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Research Article

The Pre-warning Analysis of Packaging Design Safety of Jelly Food

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Abstract: For the purpose of enhancing evaluation of packaging design safety of jelly food, this thesis follows relevant experts' opinions, explores the fuzzy clustering analysis and principal component analysis to build pre-warning system of jelly food's packaging design safety, then use the triangular fuzzy AHP analysis to empower the various indicators of the pre-warning system, combines with fuzzy comprehensive evaluation method to create pre-warning model of the jelly food's packaging design safety, finally determines the pre-warning levels of packaging safety of jelly food based on the data from the empirical researches, reorders the 10 important indicators of affecting the jelly food's packaging design safety.

Keywords: Jelly, packaging design, pre-warning, safety

INTRODUCTION

Since entering the Chinese market at the end of the last century, Jelly food won the majority of consumers especially children's favor by its bright colors, various flavors, unique taste. However, with the rapid expansion of jelly food market tragedies that children are choked to death accidentally because of unsafe packaging design occur frequently, e.g., an 8-year-old boy in Beijing chokes to death in February of 2002, a 3-year-old boy in Shaoguan, Guangdong province dies of asphyxiation caused by eating jelly in October 2004, a one and a half years old baby Chen Ruoning in Shanghai chokes to death in March 2005 and so on. Therefore, China Consumers Association issues pre-warning announcements several times to enhance the safety of jelly food (Hu, 2005). The central government improves the national standard of "jelly" in 2006 (GB19833-2005) to limit the size of the various jellies (the diameter of cup large than 3.5 centimeters) and net weight (the weight of flower-shaped, heart-shaped deformed gel jelly large than or equal to 30 g) and the described words on the packages, which improves greatly the safety of the jelly food. However, jelly that meets the new standards is also dangerous to children, e.g., a 3-year-old child Yuan Jiahao in Wuhan 2006 is stuck by a jelly with the diameter of 3.72 cm in trachea and dies.

Recently, the domestic researches on packaging design safety of jelly food are rare, only several papers to explore the controlling of jelly's packaging quality, testing and packaging design, such as "the controlling of packaging quality of plastic jelly cups" (Zhang, 2004), "the detecting methods of packaging quality of cupped fruit jellies" (Hao, 2013), "innovative design of jelly's packaging safety" (Yang and Zhang, 2009). The study of evaluation of the packaging design safety of jelly food is a blank. In order to assist relevant enterprises, markets, consumers and quality supervision departments in jelly food packaging safety production, judgment and supervision, this study will firstly build a pre-warning system of jelly food packaging design safety and on the basis of it, the study will establish a pre-warning model for the packaging design safety of jelly food.

BUDING A PRE-WARNING SYSTEM FOR PACKAGING DESIGN SAFETY OF JELLY FOOD

There needs to build a scientific pre-warning system for packaging design safety of jelly food in order to pre-warn effectively the packaging design safety of jelly food. This study uses the fuzzy clustering analysis and principal component analysis to reduce the dimension and select certain factors affecting packaging design safety of jelly food on the safe, scientific, comprehensive and hierarchical principles based on requirements of national standards "jelly" (GB19833-2005) and certain regulations of "Food Packaging Law of People's Republic of China", "Measures for the Management of Food Packaging Product Certification" following the suggestions of specialized experts, build a pre-warning system for packaging design safety of jelly food including the 4 first-class indicators for choosing materials of packages (A_1), designing structures of

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packages (A_2), designing functions of packages (A_3), designing instructions of packages (A_4), here follows the detailed indicators:

Choosing materials of packages: It includes 2 two-class indicators for raw materials of packages and auxiliary materials of packages that mainly refer to the various additives in ink printing and composite adhesives.

Designing structures of packages: It includes the sizes of packages and 3 two-class indicators for net weight, resistance to pressure, separation.

Designing functions of packages: It includes 2 two-class indicators for protecting function and convenient function that mainly refers to that the opening of jelly food's package is convenient and the use is comfortable.

Designing instructions of packages: It includes 3 two-class indicators for security warning design, anti-fake label and emotional cue. Security warning design refers to issue the warning signals for consumers through words, graphs and color in the jelly food's package in order to protect consumers from injuries caused by jelly food. Emotional cue includes such reminding messages for eating methods, opening methods, eating occasions, preservation and recovery.

STUDY ON THE PRE-WARNING MODEL THE PACKAGING DESIGN SAFETY OF JELLY FOOD

Setting a system of pre-warning indicators for packaging safety of jelly food: To set up the pre-warning indicators system for packaging safety of jelly food is the premise and basis for analyzing pre-warning of packaging safety of the jelly food.

In Table 1 a pre-warning system U for packaging design safety of jelly food, a collection of first-class evaluation factors $U=\{A_1,A_2,A_3,A_4\}$, a sub collection of second-class evaluation factors $A_i(i=1,2,3,4)$, respectively $A_1=\{B_{11},B_{12}\}$, $A_2=\{B_{21},B_{22},B_{23}\}$, $A_3=\{B_{31},B_{32}\}$, $A_4=\{B_{41},B_{42},B_{43}\}$.

Setting a collection of evaluation: According to the actual need of pre-warning analysis of packaging safety of jelly food, here needs to divide the pre-warning levels into "I level", "II level", "III level", "IV level" and "V level", i.e., a collection of evaluation is {I level, II level, III level, IV level, V level}. The "I level" stands for "very safe", "II level" stands for "safe", "III level" stands for "less safe", "IV level" represents "unsafe", "V level" stands for "very unsafe".

Using hierarchical analysis of triangular fuzzy numbers to weight the indicators: At present, Analytic Hierarchy Process (AHP) to weight all levels pre-warning indicators can be used to effectively consider and integrate all kinds of qualitative and quantitative information in the evaluation process, but shortcomings still can be found in stochastic in the evaluation process and experts' subjective uncertainty and understanding ambiguity (Yu and Fu, 2004). At the same time, because of limitation and subjectivity of human judgment, the results from comparing a group of evaluation factors by using AHP are generally of no consistency, thus here needs a consistency test. If the test does not pass, then there needs to adjust the judgment matrix to recalculate, it will increase the complexity of calculation (Zhang *et al*., 2009).

If the triangular fuzzy number is introduced into the AHP judgment matrix structure that can fully consider ambiguity of personal judgment, the structure of judgment matrix is more reasonable, while will avoid this step of consistency test, this method is called triangular fuzzy AHP (Chen *et al*., 2012). Here follows the steps of using hierarchical analysis method to empower based triangular fuzzy numbers:

- **Asking experts to compare groups of pre-warning indicators and object, building the fuzzy judgment matrix with triangular fuzzy numbers $A=(a_{ij})_{n\times n}$:** The element $a_{ij}=[l_{ij},m_{ij},u_{ij}]$ is a closed interval with m_{ij} as the mid values and $a_{ij}=a_{ji}^{-1}=[1/u_{ij},1/m_{ij},1/l_{ij}]$. When there are n expert (s) to judge, a_{ij} as an integrated triangular fuzzy number, comes the following equation: $a_{ij}=\frac{1}{n}(a_{ij}^1,a_{ij}^2,\cdots,a_{ij}^n)$ and $a_{ij}^k=[l_{ij}^k,m_{ij}^k,u_{ij}^k](i,j=1,2,\cdots,n)$ is triangular fuzzy numbers given by k expert (s), the mid values m_{ij} of triangular fuzzy numbers can be based on 1~9 scale of AHP method (Jiang, 1987).
- **Calculating the comprehensive importance degree numbers in the criteria of evaluation:** Suppose M_{Ei}^j as importance degree number to denotes i evaluating criterion in contrast to j evaluating criterion in the fuzzy judgment matrix, namely $M_{Ei}^j=a_{ij}$, Suppose S_i as comprehensive importance degree number to denote i evaluating criterion in contrast to all other evaluating criteria in the fuzzy judgment matrix, here use the formula (1) to calculate the importance of each criterion:

$$S_i=\sum_{j=1}^{n}M_{Ei}^j\otimes(\sum_{i=1}^{n}\sum_{j=1}^{n}M_{Ei}^j)^{-1},i,j=1,2,\cdots,n \quad (1)$$

- **Calculating the normalized weighting number in the criteria of evaluation:**

Suppose the triangular fuzzy number $S_1 = (l_1, m_1, u_1), S_2 = (l_2, m_2, u_2)$, $V(S_1 \geq S_2)$ as the possibility degree of triangular fuzzy number $(S_1 \geq S_2)$, in the meantime, $V(S_1 \geq S_2, \cdots, S_k)$ is supposed as the possibility degree number $S_i (i = 1, 2, \cdots, n)$ if the triangular fuzzy number S is greater than or equal to k triangular fuzzy numbers, $d'(C_i)$ as pure measurement when a criterion C_i is superior to other criteria, here comes:

when $m_1 \leq m_2$.

$$V(S_1 \geq S_2) = \begin{cases} \dfrac{l_2 - u_1}{(m_1 - u_1) - (m_2 - u_2)}, l_2 < u_1 \\ 0, l_2 \geq u_1 \end{cases} \quad (2)$$

when $m_1 > m_2$, $V(S_1 \geq S_2) = 1$:

$$d'(C_i) = V(S_i \geq S_1, \cdots, S_{i-1}, S_{i+1}, \cdots, S_n) = \min(S_i \geq S_k), \quad k = 1, 2, \cdots, n, k \neq i \quad (3)$$

Then the weight vector of all the criteria can be got:

$$w' = (d'(C_1), d'(C_2), \cdots, d'(C_n))^T \quad (4)$$

After normalized, normalized weight numbers of each criterion can be calculated:

$$w = (d(C_1), d(C_2), \cdots, d(C_n))^T \quad (5)$$

Analysis of pre-warning model for packaging safety of jelly food: Groups of evaluation expert (*n* persons) evaluate each indicator according to the its specific evaluation reference, obtain the numbers of each level $n_i (i = 1, 2, \cdots, 5)$ and the membership degree of a single factor after normalization (n_1 / n, n_2 / n, n_3 / n, n_4 / n, n_5 / n) (among them $n = \sum_{i=1}^{5} n_i$), then, comes into the pre-warning deciding matrix of each factor in each sub collection $B_{ij} (i = 1, 2, 3, 4; j = 1, 2, 3)$ of single factor $R_i (i = 1, 2, 3, 4)$ are obtained; Weight coefficient vector of a single factor $w_{A_i - B}$ and pre-warning deciding matrix R_i reaches $B_i = w_{A_i - B} \cdot R_i (i = 1, 2, 3, 4)$ through the synthetic calculation, gets $\tilde{B}_i$ being normalized, then obtains the two-level pre-warning deciding matrix $R = (\tilde{B}_1, \tilde{B}_2, \tilde{B}_3, \tilde{B}_4)$, gets $U = W_{U-A} \cdot R$ through the synthetic calculation that is result of the analysis of pre-warning model for packaging safety of jelly food, finally, gets U by normalizing U to determine the levels of pre-warning model for packaging safety of jelly food according to the principle of maximum degree of membership (Jiang, 1987).

AN EMPIRICAL STUDY

Here sets a kind of branded jelly in the market as an example to analyze pre-warning model for packaging safety of jelly food.

To determine the weight indicators of each indicator: Only 3 experts evaluate it in order to simplify the calculation, use 3 two-class indicators for security warning design, anti-fake label and emotional cue in first-class indicator for instructions design of packages to explain the calculation process of weighting.

- **Establishing fuzzy judgment matrix according:** Establishing fuzzy judgment matrix according to the evaluation of 3 experts:

$$R'_{A_4 - B} = \begin{pmatrix} (1,1,1) & (4/3,2,7/3) & (3/2,2,7/3) \\ (1,1,1) & (5/4,2,8/3) & (1/5,1,7/5) \\ (1,1,1) & (1/4,1,9/5) & (1/3,1,5/3) \\ (3/7,1/2,3/4) & (1,1,1) & (11/3,4,17/4) \\ (3/8,1/2,4/5) & (1,1,1) & (8/3,3,13/4) \\ (5/9,1/2,4) & (1,1,1) & (4/3,2,5/3) \\ (3/7,1/2,2/3) & (4/17,1/4,3/11) & (1,1,1) \\ (5/7,1,5) & (4/13,1/3,3/8) & (1,1,1) \\ (3/5,1,3) & (2/5,1/2,3/4) & (1,1,1) \end{pmatrix}$$

Calculating the average number of 3 experts' evaluation and get:

$$R_{A_4 - B} = \begin{pmatrix} (1,1,1) & (0.944,1.67,2.267) & (0.678,1.333,1.8) \\ (0.453,0.667,1.85) & (1,1,1) & (2.556,3,3.056) \\ (0.581,0.833,2.889) & (0.381,0.361,0.466) & (1,1,1) \end{pmatrix}$$

Then obtains:

$$M_E = ((2.622,4,5.067),(4.009,4.667,5.906),(1.962,2.194,4.353))$$

- **Calculating the comprehensive important degree:** Comes to comprehensive importance degree of each evaluation criterion in contrast to other criteria from the formula (1):

$$S_1 = (2.622,4,5.067) \otimes (0.065,0.092,0.116) = (0.171,0.368,0.59)$$
$$S_2 = (4.009,4.667,5.906) \otimes (0.065,0.092,0.116) = (0.262,0.43,0.687)$$
$$S_3 = (1.962,2.194,4.353) \otimes (0.065,0.092,0.116) = (0.128,0.202,0.507)$$

- **Calculating the normalized weighting number of evaluation criteria:** Use the formula (2) to calculate pure measurement degree of each criterion superior to other criteria:

Table 1: A pre-warning system u for packaging design safety of jelly food

First-class indicators	Second-class indicators	Evaluation set					Combination weights	Weight sort
		One-level	Two-level	Three-level	Four-level	Five-level		
The choice of packaging materials A_1 (0.148)	Raw materials of packaging B_{11} (0.545)	0.1	0.5	0.2	0.2	0	0.081	8
	Auxiliary materials of packaging B_{12} (0.455)	0.2	0.4	0.2	0.1	0.1	0.067	9
Structure design of packaging A_2 (0.384)	The size and the net content B_{21} (0.457)	0.1	0.4	0.3	0.1	0.1	0.175	1
	Resistance to pressure B_{22} (0.282)	0.1	0.5	0.2	0.1	0.1	0.108	3
	Separation B_{23} (0.261)	0.2	0.3	0.4	0	0.1	0.100	6
Function design of packaging A_3 (0.215)	Protecting function B_{31} (0.415)	0.1	0.4	0.3	0.1	0.1	0.089	7
	Convenient function B_{32} (0.585)	0	0.3	0.2	0.2	0.3	0.126	2
Instruction design of packaging A_4 (0.253)	Warning design B_{41} (0.4)	0.3	0.5	0	0.2	0	0.101	5
	Anti-fake label B_{42} (0.427)	0.1	0.3	0.2	0.2	0.2	0.108	4
	Emotional cue B_{43} (0.173)	0.1	0.4	0.2	0.2	0.1	0.044	10

$V(S_1 \geq S_2) = 0.937$, $V(S_3 \geq S_1) = 0.405$,
$V(S_3 \geq S_2) = 0.510$,
以及 $V(S_2 \geq S_1) = V(S_1 \geq S_3) = V(S_2 \geq S_3) = 1$

Therefore, obtains the weight vector of each criterion by the formula (3):

$d'(C_1) = V(S_1 \geq S_2, S_3) = \min(0.937, 1) = 0.937$,
$d'(C_2) = 1$, $d'(C_3) = 0.405$
Be normalized to get $W_{A_4-B} = (0.4, 0.427, 0.173)$
Similarly get $W_{A_1-B} = (0.545, 0.455)$,
$W_{A_2-B} = (0.457, 0.282, 0.261)$
$W_{A_3-B} = (0.415, 0.585)$
$W_{U-A} = (0.148, 0.384, 0.215, 0.253)$
Namely, numbers in parentheses in Table 1

- **Calculating combination weights:** Multiplying weight number of the first-class indicators and that of the first-class indicators to get the comprehensive weight number of each factor affecting the packaging safety of the jelly food as in Table 1.

The implementation of comprehensive pre-warning: For pre-warning matrix for the emotional cues on packaging design:

$$R_4 = \begin{pmatrix} 0.3 & 0.5 & 0 & 0.2 & 0 \\ 0.1 & 0.3 & 0.2 & 0.2 & 0.2 \\ 0.1 & 0.4 & 0.2 & 0.2 & 0.1 \end{pmatrix}$$

The collection of two–class weighting numbers $W_{A_4-B} = (0.4, 0.427, 0.173)$, So to get the comprehensive pre-warning on the emotional cues of packaging by experts:

$$B_4 = W_{A_4-B} \cdot R_4$$
$$= (0.4, 0.427, 0.173) \cdot \begin{pmatrix} 0.3 & 0.5 & 0 & 0.2 & 0 \\ 0.1 & 0.3 & 0.2 & 0.2 & 0.2 \\ 0.1 & 0.4 & 0.2 & 0.2 & 0.1 \end{pmatrix}$$
$$= (0.3, 0.4, 0.2, 0.2, 0.2)$$

Normalized to get:

$$\tilde{B}_4 = (0.231, 0.308, 0.154, 0.154, 0.154)$$

Similarly, a comprehensive evaluation of indicators for choosing materials of packages, designing structures of packages, designing functions of packages respectively for:

$$\tilde{B}_1 = (0.167, 0.417, 0.167, 0.167, 0.083)$$
$$\tilde{B}_2 = (0.1, 0.4, 0.3, 0.1, 0.1)$$
$$\tilde{B}_3 = (0.077, 0.308, 0.231, 0.154, 0.231)$$

Finally, the analysis results of pre-warning safety of packaging design of this jelly is:

$$U = W_{U-A} \cdot R$$
$$= (0.148, 0.384, 0.215, 0.253) \cdot \begin{pmatrix} 0.167 & 0.417 & 0.167 & 0.167 & 0.083 \\ 0.1 & 0.4 & 0.3 & 0.1 & 0.1 \\ 0.077 & 0.308 & 0.231 & 0.154 & 0.231 \\ 0.231 & 0.308 & 0.154 & 0.154 & 0.154 \end{pmatrix}$$
$$= (0.231, 0.384, 0.3, 0.154, 0.215)$$

Normalized to get:

$$\tilde{U} = (0.18, 0.299, 0.234, 0.12, 0.167)$$

Concluded analysis: From the above calculation, it can be obtained the analysis results of pre-warning safety of packaging design of this jelly are I Level, II Level, III Level, IV Level and V Level and their degree of membership are, respectively 0.18, 0.299, 0.234, 0.12 and 0.167. Because 0.299 is the 5 the largest number among them, the analysis results of pre-warning safety of packaging design of this jelly can be the II Level according to the principle of maximum degree of membership, which belongs to the "safe" level.

In addition, according to results in Table 1, it can be obtained that the top 5 indicators of the size, net content, convenient function, resistance to pressure, anti-fake and warning design and their respective rates are 17.5, 12.6, 10.8, 10.8 and 10.1%. Based on this conclusion, the relevant manufacturers and quality supervision departments should consider these factors in the design and test of the jelly food packaging.

CONCLUSION

According to the relevant laws and regulations; based on safety, scientificity, comprehensiveness and hierarchy principles and combined with the views of relevant experts, the paper adopts the fuzzy clustering analysis and principal component analysis to build pre-warning system of jelly food packaging design safety which contains four first-class indicators and ten secondary-class indicators. Meanwhile, by means of the triangular fuzzy AHP analysis, the paper empowers the various indicators of the pre-warning system, then combines with fuzzy comprehensive evaluation method to form a pre-warning model of the jelly food packaging design safety and lastly applies the model to the packaging design safety evaluation of one sort of jelly food. The evaluation result is consistent with the actual situation, indicating that the model is scientific, reliable and practical in evaluating packaging design safety of jelly food.

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