A Decision Model Forlive Pig Feeding Selection

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Abstract: With massive and intensive developmentof Chinese live pig industry, the imbalance of feeding nutritionturns out to be a primary problem. The main reason is that the nutrition needs to be adaptive tolive pig's exact growth conditions in production management process. Regarding this, the paper aims at developing a feedingselection model for pig breeding based on major nutrients predictive model proposed in the Nutrient Requirements of Swine published by U.S. NRC in 1998. The objective of this model is to achieve a minimum cost of feeding stuff under the premise that the nutrients satisfy pig's needs. According to values proposed in NRC and nutritional elements data, a feedingselection model was developedto give proper suggestions on feeding dietary nutrients as well as exact type and quantity of pig feeding stuff. The work presented in this paper would contribute to the optimal precision feeding strategies so as to guarantee live pig growth quality in management process.

Keywords:live pig breeding, nutrients prediction, daily nutrition, feeding quantity, precision feeding, nutrition requirement

1. Introduction

The main cost of live pig feedingcomes from the pig feeding stuffcost, accounting for 60-70% of the total cost of the large-scale pigfeeding, and accounting for 70-80% of the total cost of pig specialized households[1], higher than labor costs (14 -22%) and piglets costs (18 -35%) [2].There is at least 10% of the feeding stuff waste every year [3], result infeeding costs continue to rise, limiting our economic development of pig feeding and polluting the environment [4]. In the condition of ensuring the healthy growth of pigs, depending on the growing season, timing and quantitative feeding, fully tapping the feeding stuff nutrient availability, and improvingfeeding stuff conversion rate, are the key to reducefeeding costs and improve feeding efficiency.

From the live pig industry development status and trends of United States and Europe, there is a large systematic study in precision feeding aspects. In Denmark, pig daily food intake is controlled by computer, depending on the growing season, timing and quantitative feeding, pig breedingachieve information andstandardization[5]. The Danish manure normative system(DMNS) provide Danish farmers and authorities with tools for fertilizer planning control,the system includesthat dietary nutrient content, nutrient digestibility, feeding stuff intake and nutrient retention in the pig body. According to those informationthe system included, calculatingthe standard value of nutrients excreted, then getting the feeding stuff conversion rate, andproviding the basis for the next

day grain feeding. In European countries, the feeding stuff conversion rate ofDanish is the standard to correcttheir feeding stuff conversion rate [7].In the Netherlands, the farming management software(Agrovision FARM)and the intelligent sow management system(Velos)are been used in
pig feeding [8]. Agrovision FARM can record all important, true and reliable farming information. Velos can afford precise pig feedingin accordance with the feeding curve, avoiding feedwastage caused by artificial feeding and the pig body conditionuneven caused by feeding inaccurate, thus ensuring the most accurate for every pig feeding. In the United States,the *Nutrient Requirements of Swine* which was published by U.S. NRC in 1998,providing a reliable basis for pigfeeding. According to different stages of pig breeding standards, U.S. researchers designed different feed formulation to reduce nutrient waste and manure nitrogen emissions, save feeding costs [10]. By using the technology of RFID radio frequency identification, wide network video surveillance, reach the intelligentpig feeding [7].The use of automatically phased system makes pig feeding stuff conversion more efficient, feed fully compatible with the growth rate of pigs, neither because of lacking feeding stuff nutrients affect the growth rate of pigs, not because of excess nutrients in feed resultin wastage. In our country,for the differences between China and the U.S. in terms of pig breeding species and breeding conditions, Fu Linsheng, Xiong Benhai and other researchers developed pig nutrition requirements dynamic forecasting system based on the NRC swine dynamic nutrition requirements,through appropriately adjusting the parameters to match the characteristics of Chinese pig breeding [9].The system provide basic utility for a variety of pigs diet formulation designing under certain condition nutrient requirements, rationally using feed materials, and reducing feed costs and environmental pollution. The study of thissystem promotesthe fine breeding,but the choice of the kinds of feeding stuffand feeding ration is not yet involved.
For the problem of low feedingutilization rate and high breeding costinthe development of aquaculture technology, according to NRC modeling software, the objective of this study was to calculate pig daily nutritional requirements in a growth phase, based on the type of feed and the daily requirement, establishing feeding portfolio optimization model, obtainingthe mixed feed and mixed proportions by solving the model, improve feed utilization, reduce breeding costs, achieveprecise feedingof pigbreeding.

2. Method

2.1 Daily requirement

Pig daily nutritional requirements is an important basis for the dailydesign, the pig nutritional requirements the U.S. National Research Council (NRC) recommended is considered the most authoritative pig standards. It uses a mathematical model to estimate the integral energy, protein, amino acids,minerals and vitamins growing pigs needed [9].

NRC is use of three interrelated nutritional needs modes, growth model, pregnancy model and lactation model, to software calculate. In this paper, according to the growth model selectingGrowing - Finishing Pigsas the study object, the main two growing stages are 25-38kg and 38-57kg. Inputting the data pig’s weight, type, energy indicators and so on, outputtingthe nutritional requirements data, which includes digestible energy (DE)-based energy, amino acid

requirements, minerals and vitamins requirement. In the calculation, choosing nutrition requirements model of growth model to software calculate, the data obtained by NRC software model calculating shown in Table 1,Table 2,Table 3.

Table 1 Daily energy intakefor each pig

Body weight	Total energy (kg)	Digestible energy (IU)	Prediction (g)	Lipid (g)	Crude fiber (g)	Vitamin (IU)	Calcium (g)	Phosphorus (g)
25-38(kg)*	1.451	4406	119	128	69.65	1926.51	9.00	4.19
38-57(kg)*	1.904	5901	141	194	89.49	2609.65	11.31	5.26

Notes：*25-38(kg), *38-57(kg), mean sub-stages weight of growth pigs.

Table2 Daily trace elements intakefor each pig

Body Weight	Sodium (g)	Chloride (g)	Magnesium (g)	Potassium (g)	Copper (mg)	Iodine (mg)	Iron (mg)	Zinc (mg)	Manganese (mg)	Selenium (mg)
25-38(kg)	1.35	1.06	0.53	3.25	5.78	0.18	89.18	80	2.64	0.269
38-57(kg)	1.82	1.43	0.71	3.70	6.57	0.25	95.74	98	3.57	0.312

Notes：*25-38(kg),*38-57(kg), mean sub-stages weight of growth pigs.

Table 3 Daily vitamin intakefor each pig

Body Weight	A (IU)	D (IU)	E (IU)	K (mg)	B_6 (mg)	B_{12} (μg)
25-38(kg)	1714	198	14.51	0.66	1.32	13.7
38-57(kg)	2322	268	19.65	0.89	1.79	13.35

Notes：*25-38(kg), *38-57(kg), mean sub-stages weight of growth pigs.

Data in the table above are the main basis for this paper feeding selection. All selection, recipe selection must meet the growth needs, and the data obtained through the NRC modeling software are the requirements must be meet, that is theconstraints in the process of forecast calculation. According to the number of nutritional requirements and cost, select the most appropriate feeds to feed.

2.2 Feeding decision model

With the lowest cost as the objective function, the linear programming mathematic model was built [18]. Suppose there are n kinds of feeds to choose from for a growth phase,m_i

represents the ith feed, m_i^{max} and m_i^{min} represent the max andmin limits of feed, i as the nutrients necessary number for the growth of pigs, n_j represents the j th nutrient element,n_j^{max}andn_j^{min} represent the max intake of nutrient and min intake of nutrients n_j;in unit mass of m_i, the mass percentof nutrients n_j denoted u_{ij}; the market price offeed $m_i$recorded as c_i, the number of daily feed $m_i$as x_i, feeding costs can be expressed as the objective function is shown as follows:

$$\mathrm{Z} = min\sum_{i=1}^{n} c_i x_i \,(\, i \;=\; 1,2,\ldots\ldots,n)(1)$$

WhereZ represents the cost of feed fed, c_i is the$i$th feed market price, x_i represents the ith day ration of m_i feed.

Feed usage constraints [(2) - (4)]:

$$m_i^{min} \le x_i \le m_i^{max}(\, i \;=\; 1,2,\ldots\ldots,n)(2)$$

Where$x_i$represents the ith day ration of m_i feed, m_i^{max} and m_i^{min} represent the max and min limits of feed.

$$n_j^{min} \;\le \sum_{i=1}^{n} \mu_{ij} x_i \le n_j^{max}(\, i \;=\; 1,2,\ldots\ldots,n)(3)$$

Wheren_j^{max}andn_j^{min} represent the max intake of nutrient and min intake of nutrients n_j; n_j represents the jth nutrient element; u_{ij} is the mass percent of nutrients n_j denoted; the number of daily feed m_i as x_i.

$$x_i \ge 0(\, i \;=\; 1,2,\ldots\ldots,n)(4)$$

Wherex_i represents the ith day ration of m_i feed.

Though model computing can obtained $x_i$as well as get quality for all kinds of feed, while able to calculate the value of Z, which is the minimum cost of feed mix in$x_i$situations.

2.3 Data flow

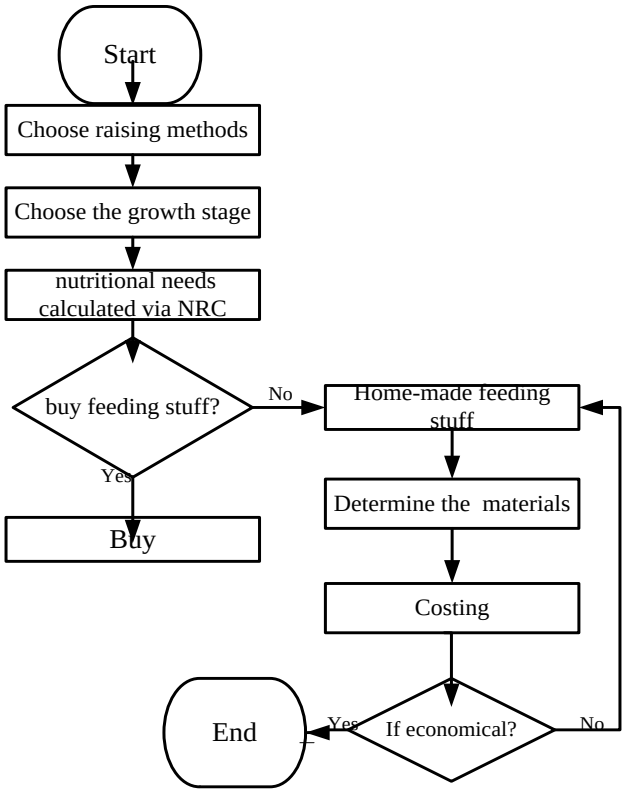

Fig1. Pig feeding selection decision process

The feeding selection decision process is illustrated in Figure 1, the model processes are listed below:

1. Determine the growth stage of pigs, getting pig weight data.
2. After knowing the weight using NRC modeling software calculate nutritional requirements the pig needed, which includes the digest energy (DE)-based energy, amino acid requirements, minerals and vitamins requirement.
3. Meeting the nutritional needs(get from 2) conditions, can purchased directly competing mixed feeding stuff, can also be mixed in accordance with the existing feeding stuff themselves ,if mixed by themselves, determining the type of breeding materials and ingredients contained in the existing ratio.
4. Known nutritional requirements data and raw data feed decision to build a mathematical model to calculate the lowest cost feeding stuff mix, that kind of feed needed, how much needs.
5. If it satisfies the minimum cost and to meet the nutritional needs, you get to choose the end result of the calculation, if not,loop to 3 recalculate until getting the outcome, the calculation ended.

3. Results and discussion

3.1 Feeding Selection

(1) Data analysis

In this section, through example represent the feeding decision mathematical model simulation process, accordingto the conditions of meeting the growth needsof pig, with the existing status quo forage species breeding farms, pigs breeding mixed feeding stuff is calculated. Thereare five different options pig feed ,such as A, B, C, D, E, the feed information as shown in Table 4.

Table 4 Proportion of the energy in the feeding stuff

feeds	Digestible energy (IU)	Prediction (g/kg)	Crude fiber (g/kg)	Vitamin (mg/kg)	Calcium (g/kg)	Phosphorus (g/kg)	Price （yuan/kg）
A	3050	280	100	9.9	45	8	7
B	3060	145	700	10	80	10	6.2
C	3050	160	200	9.5	70	9	6.3
D	3050	310	100	6	50	11	5.5
E	3060	150	100	6.5	10	5	5.2

(2) Modeling

Under theconditions of meeting the nutrients requirements of pig growth, in order to minimize the cost of keeping the goal to establish programming model ,such as the ratio of the feed formula (5-10) below.

Objective function:

$$Z_{min}= 7x_1+6.2x_2+6.3x_3+5.5x_4+5.2x_5 \quad (5)$$

Where the objective function is to get the cost of the optimal feed ration, Z_{min} is the feeding stuff ration cost; x_1, x_2,x_3, x_4, x_5 represent A, B, C, D, E are five different pig feeding stuff ration , $x_i$corresponds to the ith feeding stuff ration.

Satisfy the following constraints established:

$$280x_1+ 145x_2+ 160x_3+ 310x_4+ 150x_5 \geqslant 141 \quad (6)$$

Where the protein are the growth feed pigs needs must be meet of feeding process,x_1, x_2,x_3, x_4, x_5 represent A, B, C, D, E five different pig feeding stuff ration (x_i≥0，i= 1,2,3,4,5;).

$$100x_1+ 700x_2+ 200x_3+ 100x_4+ 100x_5 \geqslant 89.49 \quad (7)$$

Where the crude fiber is the growth feed pigs needs must be meet of feeding process,x_1, x_2,x_3, x_4, x_5 represent A, B, C, D, E five different pig feeding stuff ration (x_i≥0，i= 1,2,3,4,5;).

$$9.9x_1+ 10x_2+ 9.5x_3+ 6x_4+ 6.5x_5 \geqslant 3.54 \quad (8)$$

Where the vitamins are the growth feed pigs needs must be meet of feeding process,x_1, x_2,x_3, x_4, x_5 represent A, B, C, D, E five different pig feeding stuffration (x_i≥0, i= 1,2,3,4,5;).

$$45x_1+ 80x_2+ 70x_3+ 50x_4+ 10x_5 \geqslant 11.31 \quad (9)$$

Where the calcium are the growth feed pigs needs must be meet of feeding process,x_1, x_2,x_3, x_4, x_5 represent A, B, C, D, E five different pig feeding stuff ration (x_i≥0, i= 1,2,3,4,5;).

$$8x_1+ 10x_2+ 9x_3+ 11x_4+ 5x_5 \geqslant 5.26 \quad (10)$$

Where the phosphorus must be meet the growth feeding pigs needs during the feeding process,x_1, x_2,x_3, x_4, x_5 represent A, B, C, D, E five different pig feeding stuff ration ($x_i \geqslant 0$, i= 1, 2, 3, 4, 5;).

(3) Result

By decision model formula (5-10) constraint equation knowing that, if breeding farms choose to feedfeeding stuffA 0.0586g per pig per day, feeding stuffB 0.0762kg, feeding stuffD 0.3663kg, to meet the growing needs of pigs ,and investment the lowest total cost of 2.9 Yuan.

3.2Analysis

From the simulation knowing that, according to the nutritional requirements datawhich are shown in tables (1-3), using the mathematical models to calculate to get all kinds of decision-mixed feeding stuff requirements, mixed feeding stuff (Mix) combinations are shown in Table 5. The mixed feeding stufffeedingis better than one feeding stuff feeding, such as A, B, C, D, E are five different methods of feeding pig feeding stuff alone, in the respects of feeding stuff costs and feeding ration., A, B, C, D, E, and Mix feeding volume and feeding cost comparison data are shown in Table 6.

Table5 Calculated mixed feeding stuff (Mix)

Selected feeds	Feed ration*（kg）	Cost*（yuan）
A	0.0586	0.4
B	0.0762	0.5
D	0.3663	2.0

Note：*Feed ration, feeds a pig need a day; *Cost, feed a pig need spendinga day

Table6 Comparisons of intake and cost between mixed and singlefeeding stuff

Fed feeds	Feed ration* (kg)	Cost* (yuan)
A	0.89	6.2
B	0.97	6.0
C	0.88	5.5

D	0.87	4.8
E	0.94	4.9
Mix	0.50	2.9

Note：*Feed ration, feeds a pig need a day; *Cost, feed per pig need spendingper day

Analysis showed that, when a singlefeeding stuffbreeding meet all the nutritional needs,some nutritional elements areexcess result in feeding stuff waste. When nutrients to meet the requirements of crude fiber, protein and phosphorus ration greater than requirements, indirectly feeding stuff waste and excess nutrients polluting the environment during defecation. Selecting mixedfeeding stuff fed to reduce breeding costs and waste of resources, and with a more balanced nutritional needs.

3.2.1Price factor

In this paper, the model aims at givingthe lowest cost of feeding stuff feeding combination in the breeding process, depending on the kind of prices of feeding stuff. The changing feed prices on the marketimpact model calculations for changes in feeding stuff prices, using the simulation models in terms of price changesfeeding stuff case to get the selection result. For A, B, C, D, E the five kinds of pig feeding stuff,listingthree groups changing price(Ⅰ, Ⅱ, Ⅲ). Price Ⅰ {7,6.2,6.3,5.5,5.2}; PriceⅡ{7.0,6.9,6.5,6.5,5.7}; PriceⅢ {7.5,6.9,6.5,6.7,4.5}. Calculated by the model, the results obtained 3 Group Mixed Feed Mix Ⅰ, Mix Ⅱ, Mix Ⅲ, as the Table 7shown.

Table7 Calculated results of feeding decision model

Mix feeds	selection feeds	Costs* (yuan)
MixⅠ	A、B、D	2.9
MixⅡ	A、B、C、D	3.3
MixⅢ	B、C、D、E	3.7

Note：*Cost, feed a pig need spendinga day

Themodel results were analyzed, and the three groups ofmixed feeding stuff costs were compared with a single feeding costs (Table 6), we find that the mathematical model of mixed feeding stuff to get the lowest cost, shown in Figure 2. The priceⅠ, priceⅡ, priceⅢthree groups of different prices feeding stuff, mixed feeding stuff Mix cost obtained (shown in black bars shown in block) are minimum by solving the model, the calculation results show that the three groups of computing results, the selection of only one feeding stuff to breed, under the conditions required to meet the nutritional needs of feeding stuffcosts were greater than the cost it takes to Mix, price changes in conditions, the model still can calculate the lowest-cost breeding selection results.

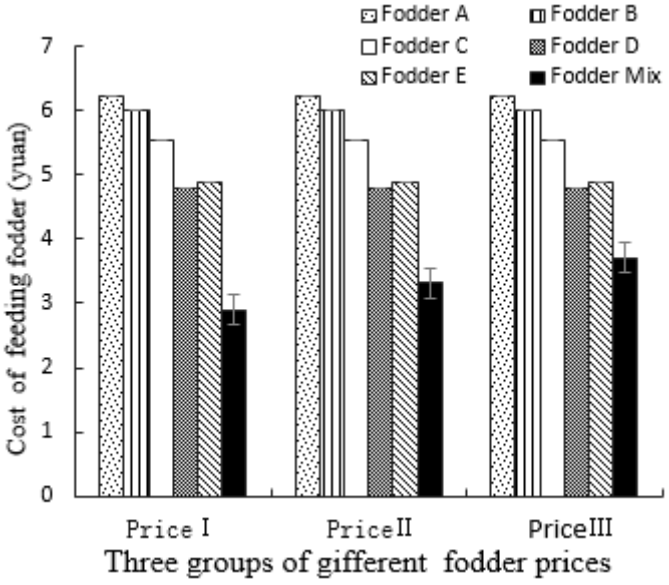

Fig. 2 Comparison of cost between mixed and single feeding stuff

3.2.2Specified mixed feeding stuff

Under certain circumstances, breeding pigfeeding stuff with special requirements, for the same growth stage pig,due to the differentgrowth status the needs of pig feeding stuff different,poor growth conditions may need to be bred a certain or a few specific pig feed feeding stuff, different growth stage with different nutritional requirements , feeding the specific needs of different feeding stuff, in order to meet these conditions, in particular the feeding stuff of feed A and feeding stuff of fed specific B, D, use the model to calculate the breeding selection decision, the results shown in Table 8.

Table 8 Calculated results of feeding decision model

Mix feeds	selection feeds	Costs* (yuan)
Specific A	A、	3.70
Specific B、D	B、C、D、E	3.71

Note：*Cost, feed a pig need spendinga day

The results of the data analysis showed that under certain circumstances the feeding stuff ration, the model calculated the lowest cost of mixed feed, shown in Figure 3.Feeding stuffA in the feeding of two specific and particular conditions of feeding stuff B of A, B, C, D, E, Mix these six kinds of feeding costs compared to Figure 3,breeding feeding stuff A group known specific investment Mix Hey cost of 3.70 Yuan, the specific feed fed group B, D Mix feeding cost of 3.71 Yuan, the lowest point are in the fold, the minimum cost of breeding, feeding fixed feeding stuff under specific conditions, to get through the model to calculate the most cost excellent choice of feeding stuff result.

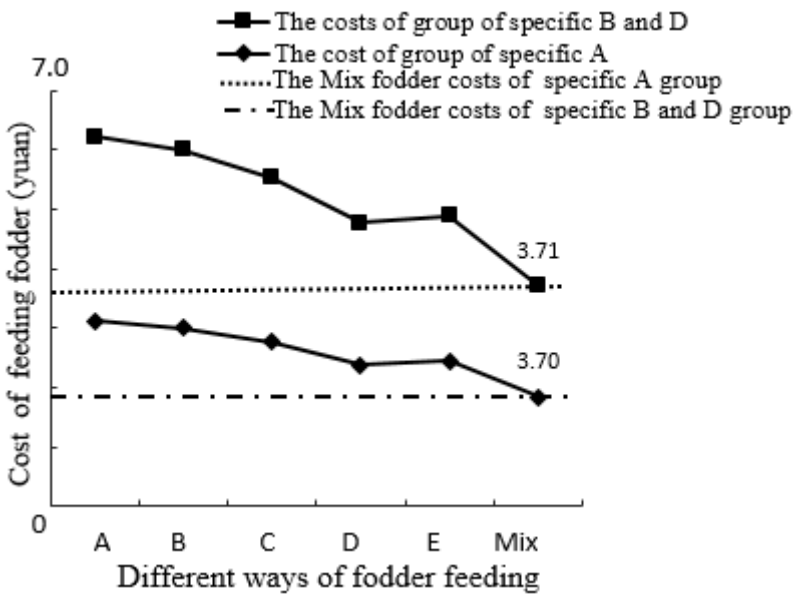

Fig.3 Comparison of cost between specific feeding A and feeding B, D

3.2.3Nutritional needs

In the process of pig breeding, different season with different effects on pig growth, higher temperatures summer and low temperatures winter have different effects on pig feeding stuff intake and nutrient requirements. Summer reduce the needs for appropriate high crude fiber intake of growth pig, and winterlow temperatures need to increase energy intake of protein for pig , which is required to change the conditions of the model equation constraint. In summer and winter the two conditions, for example, through a decision-making model for solving the feed mixed feeding stuff to get the results shown in Table 9.

Table 9 Calculated results of feeding decision model

Constrains	Selection feeding stuff	Costs (yuan)
Winner	A、B、D	2.90
Summer	B、D	3.3

Note：*Cost, feed a pig need spendinga day

Though the results of the analysis ,we know that in the summer and winter both cases, the results calculated by the model are bred in to meet the nutritional needs of growing conditions, day feeding stuff costs 2.9Yuan and 3.3Yuan, comparing with a separate feeding A, B, C , D, E five kinds of feed costs necessary 6.2,6.0,5.5,4.8,4.9 (Yuan) , is the optimal cost of the pig breeding, that seasonal changes in nutritional requirements change of pig growth conditions, the model calculated optimal costs mixed feeding stuff.

4. Conclusion

The aim of this paper is to build a pig feeding optimization mathematical model and obtain the lowest-cost feeding mixed results.A model was developed based on optimal cost, considering three elements: price factor, specified feeding stuff and nutritional requirements. The results were analyzed demonstratingits validity according to growing pig conditions. Use of the feeding selection decision model can enable more precise feeding, proper selection of feeding stuff,lower cost and increasing economic benefit of pig breeding.

Acknowledgement

This paper was supported by the Shandong Province innovation special (2014XGA13054).Supported by National Science and Technology Supporting Program (2014BAD08B05).

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