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The Natural Formula Design uses Mobile Application in Data Management

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Abstract. The purpose of this study is to apply Unified Modeling Language (UML) to the development of commercial tube-feeding milk formulas and establish the most suitable processing method for natural formula tube feeding. The study also incorporates response surface methodology (RSM) to explore the UML workflow for formula design and optimize processing conditions. According to the formula design process, the raw material composition for each 300-kcal can consists of 5 grams of germ rice, 60 grams of potatoes, and 15 grams of corn flour. The optimal viscosity for passing through a nasogastric tube is 223 cps. The processing steps include fine grinding, sterilization, and sensory evaluation at different rotation speeds, temperatures, and durations. The optimal fine grinding conditions are 1500 rpm for 5 minutes, which allows 95% of the raw materials to pass through an 80-120 mesh sieve. Sterilization is best achieved at 121°C for 20 minutes, which minimizes nutrient degradation. In a taste test, the egg formula had the highest acceptance rate. Overall, the use of UML modules for processing workflow and data analysis enables optimal operational procedures, precise data analysis, and the fulfillment of nutritional requirements.

Keywords: unified modeling language, tube-feeding, workflow, response surface methodology

1 Introduction

UML is a modeling standard for software engineering [1]. It primarily provides visual and object-oriented diagrams of system specifications at different design levels and conveys information that is not easily retrievable from program code. UML facilitates communication and understanding of various system attributes. It also supports traceability, enabling rapid identification of the relevant system parts that need to be understood or modified to implement changes or resolve problems [2]. UML provides several types of diagrams to describe the functional and structural aspects of systems—for example, sequence diagrams and structural model diagrams, which are crucial for information systems design [3].

Currently in Taiwan, there are tens of thousands of patients who are unable to eat or chew on their own due to physical paralysis. According to the total medical expenses paid by National Health Insurance Institutions announced in 2021 [4], the cost of enteral nutrition in 2020 accounted for 1.1% of the total hospital health insurance cost, approximately 2.5 billion New Taiwan Dollars. The types of enteral nutrition provided by hospitals are mainly commercial ready-to-eat formulas. These provide patients with daily meals, which must be pushed into the body through a nasogastric tube with a syringe to maintain the body's calorie needs (Cochran and Cox 1957). The supplied enteral nutrition can be divided into two main categories. One category is the regular diet (Routine diet), which varies depending on the concentration and caloric supply form of the food blend. The other category is the therapeutic diet (Modified diet), which mainly depends on the patient's disease control needs, limiting the proportion of various nutrients or calories in the diet [5].

Currently, the types of tube-fed formulas available are commercial aggregated formulas and natural food-blended formulas. The former's nutritional composition mainly relies on intact nutrients as the base. For instance, the protein sources are predominantly casein, soy protein, or albumin. The carbohydrate sources pri-

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marily include maltodextrin, corn syrup, or glucose polymers. Fat sources mainly comprise soybean oil, corn oil, or medium-chain fatty acid oil. The advantages of these are convenience, sanitary safety, and uniform nutrient concentration. The disadvantages include high cost, high osmotic pressure, which can lead to diarrhea, and lack of comprehensive dietary fiber supply. On the other hand, the latter's nutritional composition involves common natural foods blended into a liquid form using a homogenizer. The advantages of these are natural ingredients, balanced nutrition, and low cost. However, the disadvantages include time consumption, difficulty in preservation, larger particle size that can easily block the nasogastric tube [6, 7].

The aim of this research on the preparation and processing of Chinese-style tube feeding formulas is to use natural food as raw materials. The formula design is based on the daily dietary guidelines and recommended nutrient intake announced by the Department of Health, Executive Yuan. By calculating the required food portions and calorie count through food substitution, we utilize experimental design through response surface methodology to find the most suitable staple food formula proportion. This will enable the preparation of a balanced Chinese-style tube feeding nutritional product suitable for the physique of the local population, which could potentially substitute the nutrient deficiencies found in current commercial products. The goal is to devise the most economical and complete formula for tube feeding products, thereby reducing the cost of current tube feeding products.

The Response Surface Methodology (RSM) is widely used in experimental designs for seeking optimal operating conditions in food processing to produce the best quality product [8], RSM is applicable for multi-factor experiments and serves as a statistical tool for finding relationships between factors and optimal conditions. Another characteristic of RSM is that the center point can be repeated many times, providing N-1 (N is the number of repetitions at the center point) degrees of freedom, which can be used to assess the determination of experimental errors. This aids in the accuracy of the response surface near the center point. In the variance analysis of the regression equation, the square of the deviation can be used to measure the lack of fit [9]. When the lack of fit does not reach a significant standard ($P > 0.05$), the established regression model is quite suitable. If the lack of fit reaches a significant level, it implies that the established regression response surface model is not applicable, and the module must be discarded or redone [10].

On the other hand, dietary design requires multiple experiments and tests. To reduce fatigue during the experimental process and minimize the time cost associated with manual paper documentation, a UML management system was designed to outline the experimental process. A UML management system is a software system that defines, coordinates, manages, and executes complex business activities. Additionally, a mobile application was developed to allow researchers to quickly log data and perform real-time statistical analysis via API, improving research efficiency [11].

Therefore, the main objectives of this study are:

(1) To use the Response Surface Methodology (RSM) to explore the impact of optimal operating conditions (composition of the formula, viscosity, and particle size of grinding) on the physical properties of the innovative natural tube feeding formula.

(2) To investigate their correlations through the analysis of the reactivity of various formula ingredients.

2 Materials and Methods

(1) Workflow with UML: Process map can fully express the connotation of food process with relatively simple symbols as Fig. 1.

(2) Experimental Ingredients: Ingredients like germinated brown rice, potatoes, corn flour, Chinese cabbage, egg whites, corn germ oil, and salt were purchased from a traditional local market, while corn flour was sourced from Taiwan Yifu Co., Ltd.

(3) Statistical Formula: analysis system Table 1 and Experimental Design.

The process of preparing the Chinese-style enteral formula involves formulation design, where each can contain 300 mL, and each milliliter has 1 kilocalorie. The chosen ingredients for the formula are as follows: staple food class including brown rice flour, potatoes, and sugar syrup. Every 100 grams brown rice contains 23.6% crude fat, 22% protein, and vitamins B_1 3mg, B_6 4mg, and niacin 0.35 mg. Its plumule content is around 3g, making it highly nutritious. The use of potatoes and sugar syrup mainly compensates for the lack of calories from using brown rice and to prevent an increase in viscosity. Vegetable class: Chinese cabbage, which in every 100 grams edible portion, contains 2.1~2.4 grams, 0.5 grams of fat, 3.4~3.9 grams of carbohydrates, 1.0~1.2grams of ash. For minerals, it contains sodium 42mg, potassium 90mg, calcium 216 mg, and magnesium 33 mg, Vitamins B_1 0.03 mg, B_2 0.08 mg and folic acid 9~11μg, with the advantage of not being affected by seasonality and stable prices. Proteins: egg whites and pork loin, mainly because, besides providing a primary protein source, they also offer fatty acid content such as monounsaturated fatty acids (palmitoleic acid 16:1, oleic acid 18:1, erucic acid 22:1) and polyunsaturated fatty acids (linoleic acid 18:2, alpha-linolenic acid 18:3, octadecatetraenoic acid 18:4, arachidonic acid 20:4, eicosapentaenoic acid 20:5, docosapentaenoic acid 22:5, docosahexaenoic acid 22:6). Oil: corn germ oil is used to provide essential fatty acids and is a primary source of calories [12].

For the optimization of multi-variable factor systems, traditionally, the one-factor-at-a-time technique is often used to find the optimal point. However, this method often does not consider the interactive effects between factors. Even if this effect is taken into account, the number of experiments required is relatively high. The response surface methodology (RSM) is an effective method that can simultaneously measure the effect of each factor and the interactions between them, and find the optimal conditions [13].

Therefore, in this study, the three factors of the experiment, namely, brown rice flour (rice), potatoes and corn, and the weight of the formula, specifically, brown rice flour (5g, 7g, 9g), potatoes (60g, 70g, 80g), corn (10g, 15g, 20g) and the desired number of experiments (15) were inputted. These were designed into three-factor and two-level experimental conditions. The APP program was used for numerical analysis, and the results were analyzed using contour plots to discuss their correlation and the optimal conditions.

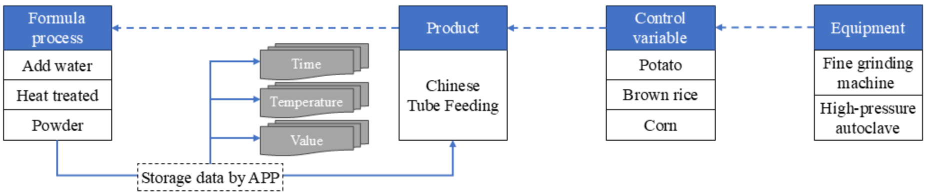


Fig. 1. Food experiment UML workflow

2.1 Formula Viscosity Measurement

In this experiment, the three-factor formula was first processed into powder form. The respective predetermined processing use amounts were added with water to 300 mL to measure their viscosities. The three factors were then individually heat treated into raw material liquid.

After the raw material liquid was heated to 100℃ and cooled to 25℃, the viscosity was measured with a Brookfield viscometer each time the temperature drops by 5℃. (The No.1 spindle is chosen for viscosity measurement. The viscosity number setting was set to 30 rpm when the sample solution viscosity is low, and 12 rpm when the sample solution viscosity is high). The viscosity changes of the three-factor formula under heat were measured. Then, using the 15 sets of formulas set out by the experimental design software (APP) (Table 2).

The viscosity measurements were conducted on a three-factor mixture formulation. A custom-developed mobile application was utilized to save real-time experimental design references to a cloud database. This application allows users to retrieve historical data on demand for statistical analysis. Data transmission between the application and the statistical analysis server is facilitated via API, enabling the server to perform analyses such as Response Surface Methodology (RSM). The results provide optimized formulation analysis, closely matching the viscosity values required for commercial enteral products. As illustrated in Fig. 2, on the left, the app enables real-time recording of experimental variables during each trial, including the weight of each additive, temperature, and humidity. In the center, it allows users to retrieve detailed logs of each experimental process and access them instantly via the cloud database. On the right, this system replaces the manual input and adjustment typically required with tools like SAS (Statistic Analysis System) or R after each experiment, streamlining the process. The app accelerates experimental design and reduces the labor costs associated with manual data entry, verification, and adjustment.

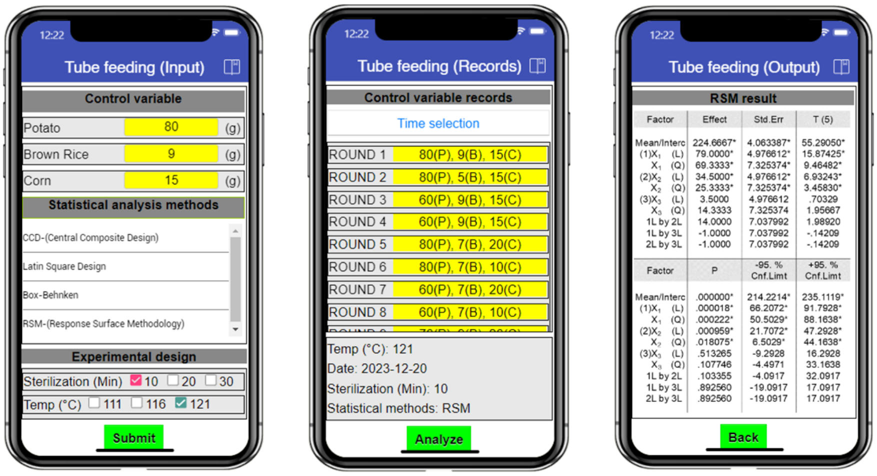
Table 1. The statistical analysis system for the Formulation

Data diet;	
Input	p, r, c, cps;
No	
1	80, 9, 15, 335
2	80, 5, 15, 295
3	60, 9, 15, 235
4	60, 5, 15, 223
5	80, 7, 20, 304
6	80, 7, 10, 301
7	60, 7, 20, 233
8	60, 7, 10, 228
9	70, 9, 20, 267
10	70, 9, 10, 265
11	70, 5, 20, 225
12	70, 5, 10, 221
13	70, 7, 15, 226
14	70, 7, 15, 223
15	70, 7, 15, 225;
proc sort;	by p r c;
proc rsreg;	
model	cps=p r c/lack fit;
run;	

Table 2. Fifteen experimental formula combinations

No	Potato (X_1)	Brown rice (X_2)	Corn (X_3)
1	(1) 80g	(1) 9g	(0) 15g
2	(1) 80g	(-1) 5g	(0) 15g
3	(-1) 60g	(1) 9g	(0) 15g
4	(-1) 60g	(-1) 5g	(0) 15g
5	(1) 80g	(0) 7g	(1) 20g
6	(1) 80g	(0) 7g	(-1) 10g
7	(-1) 60g	(0) 7g	(1) 20g
8	(-1) 60g	(0) 7g	(-1)10g
9	(0) 70g	(1) 9g	(1) 20g
10	(0) 70g	(1) 9g	(-1) 10g
11	(0) 70g	(-1) 5g	(1) 20g
12	(0) 70g	(-1) 5g	(-1) 10g
13	(0) 70g	(0) 7g	(0) 15g
14	(0) 70g	(0) 7g	(0) 15g
15	(0) 70g	(0) 7g	(0) 15g

Potato (X_1): (-1) 60g, (0) 70g, (1) 80g
Rice (X_2): (-1) 5g, (0) 7g, (1) 9g
Corn (X_3): (-1) 10g, (0) 15g, (1) 20g



Control variable

Potato	80	(g)
Brown Rice	9	(g)
Corn	15	(g)

Statistical analysis methods

- CCD-(Central Composite Design)
- Latin Square Design
- Box-Behnken
- RSM-(Response Surface Methodology)

Experimental design

Sterilization (Min) ☑ 10 ☐ 20 ☐ 30
Temp (°C) ☐ 111 ☐ 116 ☑ 121

Control variable records

Time selection

ROUND 1	80(P), 9(B), 15(C)
ROUND 2	80(P), 5(B), 15(C)
ROUND 3	60(P), 9(B), 15(C)
ROUND 4	60(P), 9(B), 15(C)
ROUND 5	80(P), 7(B), 20(C)
ROUND 6	80(P), 7(B), 10(C)
ROUND 7	60(P), 7(B), 20(C)
ROUND 8	60(P), 7(B), 10(C)

Temp (°C): 121
Date: 2023-12-20
Sterilization (Min): 10
Statistical methods: RSM

RSM result

Factor	Effect	Std.Err	T (5)
Mean/Interc	224.6667*	4.063387*	55.29050*
(1)X_1 (L)	79.0000*	4.976612*	15.87425*
X_1 (Q)	69.3333*	7.325374*	9.46482*
(2)X_2 (L)	34.5000*	4.976612*	6.93243*
X_2 (Q)	25.3333*	7.325374*	3.45830*
(3)X_3 (L)	3.5000	4.976612	.70329
X_3 (Q)	14.3333	7.325374	1.95667
1L by 2L	14.0000	7.037992	1.98920
1L by 3L	-1.0000	7.037992	-.14209
2L by 3L	-1.0000	7.037992	-.14209

Factor	P	-95. % Cnf.Limt	+95. % Cnf.Limt
Mean/Interc	.000000*	214.2214*	235.1119*
(1)X_1 (L)	.000018*	66.2072*	91.7928*
X_1 (Q)	.000222*	50.5029*	88.1638*
(2)X_2 (L)	.000959*	21.7072*	47.2928*
X_2 (Q)	.018075*	6.5029*	44.1638*
(3)X_3 (L)	.513265	-9.2928	16.2928
X_3 (Q)	.107746	-4.4971	33.1638
1L by 2L	.103355	-4.0917	32.0917
1L by 3L	.892560	-19.0917	17.0917
2L by 3L	.892560	-19.0917	17.0917

Fig. 2. Data access and analysis applications

2.2 Formula Raw Material Fine Grinding Process

After the raw materials were selected, weighed, and processed, the amount of water to be added into the fine grinding machine was calculated based on the water content in the formula raw materials. These were put into the machine for fine grinding, with the rotation speed of the fine grinding machine set at 1500 rpm and the grinding time set at 3 min, 5 min, and 7 min. The optimal grinding conditions were those that result in the maximum number of particles passing through the 80-120 mesh.

2.3 Sterilization Test of the Finished Product

The canned samples prepared from the ingredient formula were sterilized using a high-pressure autoclave. Tests were conducted at various sterilization durations (10 minutes, 20 minutes, 30 minutes) and temperatures (111°C, 116°C, 121°C) to determine the optimal sterilization time and temperature for the enteral product.

2.4 Sensory Evaluation Test

Post-sterilization, sensory evaluation tests were conducted on two different formula variations - egg and pork. Fifteen evaluators utilized a 9-point hedonic scale for this sensory analysis, where 1 point signifies ‘extremely dislike’, 5 points indicate ‘neither dislike nor like’, and 9 points represent ‘extremely like’. These evaluations were used to determine the most appealing flavor of the sterilized, canned product [14].

2.5 Nutrient Analysis

Moisture Content. The moisture content (MC) was determined using AOAC (Citation2000) method [14]. About 3 g of samples were weighed into a pre-weighed clean dried moisture can, after which the can was placed in a well-ventilated oven (Memmert GmbH+co.Kg, Oven model D-91126 Schwabach FRG, Germany) maintained at 105 ± 2°C for 16 h. The loss in weight was recorded as moisture content.

Ash Content. This was determined using the method of AOAC (Citation2000) [14]. It involves burning off moisture and all organic constituents at 600°C for 6 h in a furnace (Ney Vulcan TM furnace model 3–1750, USA). The weight of the residue after incineration was then recorded as the ash content.

Fat Content. The percentage fat content of the sample was determined by the conventional Soxhlet extraction method with hexane as the solvent, according to AOAC (Citation2000) [14].

Protein Content. This was determined by the Kjeldahl method using Kjeltec™ model 2300, as described in the FOSS Manual (Foss Analytical AB, Citation2000) [11]. The technique involved digestion of the sample at 420°C for 1 h to liberate the organically bound nitrogen in the form of ammonium sulfate. The ammonia in the digest (ammonium sulfate) was then distilled into a boric acid receiver solution, then titrated with standard hydrochloric acid. A conversion factor of 6.25 was used to convert from total nitrogen to percentage crude protein.

Starch and Sugar Content. Starch and sugar content was determined by the method described by Onitilo et al., (Citation2007) [15]. This involves weighing 0.02 g of the sample into a centrifuge tube with 1 ml ethanol, 2 ml distilled water, and 10 ml hot ethanol. The mixture was vortexed and centrifuged at 2000 rpm for 10 min. The supernatant was decanted and used for determining sugar content, while the sediment was hydrolyzed with perchloric acid and used to estimate starch content. Phenol and sulfuric acid reagents were used for color development, and glucose standards were used to estimate sugar. The absorbance was read with a spectrophotometer (Genesys 10S UV-VIS, China) at 490 nm.

Statistics. We took the different ratios of the previously mentioned three-factor ingredients as operational conditions, while considering viscosity, grinding coefficient, sterilization conditions, and sensory evaluation as references for the optimal processing conditions. The pattern analysis was performed based on the impact on reaction conditions when operational conditions change, using the Statistical Analysis System (Version 14) program to carry out the Response Surface Method (RSM) statistical analysis. This allowed us to find the most suitable operational conditions for various physicochemical regression models.

From the combination of experimental conditions of the transformed values (X) and the results obtained from the reaction condition Y, a second-order polynomial equation of the three variables is listed as follows Eq(1).

$$Y=a_0+a_1X_1+a_2X_2+a_3X_3+a_{12}X_1X_2+a_{23}X_2X_3+a_{13}X_1X_3+a_{11}X_{12}+a_{22}X_{22}+a_{33}X_{32} \tag{1}$$

Where ‘a_i’ represents the coefficient values for each term.

After the aforementioned model was regressed using the APP with statistical module, we used a plotting software (Stat graphics 7.0) to draw the response surface plot for each characteristic (Y) with respect to the operational conditions. We then proceeded to further analyze and explored the correlation between each operational variable and the reaction condition of the formula.

3 Results and Discussions

3.1 Viscosity Measurement of the Formula

After heating the germ rice flour, maltose syrup, and potatoes in the formula ingredients, the viscosity changed during the cooling process was the most significant in the germ rice slurry and potato mash. However, cornstarch did not show significant viscosity change due to temperature changes during heating. When the germ rice flour, maltose syrup, and potatoes were heated in proportion and left at room temperature (25°C), the viscosities of fifteen groups measured by a viscometer Table 3.

Table 3. Corresponding viscosity values of fifteen formula groups X_1, X_2, X_3 at 25 °C

NO	Composition X_1(g):Potato, X_2(g):Rice, X_3 (g):Corn	cps
1	80, 9, 15	335
2	80, 5, 15	295
3	60, 9, 15	235
4	60, 5, 15	223
5	80, 7, 20	304
6	80, 7, 10	301
7	60, 7, 20	233
8	60, 7, 10	228
9	70, 9, 20	267
10	70, 9, 10	265
11	70, 5, 20	225
12	70, 5, 10	221
13	70, 7, 15	226
14	70, 7, 15	223
15	70, 7, 15	225

The interaction analysis results of the three factors in the formula ingredients analyzed by the experimental design software (STATISTICA) Table 4.

The SAS (Statistic Analysis System) program language was used for analysis. This software can find the coefficients of Eq(2), which represent the effect of each factor or two factors on the Y value (viscosity). This software can also be used to find the formula conditions for the minimum viscosity value are showed in Table 5.

The theoretical minimum of the formula weight was 5.61g of germ rice, 64.25g of potatoes, and 12.86g of maltose syrup, resulting in the lowest viscosity of 212.4 cps. The maximum condition values are showed in Table 6.

Table 4. Results from STATISTICA experimental design analysis

STAT. EXPERIM. DESIGN.	Effect Estimates; Var: Y; R-sqr=.998774; adj:.96566 (data sta) 3 factors, 1 Blocks, 15 Runs; MS Residual=49.53333 DV: Y					
					-95. %	+95. %
Factor	Effect	Std.Err	T (5)	*P*	Cnf.Limt	Cnf.Limt
Mean/Interc.	224.6667*	4.063387*	55.29050*	.000000*	214.2214*	235.1119*
(1)X_1 (L)	79.0000*	4.976612*	15.87425*	.000018*	66.2072*	91.7928*
X_1 (Q)	69.3333*	7.325374*	9.46482*	.000222*	50.5029*	88.1638*
(2)X_2 (L)	34.5000*	4.976612*	6.93243*	.000959*	21.7072*	47.2928*
X_2 (Q)	25.3333*	7.325374*	3.45830*	.018075*	6.5029*	44.1638*
(3)X_3 (L)	3.5000	4.976612	.70329	.513265	-9.2928	16.2928
X_3 (Q)	14.3333	7.325374	1.95667	.107746	-4.4971	33.1638
1L by 2L	14.0000	7.037992	1.98920	.103355	-4.0917	32.0917
1L by 3L	-1.0000	7.037992	-.14209	.892560	-19.0917	17.0917
2L by 3L	-1.0000	7.037992	-.14209	.892560	-19.0917	17.0917

*Statistically significant (P <0.05).

Table 5. Theoretical minimum viscosity of formulations derived using SAS

Coded	Estimated	Standard	Uncoded factor values		
Radius	Response	Error	X_1 (Potato)	X_2 (Rice)	X_3 (Corn)
0.0	227.000000	6.360263	70.000000	7.000000	15.000000
0.1	223.029458	6.314155	69.090961	6.917218	14.975872
0.2	219.698835	6.213652	68.210038	6.823076	14.941949
0.3	216.993757	6.058969	67.370504	6.714332	14.893235
0.4	214.892799	5.851308	66.591746	6.587375	14.821587
0.5	213.354436	5.593004	65.899502	6.439341	14.713881
0.6	212.364325	5.290111	65.321585	6.270551	14.549992
0.7	211.835021	4.958149	64.877274	6.087636	14.302242
0.8	211.709646	4.630570	64.566339	5.904789	13.940740
0.9	211.918283	4.362930	64.367663	5.740094	13.451398
1.0	212.395848	4.224016	64.248319	5.606390	12.857316

$$Y=224.6667+79.0000X_1+34.5000X_2+69.3333X_{12}+25.3333X_{22} \quad (2)$$

Table 6. Theoretical maximum viscosity of formulations derived using SAS

Coded	Estimated	Standard	Uncoded factor values		
Radius	Response	Error	X_1 (Potato)	X_2 (Rice)	X_3 (Corn)
0.0	227.000000	6.360263	70.000000	7.000000	15.000000
0.1	231.620177	6.352818	70.928384	7.073997	15.017435
0.2	236.896669	6.294140	71.870340	7.141165	15.030154
0.3	242.834167	6.188256	72.822027	7.202972	15.039452
0.4	249.436040	6.041888	73.780840	7.260516	15.046204
0.5	256.704758	5.864850	74.744977	7.314629	15.051015
0.6	264.642167	5.671325	75.713168	7.365946	15.054318
0.7	273.249671	5.481124	76.684498	7.414958	15.056429
0.8	282.528357	5.320874	77.658293	7.462051	15.057579
0.9	292.479079	5.224255	78.634054	7.507530	15.057948
1.0	303.102512	5.229857	79.611402	7.551640	15.057672

The theoretical maximum value of the formula was Potato=79.61, Rice=7.55, and Corn=15.06, resulting in the highest viscosity of 303.10 cps. The calculated maximum and minimum values were within the experimental design range. If the three-factor formula was outside this range, these two extreme values were not applicable.

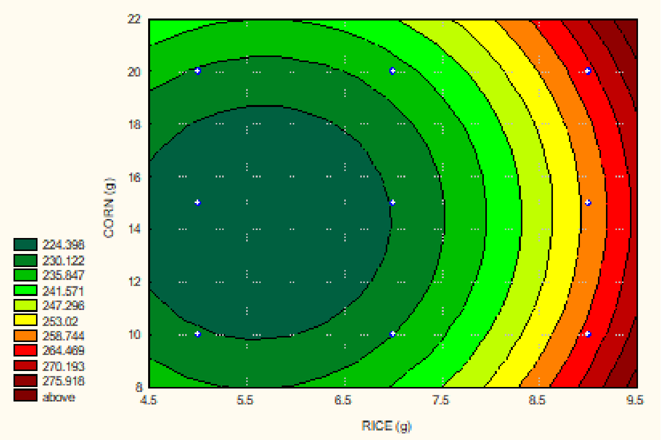


Fig. 3. Contour plot of viscosity corresponding to corn and rice

Fig. 3 shows that when the concentration of cornstarch is fixed at the center, the contour map of viscosity corresponding to the addition of germ rice flour is drawn. As the amount of germ rice flour increases, the viscosity is directly proportional to the concentration of germ rice flour. However, the addition of cornstarch has no significant impact on the viscosity value.

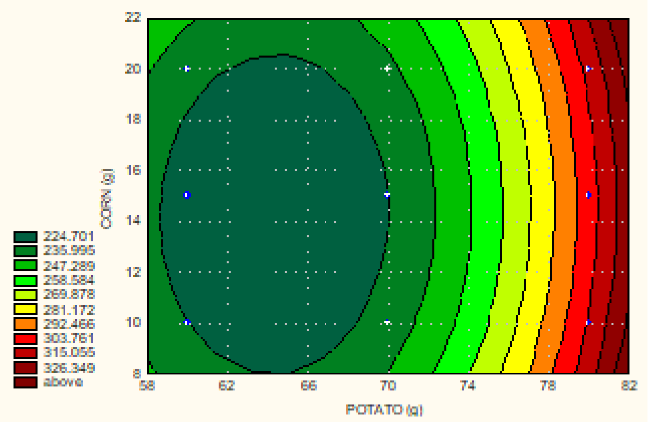


Fig. 4. Contour plot of viscosity corresponding to corn and potato

Fig. 4 shows that when the concentration of germ rice flour is fixed at the center, the contour map of viscosity corresponding to the addition of potatoes is drawn. From the figure, it can be observed that as the amount of germ rice flour increases, the viscosity tends to increase, and as the number of potatoes increases, the viscosity also increases. The viscosity is thus related to both the germ rice flour and potatoes.

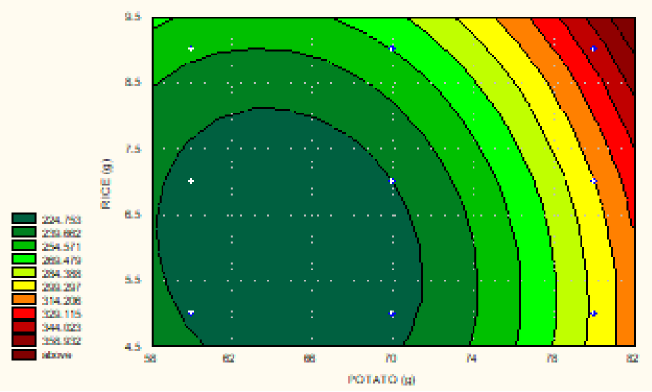


Fig. 5. Contour plot of viscosity corresponding to corn and rice

Fig. 5 shows that when the concentration of cornstarch is fixed at the center, the contour map of viscosity corresponding to the addition of potatoes is drawn. As the number of potatoes increases, the viscosity increases along with it. In summary, it was found that cornstarch has the ability to stabilize the viscosity of the formula. Among the formula groups, the viscosity value ratio closest to the commercial formula viscosity value of 233 cps was germ rice: 5g, potatoes: 60g, cornstarch: 15g, which is the closest to the formula design value.

3.2 Fine Grinding Process of Chinese Tube Feeding Formula Ingredients

The optimal tube feeding formula ingredients I and II, after being proportionally mixed, were put into the fine grinding machine for processing. In each 300 ml can, the water content of formulas I and II were calculated to be 127g and 121g respectively, so the amount of water that needs to be added to the fine grinding machine per can was 163g and 179g respectively. The fine grinding time was set for 3, 5, 7 minutes under three conditions, with a fixed rotation speed set at 1,500 rpm. After grinding, 300 grams were taken from each, dried for 3 hours, crushed, and the number of particles that pass through the 80-120 mesh was determined using a standard oscillating sieve. The results were compared (Table 7). When the fine grinding time is set to 7 minutes, although the formula had a higher sieve passing rate, the longer the grinding time, the higher the viscosity will become [4]. When the grinding time was set to 5 minutes, the sieve passing rates for the egg and pork formulas were 95% and 85% respectively, and their viscosity was also close. However, the sieve passing rate of the egg formula was higher and met the requirements for tube feeding, so overall, a grinding time of 5 minutes was considered optimal.

Table 7. The effect of grinding time om the ratio of particles passing 80-120 mash test

Grinder time	3 min	5min	7min
Revolution	1500 rpm	1500 rpm	1500 rpm
Formula(g) : Water(mL)	(I) 127 : 163 (II) 121 : 169	(I) 127 : 163 (II) 121 : 169	(I) 127 : 163 (II) 121 : 169
Baker (g)	(I) 68 (II) 65	(I) 67.5 (II) 65.3	(I) 70 (II) 66.5
Pass 80-120 Mash ratio (%)	(I) 70 (II) 73	(I) 90 (II) 85	(I) 95 (II) 87
Viscosity (CPS)	(I) 235 (II) 226	(I) 233 (II) 235	(I) 262 (II) 283

(I): Egg formula, (II): Pork formula

3.3 Analysis of Sterilization Results

The finely ground samples were degassed using a degassing box for a fixed time of 16 minutes. After degassing, the core temperature was maintained between 97-99°C. Immediately after degassing, the samples are sealed and sterilized, with the sterilization results (Table 8). Sterilization at 121°C for 30 minutes caused a burnt taste in both types of samples, and also made them taste bitter, a phenomenon not observed with other sterilization conditions. In the egg formula, can swelling occurred 2-7 days after sterilization under conditions of 111°C for 10 minutes, 111°C for 20 minutes, and 116°C for 10 minutes. Can swelling also occurred after 28 days and 15 days under conditions of 111°C for 30 minutes and 121°C for 10 minutes respectively, and after 22 days at 116°C for 20 minutes. However, no can swelling occurred under conditions of 116°C for 30 minutes and 121°C for 20 minutes. For the pork formula, can swelling only did not occur under the sterilization condition of 121°C for 20 minutes, but it did occur under all other conditions. Can swelling generally occurred due to the settings for sterilization temperature and time; incomplete sterilization can lead to the effects of spoilage bacteria, which caused can swelling. Additionally, empty cans subjected to strong acidic contents can also cause can swelling due to the presence of air [16, 17].

Table 8. Swelling situation of the two Chinese enteral formulas after sterilization at different temperatures and times

(I) Egg formula		(II) Pork formula	
Sterilization terms	Swelled can duration(day)	Sterilization terms	Swelled can duration(day)
111°C, 10 min	2 day	111°C, 10 min	1 day
111°C, 20 min	7 day	111°C, 20 min	2 day
111°C, 30 min	28 day	111°C, 30 min	7 day
116°C, 10 min	5 day	116°C, 10 min	5 day
116°C, 20 min	22 day	116°C, 20 min	9 day
116°C, 30 min	-	116°C, 30 min	16 day
121°C, 10 min	15 day	121°C, 10 min	15 day
121°C, 20 min	-	121°C, 20 min	-
121°C, 30 min	- (Burned flavor)	121°C, 30 min	- (Burned flavor)

3.4 Sensory Evaluation Test

The sensory evaluation results for the color, taste, and overall preference of the Chinese tube feeding product formulas are showed in Table 9. In terms of taste acceptability, the egg formula was rated highest on average, while the pork flavor was less accepted. For color, there were no significant differences between the egg and pork formulas. In terms of overall preference, the egg formula was most preferred on average, while the pork flavor was less preferred.

Table 9. Results of a nine-point preference sensory evaluation of enteral formula samples

Formula	Color	Flavor	Total preference
(I) Egg	6.80*	7.20	6.90
(II) Pork	6.00	5.70	5.90

*Each value on the right superscript of means on the same row bearing different letters are significantly different ($P < 0.05$).

3.5 Nutrient Analysis

The formula samples in this experiment, specifically those using egg as an ingredient, were sterilized at conditions of 116°C for 30 minutes and 121°C for 20 minutes. After the analysis, the optimal sample sterilization condition was 121°C for 20 minutes, which can meet the nutrient design reference values (Table 10).

Table 10. The egg formula samples nutrient composition of analysis

Food item / Nutrient	Kcal	Water	Protein	Fat	CHO	Fiber	Ash	Vitamin							
								A	E	B_1	B_2	Niacin	B_6	B_{12}	C
	(kcal)	(g)	(g)	(g)	(g)	(g)	(g)	(RE)	(α-TE)	(mg)	(mg)	(mg)	(mg)	(mg)	(mg)
Rice	28.6	1.17	0.62	0.22	7.91	0.15	0.09	0	0.07	0.03	0	0.35	0.01	0	0
Potato	16.2	15.9	0.54	0.06	3.3	0.08	0.2	0	0	0.01	0.01	0.26	0.01	0	5
Egg	93.7	50.7	7.99	4.53	0.3	0	0.59	135	0.34	0.05	0.28	0.92	0.14	1.33	0
Corn	86	1			29										
Corn oil	70.6	0.01	0	7.99	0	0	0	172	1.12	0	0	0	0	0	0
Total	305	127	10	13	42	2.4	2.5	399	1.53	0.1	0.31	2	0.18	1.33	29
RDNA*	300		10	13	40			234	1	0.1	0.15	2	0.15	0.8	10

*Recommended Daily Nutrition Allowances, Calorific: 300 Kcal/can.

4 Conclusion

This research introduces innovations to the tube-feeding manufacturing process and formula design. Compared to the limitations of traditional processes, which include challenges in controlling formula concentration, processing time, and cost, it is difficult to accurately monitor processing conditions. By establishing UML modules, teams can effectively communicate and execute tasks efficiently. Additionally, we designed a Web-APP based on the UML module to input, analyze, and produce formula data. The output formula data was processed through the response surface experimental design method to produce a formula containing 300 calories per can, which can be passed through the nasogastric tube. The optimal viscosity value is 223 cps. The optimal fine grinding conditions were determined to be 1500 rpm for 5 minutes, allowing 95% of the raw materials to pass through an 80-120 mesh sieve. Sterilization was optimally achieved at 121°C for 20 minutes, a condition that minimizes the impact on nutrients. In the taste test, the egg formula received the highest acceptance rate. Overall, by utilizing UML modules to establish a processing workflow and analyze formula data, it is possible to achieve optimal process operations and obtain accurate data analysis that meets nutritional needs.

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