheme, the total attention time of Scheme 1 is 149.3s when adding up the attention time of 12 subjects, while the total attention time of Scheme 2 is 55.4s. Obviously, the newly designed egg cake product packaging by applying this paper's food packaging design method has a relatively greater attraction for the subjects, and the total attention time is higher than that of Scheme 2 (93.9s), while the total attention time of subjects is higher than that of Scheme 2 (93.9s). 93.9 s. As for the subjective scoring of the food packaging design by the subjects, the total score of Scheme 1 is 85 points and the total score of Scheme 2 is 63 points, which is 34.92% higher than that of the former. In terms of the subjects' individual scoring, Option 1 gave four highest scores of 9 points, while Option 2 gave relatively low scores except for the highest score of 8 points, and the rest of the subjects gave relatively low scores. From the subjective scoring data, it can be seen that the subjects were more satisfied with Scheme I. The new egg cake product packaging design designed by the food packaging design method in this paper is more aesthetically pleasing to consumers and is more likely to be favored by consumers.

Table 1. Time of observation and subjective score

Subjects	Time of observation (s)		Subjective score	
	Plan 2	Plan 1	Plan 2	Plan 1
1	7.3	13.7	4	8
2	5.1	9.3	5	8
3	2.8	16.4	5	9
4	6.9	9.9	6	9
5	3.3	8.3	5	5
6	3.3	15.1	6	9
7	3.6	11.6	4	6
8	3	12.6	5	8
9	8	10.5	8	5
10	5.8	13.2	3	9
11	1.4	12.9	5	4
12	4.9	15.8	7	5
Total	55.4	149.3	63	85

5.2. Evaluation of Food Production Efficiency Improvement

The food production efficiency improvement model proposed in this paper is used to optimize and improve the production process of egg cake products in Company A. Flexsim software is used to simulate the production process of egg cake products in the workshop of Company A. The time of each process is measured by the stopwatch method, and the dynamic simulation is performed through the software, focusing on the processing time occupancy rate of each process, the output of production capacity of the same period of time, and the comparison of the simulation effect between the process before and after the improvement, so that we can fully verify the important role of the improved process in the enhancement of the production efficiency of food products. Important role of the improved process for the improvement of food production efficiency.

Company A's workshop egg cake production process is “order quantity filling - cake production - cake weight check - bagging and packaging - Paste the label - send quality control”, a total of six links, the six links in accordance with the order of the process named T1 ∼ T6 in turn.

5.2.1. Operational efficiency. Through 18 rounds of simulation under the simulation operation, applying the food productivity improvement model in this paper to continuously improve and optimize the operation content of the production process of the egg cake product, and complete the final optimization at the 18th round. The stacked diagrams of the operation time share of different cycles and longer time before and after the process improvement by applying the food production efficiency improvement method of this paper are shown in Fig. 4. It is obvious from the graph that the sum of the operating time share of the production process for the egg cake product is reduced from the original 73.8% to 35.1% after the process improvement. At round 11, the order quantity filling process (T1) is completely outlawed, automated order filling equipment is introduced to reduce the labor intensity of the employees' work, and the percentage of the order quantity filling process (T1) is changed to 0%.

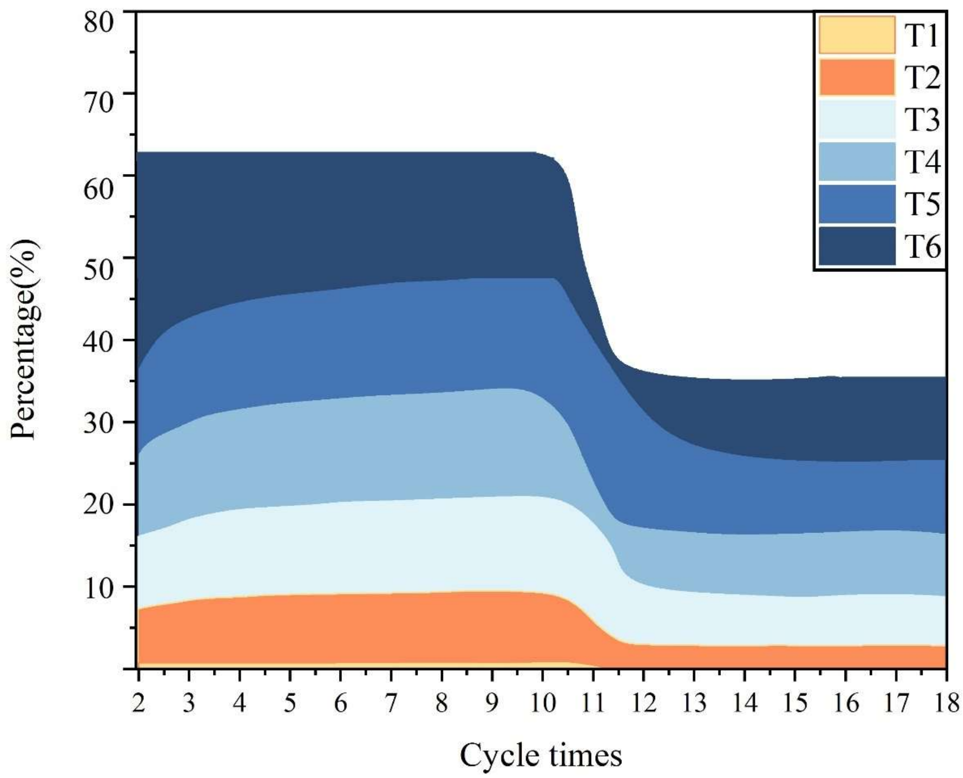

Fig. 4. Operating time ratio

5.2.2. Production line capacity. The simulated production output before and after the production process optimization by applying the productivity improvement model in this paper is recorded separately. The simulated production capacity results are recorded every 1 day, and the simulated production capacity quantity situation is specifically shown in Figure 5. By studying the ratio of capacity after process improvement and before improvement, it is found that the capacity after improvement is steadily increased by about 6% compared to the capacity before improvement. Between 1 day and 4 days of operation, the ratio of capacity after process improvement to capacity before process improvement is 1.15, 1.07, 1.09, 1.05. After 4 days of operation, the ratio of capacity output gradually stabilizes, and the ratio of capacity after improvement to capacity before process improvement stabilizes at about 1.06.

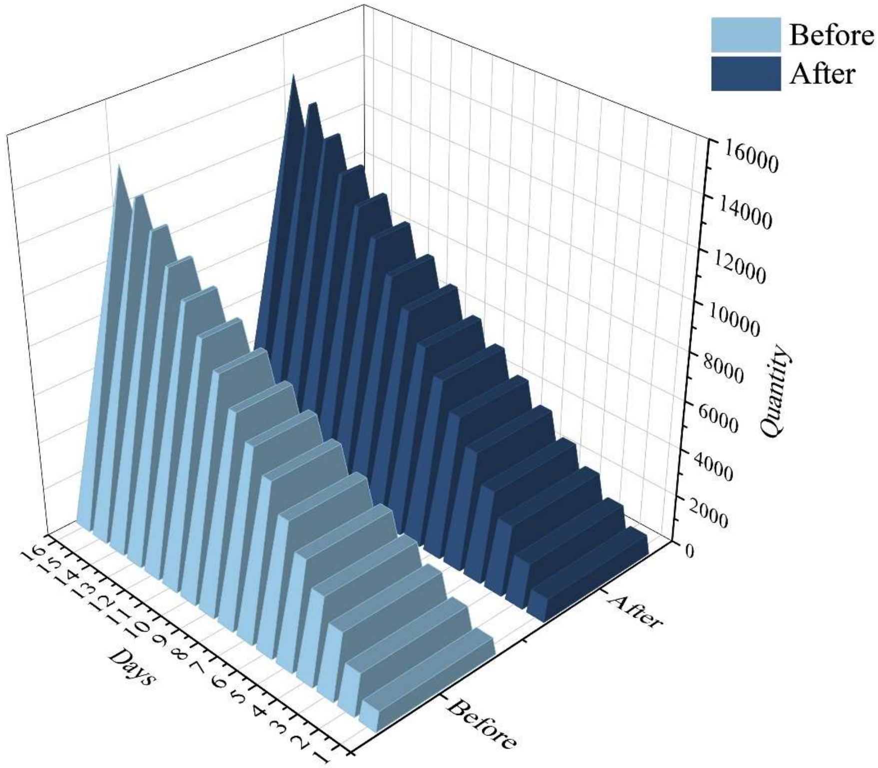

Fig. 5. Capacity quantity

6. Conclusion

This paper takes the packaging design and production of the food industry as the research landing point, constructs a food production efficiency improvement model and a food packaging design model based on digital simulation technology, and carries out experimental tests respectively. Taking diversity as a measure, the diversity of the food packaging design model in this paper is always higher than 92% and fluctuates smoothly, while the diversity of the design method based on SPA algorithm and the design method based on FPGA show larger fluctuations. Taking the standard genetic algorithm as a comparison, the food production efficiency improvement model incorporating the simulated annealing genetic algorithm in this paper stabilizes the processing time at about 55 min in 85 iterations, while the standard genetic algorithm stabilizes in 130 iterations, and the processing time finally stabilizes at about 87 min, which means that the former method has a better performance.

Application of this paper's food production efficiency improvement model and food packaging design model, to A Food Co. The packaging design of the egg cake product designed by the food packaging design model in this paper obtains an attention span of 149.3s from the subjects, which is much longer than that of the original packaging design as a comparison, and the subjective evaluation score is as high as 85, which is higher than that of the original packaging design by 22 points. In the real simulation of the production process, after applying this paper's food production efficiency enhancement model to improve and optimize, the total operating time of the production process of egg cake products was reduced from 73.8% to 35.1% after the process improvement. The production capacity of the production line is increased by about 6% from stable.

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