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Research Article

On Security Evaluation of Liquid Milk Packaging Based on Tetra Pak Case

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Abstract: Milk Campaign has played a key role in national strategy of prosperous and vigorous economy in one country, consequently, milk security will have a direct impact on sound mind and body of the nation. By means of accelerating the fuzzy AHP screening index of genetic algorithm and constructing evaluation index system of liquid milk packaging security, the study puts forward the information entropy with objective and subjective empowerment and improving the AHP coupling weighting. By sequencing the influence factors of liquid milk packaging security, the liquid milk packaging security evaluation model is eventually established with the fuzzy comprehensive evaluation method. It is proved by sufficient practices that the model features as scientific, objective, reasonable and easy, therefore, by means of this model, liquid milk packaging security status can be evaluated and judged promptly, which can provide theoretical support for liquid milk packaging security supervision conducted by relevant departments. Furthermore, the model has certain application value in various comprehensive evaluation issues and researches.

Keywords: Entropy, evaluation, fuzzy, improved analytical hierarchy process, liquid milk, packaging, security

INTRODUCTION

In recent years, with continuous exposure of such scandals as PVC (PVC) cling film carcinogenic incident, Three Deer Accident and Nestle infant milk contamination by packaging printing inks, milk quality and safety has gradually becomes the focus of public. However, milk quality security is not only affected by dairy product itself, but also has substantial connection with its packaging to a large extent. Since 2008, China has issued Food Packaging and Certification Regulation and The Law on Food Security in People's Republic of China, both of which make clear regulation to the security requirements for food packaging materials and packaging support materials. Currently, in most cases, the domestic scholars make researches into food packaging security mainly from aspect of security of packaging materials. For instance, in the study On Food Packaging Security in the Case of Tainted Milk-powder (Tang and Wang, 2008), the authors make analysis into security risks of milk package from the perspective of package materials, printing inks and the printing support materials. The papers On Security of Food Packaging Materials and Countermeasures (Guo *et al*., 2006) and Security Analysis of Food Packaging Materials (Liu and Zhao, 2009) respectively described the factors that can affect the safety of common food packaging materials in plastic, paper, metal, glass and ceramics. However, it is hard to find the researches on food packaging by means of fuzzy mathematics evaluation method especially on security evaluation index system and evaluation model of liquid milk packaging. Hence, based on the typical Tetra Pak case of liquid milk packaging and from the perspective of physical, chemical and accessory material factors affecting packaging security, the paper adopts Accelerating Genetic Algorithm based Fuzzy Analytic Hierarchy Process (AGA-FAHP) (Jin *et al*., 2004) for the purpose of security evaluation system construction of liquid milk packaging. At the same time, subjective and objective improvement of AHP weighting method coupled with the information entropy is applied to entitle the established evaluation system. What's more, combining with fuzzy comprehensive evaluation method to establish milk packaging security evaluation model, the paper attempts to evaluate and judge the milk packaging security status in a scientific and logical way, for the purpose of providing theoretical support for liquid milk packaging security supervision conducted by relevant departments.

METHODOLOGY

Establishment of security evaluation index system of liquid milk packaging: Liquid milk packaging security evaluation is a multi-level, multi-attribute decision making problem. Hence, in order to establish security evaluation index system of liquid milk packaging, the

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following part will be based on The Law on Food Security in People's Republic of China and The Standard of Co-extruded Packaging Film and Bag of Liquid Milk, making scientificalness, comprehensiveness, feasibility, comparability and independence as the basic principles and applying Accelerating Genetic Algorithm based on Fuzzy Analytic Hierarchy Process (AGA-FAHP) screening index.

Screening by AGA-FAHP index: By Inviting the relevant experts to compare the importance between the two evaluation indexes, the Fuzzy Complementary Judgment Matrix $P=(p_{ij})$ can be established, with the requirement of $0 \le p_{ij} \le 1$, $p_{ij}+p_{ji}=1$. p_{ij} indicators i is better than j in terms of degree, which is specifically defined as follows: at the time $p_{ij}>0.5$, i is important than j; the greater p_{ii} is, the more important i is than j and vice versa. If P can't meet the requirement of a satisfactory agreement, you need to amend.

Suppose that amendment of P designed to determine matrix $Q=(q_{ij})$, the weight of each index for Q is still denoted by $w_j\,(j=1,\cdots,M)$ and in the following formula, the minimum Q is called the optimal fuzzy consistent comparison matrix of P (Jin *et al*., 2004):

$$\min CIC(M)=\sum_{i=1}^{M}\sum_{j=1}^{M}\left|q_{ij}-p_{ij}\right|/M^2 + \sum_{i=1}^{M}\sum_{j=1}^{M}\left|0.5(M+1)(w_i-w_j)+0.5-q_{ij}\right|/M^2 \qquad (1)$$

where, the objective function CIC (M) is called the consistency index coefficient; d is non-negative parameters, generally selected from within (0, 0.5); and the remaining symbols are the same as the above. In Eq. (1), the weight $w_j\,(j=1,\cdots,M)$ and correction of upper triangular matrix $Q=(q_{ij})$ elements are defined as the optimization variables and for order Fuzzy Complementary Judgement Matrix *M*, the total independent optimization variables of P is $M(M+1)/2$.

Simulation of biological survival of the fittest rules and group information exchange mechanism within the chromosome Accelerating Genetic Algorithm (AGA) is a general global optimization method (Jin and Ding, 2006), which is a simple and effective way to solve the problems shown in Eq. (1).

When CIC (M) is less than a certain critical value, it can be considered that P has the satisfactory consistency and whereby the various elements of sort of calculated weight of w_i are acceptable; otherwise the parameter of d need to be improved or the original matrix of P need to be modified until a satisfactory consistency is obtained.

In order to improve index selection reliability, *N* experts can be invited to independently establish a fuzzy complementary matrix *P* containing *N* individuals. In the process, by means of *AGA-FAHP* the evaluation index weights set $w_{k,j}\,(j=1,\cdots,M, k=1,\cdots,N)$ of N can be obtained. Then by selection of the index of average weight $\overline{w}_j=\sum_{k=1}^{N} w_{k,j}/N$, the biggest m indicators form the final liquid milk packaging security evaluation index system x_i (i = 1,…, m).

Security evaluation index system of liquid milk packaging: The set of evaluation system elements of liquid milk packaging is the prerequisite and basis for security assessment. The setting of reasonable and accurate index system directly affect the evaluation results in terms of scientificalness, reliability and accuracy.

Via $AGA-FAHP$, the following 3 primary indexes can be obtained, including physical properties of packaging materials, chemical properties of packaging materials and packaging support materials:

- **Physical properties of packaging materials:** Physical properties mainly include such 5 secondary indexes as mechanical, barrier, heat sealing, thermal stability and resistance to ultraviolet.
  Mechanical focuses on packaging materials in terms of mechanical filling and sealing; the natures of press-resistance, impact-resistance and puncture resistance; various outside damage-resistance in storage stacking, transportation and handling process (Yang, 2009). Barrier requires that barrier packaging material should have the features of oxygen barrier, light resistance, moisture proof, long-term fragrance and odors prevention and keep the packaging bag away from some factors in the external environment bacteria, dust, gas, light and water. Furthermore, it must be ensured that some essential components for product quality of milk, such as water, oil, aromatic components should not be outward osmotic (Liu, 2005); heat sealing here mainly focuses on whether the packaging material has a certain sealing contamination resistance; thermal stability mainly inspects whether the packaging material will have physical or chemical changes in the sterile thermal processing; UV resistance focuses on whether organic structure of material will change in the ultraviolet sterilization process.
- **Chemical properties of packaging materials:** Three secondary indexes of non-toxic chemical resistance and migration are mainly included in this aspect. Non-toxic requires that in plastic film

Table 1: Liquid milk of tetra pack packaging security evaluation index system, weights and sorts

Primary index	Secondary indexes	High security	Security	Relatively high security	Base security	Less security	Combination weights	Sort of weights
Physical properties of packaging materials B_1 (0.402)	Mechanical properties C_{11} (0.320)	0.2	0.6	0.2	0	0	0.129	1
	Barrier properties C_{12} (0.242)	0.3	0.4	0.2	0.1	0	0.097	5
	Heat sealing properties C_{13} (0.212)	0	0.6	0.4	0	0	0.085	7
	Thermal stability C_{14} (0.180)	0.4	0.5	0	0.1	0	0.072	9
	UV resistant properties C_{15} (0.046)	0.3	0.6	0.1	0	0	0.018	11
Chemical properties of packaging materials B_2 (0.321)	Non-toxic properties C_{21} (0.403)	0	0.5	0.4	0	0.1	0.129	2
	Chemical resistant C_{22} (0.350)	0.2	0.3	0.3	0.1	0	0.112	4
	Migration performance C_{23} (0.247)	0.5	0.3	0.1	0	0.1	0.079	8
Packaging support materials B_3 (0.277)	Printing inks C_{31} (0.413)	0.3	0.3	0.3	0.1	0	0.114	3
	Packaging additives C_{32} (0.341)	0.2	0.4	0.3	0	0.1	0.094	6
	Packaging adhesive C_{33} (0.246)	0.1	0.4	0.3	0.1	0.1	0.068	10

packaging material added antioxidant, antistatic agent and smooth agent should be non toxic in the processing process; chemical resistance requires that organic structure of material should not change when chemical agents are used in aseptic processing; migration focuses on whether primary packaging materials will release toxic and harmful substances into the food.

- **Packaging support materials:** This section mainly covers 3 secondary indexes of printing ink, packaging additives and packaging adhesive. In addition to the general technical requirements containing adhesive force, wear resistance and scratch resistance the printing ink of liquid milk packaging requires the abilities to withstand pasteurization, sterilization and hydrogen peroxide water treatment. Meanwhile, ink must also has the abilities of oxidation resistance, water resistance, heat resistance and freeze resistance; non-toxic or low toxicity additive should be applied in package additive; packaging adhesive should be non-toxic and non-odors, no harmful food packaging extract is found and no printing patterns and ink are corroded.

Based on the above analysis, the security evaluation index system of liquid milk Tetra Pak packaging the liquid state milk Tetra Pak packaging safety evaluation index system as shown in Table 1.

ESTABLISHMENT OF EVALUATION MODEL

Setting of evaluation index system: The setting of reasonable and accurate index system directly affects the evaluation results in terms of scientificalness, reliability and accuracy. The established evaluation index system of liquid milk packaging security in 2.2 is shown in Table 1. In this table, the collection of the evaluation is A = {B_1, B_2, B_3} and the subsets of all the single factors are:

$$B_1 = \{C_{11}, C_{12}, C_{13}, C_{14}, C_{15}\}$$

$$B_2 = \{C_{21}, C_{22}, C_{23}\}\ ,\ B_3 = \{C_{31}, C_{32}, C_{33}\}$$

Determination of the remarks sets: Based on the actual needs of the evaluation and decision, the standards of the evaluation grades can be divided into five levels: High Security, Security, Relatively High Security, Base Security and Less Security. That is, remarks sets are expressed as follows:

$V = \{v_1, v_2, v_3, v_4, v_5\}$ = {High Security, Security, Relatively High Security, Base Security and Less Security}

The assignment can be obtained with the result:

$$V = \{100, 90, 80, 70, 60\}$$

Determining of entropy and improved AHP coupling weight:

- **Empowering of the improved AHP:**
  - **Construction of complementary judgment matrices:** In the complementary judgment Matrices-0-l scale, "0" means that A is inferior to B; "0.5" means that A equals B; and "1" means A is prior to B. The complementary judgment Matrices can be constructed through a 0-1 scale method.
  Hence, the following Matrices could be obtained:

  $$F = (f_{ij})_{m\times m}$$

  - **Establishing fuzzy consistent matrix:** Based on According to the conversion equation $r_{ij} = \frac{r_i - r_j}{2m} + 0.5$ (2) ($r_i = \sum_{j=1}^{m} f_{ij}$ means sums of the rows) shown in reference (Xu, 1999), complementary judgment Matrices can be converted to fuzzy consistent matrix, i.e., $F' = (f_{ij}')_{m\times m}$.

- **Factors weight:** According to method of calculation-the traditional hierarchy analysis, the factors weight W can be figured out.

* **Determining of entropy weight:** If there is m evaluating indicators and n evaluating objects, the original formed data matrix is $X^{'} = (x_{ij}^{'})_{m \times n}$. Hence, the calculation procedure of entropy weight is as follows:

- We can get the matrix $X = (x_{ij})_{m \times n}$ from the normalization to the data of X index values (Jiang, 1987). The method is as follows:

$$x_{ij} = (x_{ij} - \min_j x_{ij}) / (\max_j x_{ij} - \min_j x_{ij}), [i \in I_1] \quad (2)$$

$$x_{ij} = (\max_j x_{ij} - x_{ij}) / (\max_j x_{ij} - \min_j x_{ij}), [i \in I_2] \quad (3)$$

where,
I_1 = Effective index
I_2 = Cost target

- Calculation of the j evaluation index weight in the i index is:

$$p_{ij} = x_{ij} / \sum_{j=1}^{n} x_{ij} \quad (4)$$

- Calculation of the entropy values of the i index is:

$$e_i = -k \sum_{j=1}^{n} p_{ij} \ln p_{ij} \quad (5)$$

and

$$k = \frac{1}{\ln n}$$

- Determining entropy weights of the i index is:

$$w_i = (1 - e_i) / \sum_{i=1}^{m} (1 - e_i) \quad (6)$$

* **Entropy weight and improvement of AHP to empower the couple:** By applying the formula:

$$\omega_i = \sqrt{W_j w_j} / \sum_{j=1}^{m} \sqrt{W_j w_j}, \ j = 1, 2, ..., m$$

and revising each evaluating indicator, we can get the final liquid milk packaging security evaluation index system of coupled weights of indexes at all levels.

Fuzzy comprehensive evaluation: In the first place, based on the evaluation standard stated by the evaluation expert panel (n persons contained), we can calculate the number of persons (n_1, n_2, n_3, n_4, n_5 and $n = \sum_{i=1}^{5} n_i$) in five levels: v_1 (High Security), v_2 (Security), v_3 (Relatively High Security), v_4 (Base Security), v_5 (Less Security). After the normalization, we can obtain the grade of membership (n_1 / n, n_2 / n, n_3 / n, n_4 / n, n_5 / n). From which we know the evaluation and decision-making matrix of single factor $R_i (i = 1, 2, 3)$ in each subset $C_i (i = 1, 2, 3)$, then, we get the evaluation and decision-making matrix in each subset according to the multistage Comprehensive Evaluation from documents (Chen *et al*., 2010) and eventually liquid milk packaging security evaluation results can be achieved.

Case application:

Various indexes weight determination: Printing inks (C_{31}), packaging additives (C_{32}), packaging adhesive (C_{33}), the three secondary indexes covered by the first class index of packaging support materials (B_3), are taken as the cases to illustrate the determination of the coupling weight:

* **Improved AHP empowerment:**

- **Tectonic complementary judgment matrix:** Experts are invited to compare the pair wise importance of these three factors and form the complementary judgment matrix:

$$F_{C_3} = \begin{pmatrix} 0.5 & 1 & 1 \\ 0 & 0.5 & 1 \\ 0 & 0 & 0.5 \end{pmatrix}$$

- **Establishing fuzzy consistent matrix:** According to the Eq. (2), it is required to transform the F_{C_3} into:

$$F_{C_3}^{'} = \begin{pmatrix} 0.5 & 0.67 & 0.83 \\ 0.33 & 0.5 & 0.67 \\ 0.17 & 0.33 & 0.5 \end{pmatrix}$$

- **The determination of the weights of all factors:** By using the analytic hierarchy process suggested by literature (Jiang, 1987), the calculation method for weights can be applied to obtain that $W_{C_3} = (0.454, 0.333, 0.213)$.

* **Determination of the entropy weight:** In the case of the three evaluation indexes-printing inks, packaging additives and packaging adhesive, 10 experts are invited to grade for the importance of different indexes (Table 2).

Table 2: Expert rating form from each indicator of package support materials

Index	High importance	Importance	General importance
Printing inks C_{31}	0.30	0.60	0.10
Packaging additives C_{32}	0.30	0.50	0.20
Packaging adhesive C_{33}	0.40	0.40	0.20

By using the formula (3) and normalizing the raw data:

$$X_{C_3} = \begin{pmatrix} 0.3 & 0.6 & 0.1 \\ 0.3 & 0.5 & 0.2 \\ 0.4 & 0.4 & 0.2 \end{pmatrix}, \; X_{C_3}^{'} = \begin{pmatrix} 0.4 & 1 & 0 \\ 0.33 & 1 & 0 \\ 1 & 1 & 0 \end{pmatrix}$$

can be got.

By Eq. (4) to (6), we can calculate entropy weight $\omega_{C_3} = (0.413, 0.341, 0.246)$

- **Entropy weight and improvement of AHP to empower the couple coupling weight:** By using the formulas (7) to amend the 3 evaluation indexes, we get the $\omega_{C_3} = (0.413, 0.341, 0.246)$.

Using the same method, coupling weights of the all the rest indexes can be obtained, with the results shown in the brackets in Table 1.

Implementation of the comprehensive evaluation: Taking one liquid milk brand in Tetra Pack packaging as the example, the following comes an evaluation on E-E. Ten related experts have been organized to vote for Secondary indexes according to the five grades centralized by the comment. The normalized results are shown in Table 1. Thus, the Weight vector of packaging support materials B_3 is expressed as follows:

$$W_{B_3} = W_{C_3} \cdot R_3$$
$$= (0.413, 0.341, 0.246) \cdot \begin{pmatrix} 0.3 & 0.3 & 0.3 & 0.1 & 0 \\ 0.2 & 0.4 & 0.3 & 0 & 0.1 \\ 0.1 & 0.4 & 0.3 & 0.1 & 0.1 \end{pmatrix}$$
$$= (0.3, 0.341, 0.3, 0.1, 0.1)$$

By normalization, the primary factor Weight vector of packaging support materials B_3:

$$\bar{W}_{B_3} = (0.263, 0.299, 0.263, 0.088, 0.088)$$

Similarly, we can find out each Weight vector of the other two primary factors by normalization. They are expressed as follows:

$$\bar{W}_{B_1} = (0.277, 0.366, 0.243, 0.114, 0)$$

$$\bar{W}_{B_2} = (0.198, 0.322, 0.320, 0.080, 0.080)$$

So the security evaluation quotient could be reached:

$$W_A = W_B \cdot R_B = W_B \cdot (\bar{W}_{B_1}, \bar{W}_{B_2}, \bar{W}_{B_3})$$
$$= (0.402, 0.321, 0.277) \begin{pmatrix} 0.277 & 0.366 & 0.243 & 0.114 & 0 \\ 0.198 & 0.322 & 0.320 & 0.080 & 0.080 \\ 0.263 & 0.299 & 0.263 & 0.088 & 0.088 \end{pmatrix}$$
$$= (0.277, 0.366, 0.320, 0.114, 0.088)$$

In this way, we get the results of the evaluation on the liquid milk packing security: By normalization, Weight vector of A is like this:

$$\bar{W}_A = (0.238, 0.314, 0.275, 0.098, 0.076)$$

According to the maximum subordination principle, we get the conclusion that the Security Evaluation for the liquid milk packaging can be called "security".

Assessment score: From the formula $Z = W_A \cdot V^T$, we can see the score of the comprehensive evaluation of the liquid milk security:

$$Z = (0.238, 0.314, 0.275, 0.098, 0.076) \cdot (100, 90, 80, 70, 60)^T$$
$$= 85.41$$

RESULTS ANALYSIS

- Through these calculations and on the basis of fuzzy comprehensive evaluation method, the liquid milk in Tetra Pack packaging security evaluation results indicate that, 23.8% are of high security, 31.4% are of security, 27.5% are of relatively high security, 9.8% are of basic security and 7.6% are of less security. Based on the maximum subordination principle, the security level of this brand liquid milk packaging is "security" and its composite score is 85.41. It can be concluded that its security level is satisfactory, the results of which is basically consistent with the realities.
- Calculation results in Table 1 indicate: of all the primary indexes, physical properties of packaging materials is the greatest factor that affects the security of liquid milk packing, with 40% percent; of all the secondary indexes covered by primary indexes, Mechanical properties, Non-toxic properties and printing inks are the greatest factors that affect their corresponding primary indexes, with 32, 40.3 and 41.3%, respectively; mechanical properties, Non-toxic properties, printing inks and chemical resistance of packaging security are the top 4 in all the 11 indicators of secondary indexes

that generally affect liquid milk packing security, with the weight of 12.9, 12.9, 11.4 and 11.2, respectively. Therefore, in the process of liquid milk packaging security precaution, particular attention should be paid to the effects of above factors on liquid milk packaging security.

CONCLUSION

Liquid milk security evaluation is a multi-level and multi-attribute decision issue. By means of accelerating the fuzzy AHP screening index of genetic algorithm and constructing evaluation index system of liquid milk packing security, the paper puts forward the information entropy with objective and subjective empowerment and improving the AHP coupling weighting. By empowering the indexes of all the levels, the paper gains the importance sequencing of 11 factors affecting liquid milk packaging security. At the same time, the liquid milk packing security evaluation model is finally established with the fuzzy comprehensive evaluation method. It is proved by case calculation that the model features as scientific, objective, reasonable and easy and the evaluation result can reflect the liquid milk packaging security conditions with certain practicability.

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