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Research and application of carya cathayensis classification based on fuzzy comprehensive evaluation

Songwei Zeng[1,2], Changying Ji[2] and Qinfeng Yu[1]

[1]*School of Information Engineering, Zhejiang Agriculture & Forestry University, Lin'an, PR China*
[2]*College of Engineering, Nanjing Agricultural University, Nanjing, PR China*

ABSTRACT

The existing grading evaluation system of Carya cathayensis is not suitable for the development of Carya cathayensis market in China. In this paper, a new grading standard and evaluation system (GSES) is proposed for Carya cathayensis classification problem based on fuzz rules. The proposed scheme consists of three levels, namely, target layer, factor evaluation layer and further refinement layer. Finally, the proposed method is applied into the evaluation for Carya cathayensis of three different brands, and the results are satisfactory. Compared with the conventional method, the proposed scheme is effective and reasonable for the evaluation of Carya cathayensis.

Keywords: *Carya cathayensis*; Classification; Fuzzy comprehensive evaluation; Agriculture product quality grading (APQG)

INTRODCUTION

Carya Nutt is one of the most popular nuts, which belongs to walnut carya of juglandaceae. It contains 18 species and 3 varietas, and is mainly distributed in Asia, Europe and America. In those species, there exists two species with features of high economic value and artificial cultivation, namely, Carya illinoensis from North America and Carya cathayensis from China. Carya cathayensis shown in Figure 1 is one of the oldest relic species, which mainly comes from the Mountain Tianmu district between Anhui and Zhejiang. As an important trees of nuts and wood oil, Carya cathayensis can be used as the source of fragrant oil, and can reduce blood lipoid, nourish lung, prevent and cure the heart and cerebral vascular diseases. Its pulp is delicious, and contains rich minerals, about 7-9% proteins, and 17 kinds of amino acids (including 7 kind of human body essential amino acids) [1-2].

Fig. 1. Carya cathayensis

There are a great variety of processed products of Carya cathayensis, such as spiced salt, spiced, creamy, and crisp. There is also a series of foods made from Carya cathayensis, such as cakes, candies and chocolates. Since the 1990s, Carya cathayensis and its kernel in small package have been assigned for aviation catering by many domestic airlines, and have been sold in international markets. However, Classification of Carya cathayensis still adopt national quality grade standard of 1987 and 1988 Edition in China, which is not suitable for expansion of products export, improvement of market efficiency, and sustainable development of Carya cathayensis industry[3]. In this paper, a new grading standard and evaluation system (GSES) is proposed for Carya cathayensis classification problem.

The remainder of this paper is organized as follows. Section 2 introduces the current development situation, discusses the insufficiency of Carya cathayensis GSES, and proposes a new grading standard and evaluation system. Section 3 presents model checking and results. Finally, a conclusion is given in Section 4.

EXPERIMENTAL SECTION

2.1 Materials

According to the most popular brand of Lin'an Carya cathayensis (2008), we select three brand products of “Donglin”, “Linjia”, “Longjing”, and 0.5 kg of each sample is used to analyze.

2.2 Instruments and tools

Vernier caliper: Mitutoyo-530
Electronic balance: Ab204-N（Mettler Toledo）.
Automatic azotometer:（kjeltec2300）.
Electric heating air-blowing drier : LDHG-9140AS（Ningbo）

2.3 Methods

To determine the nutritional composition, sensory, physical and chemical indicators, We adopt the mentioned methods in[4-6].

2.4 PRESENT CONDITION OF CARYA CATHAYENSIS GSES

Agricultural modernization depends heavily on an agricultural products market, which can efficiently allocate various resource factors. As the base of agricultural products market, agriculture product quality grading can reduce transaction costs of agricultural products, improve market efficiency, promote technology innovation.

Agriculture product quality grading (APQG) is generally divided into grade classification and size classification, involving many physical and chemical indicators[7]. The grade grading refers to excellent, good, medium, pass, substandard, etc., and its evaluation indicators refer to surface color, luster, internal sugar content, acidity, flesh firmness, nutrition and trace elements, kernel rate, external damage, internal defects, grotesque, etc.. The size grading refers to diameter, length, thickness, weight and other evaluation sites.

The quality grading of Carya cathayensis refers to classifying products into different quality grades according to its quality standards. Now, Carya cathayensis in Chinese markets mostly transacts business by mixed-grade or by manual rough classification. Naturally, it is difficult to improve the commercialization of products and to increase its industrial added value. In addition, the disadvantages caused by manual classification, such as time-consuming, inefficient, low accuracy and poor consistency, can affect the sequent product processing [8].

Under the background of promoting agricultural modernization and increasing farmers’ production and incomes, Chinese government realized gradually the importance of APQG, and took a series of policies and measures to promote the level of APQG. For example, “High yield of walnut and quality of nuts (No. GB 7907-1987)” and “Carya cathayensis quality grade (No. GBT 20398-2006)” were issued in 1987 and 2006, respectively[9-11]. With the development of cultivation and processing technique of Carya cathayensis, and the appearance of new varieties and export growth, there exist some disadvantages in the old national standards, such as unreasonable index and basis of grading, and low acceptability of markets. These standards are antiquated and unsuitable for the sustainable development of Carya cathayensis industry, and seriously impede classification functions. Thus, the related quality grading should be revised and modified[12]. (He,2010) took Carya cathayensis side size as classification index to develop walnut grading rules. (Liu,*et al*.2010.1) analyzed characteristics of Carya cathayensis in Lin'an district, and proposed a new grading standard by adding a roundness index into the original national standards to be suitable for the current practices of products[13]. (Liu,*et al*.2010.2) adopted a camera to acquire digital images, and applied a mathematical morphology method to extract the features such as diameter, fruit length and size[14-15]. According to the size of Carya cathayensis, a mathematical geometry model was established. And a comprehensive evaluation system was established by giving different weights to these features according to farmer’s experience. However, these studies are based on the principles of the existing classification standards, the relevant usage, transaction cost reduction, and maintaining some continuity. Therefore, the current APQG places great emphasis on its appearance standards, and the classification is mainly reflected at the circulation of agricultural products, such as the needs of packaging, transport and storage. It lacks a synthetic consideration.

In short, the current grade criteria are mostly qualitative rather than quantitative. Therefore, the quality difference is very large even though among the same grade products owing to their different origins. Such case causes easily confusion or misunderstanding for consumers. APQG can play a certain role in the aspects of reduction of diversity and transaction costs. However, some aspects, such as scientificity of grading criteria, grading support services, and the actual combination degree among grading criterion, production, circulation and sales, need to be further strengthened. There are a series of problems to be solved, such as oversimplified and fuzzification, lack of quantitative indexes, lack of understanding of organoleptic indexes, physiochemical indexes and health indexes, lack of maneuverability and lagged update of graded indexes.

2.5 GRADING STANDARDS AND COMPREHENSIVE EVALUATION SYSTEM OF CRAYA CATHAYENSIS

A complete product quality classification system should include quality grades, quality standards, quality inspection, and quality certification. APQG and its different criteria are the foundation of the classification. Due to the quality indexes including size, chromaticness, saturation, palate, kernel ratio, nucleolus fat content and protein content, we should consider the above factors when formulating a scientific, normative and effective grading evaluation system of Carya cathayensis, which should follow the formulation principle of sciences, practicality, easy operating, diversification and guidance. The system is divided into three levels, the first level is a target layer; the second level is a factor evaluation layer including main factor layer and sub factor layer, and the sub factor layer is taken into account the different needs of production, sale and circulation, which consists of several parts such as sensory evaluation, physical and chemical evaluation; the third level is a further refinement for the second level, and the weights or grades are given according to the above-mentioned quality indexes. According to the above formulation principles, a new quality evaluation system of Carya cathayensis is proposed based on fuzzy rules as shown in Table 1.

Table 1: Quality evaluation system of Carya cathayensis based on fuzzy rules

Target layer	Main factor layer	Sub factor layer	The 3th level factor layer(range)
Fuzzy Rules-Based Index Comprehensive Evaluation System for Carya cathayensis	Sensory Index	color	Light yellow or light amber color
			dark yellow
			dark brown
			dark
		size	Side diameter<16.8mm(Sutures short axis)
			Side diameter: 19mm±2mm
			Side diameter: 21mm±2mm
			Side diameter >23mm
		kernel rate	>57.1（percentage）
			53.5±3.5
			46.4±3.5
			<42.8
		Shell thickness	0.56-0.62（Millimeters, the same below）
			0.63-0.72
			0.73-0.84
			0.95
	Physiochemical Index	quality	5.0（g，the same below）
			3.3-4.9
			1.7-3.2
			1.6
		nucleolus fat content	71.5（percentage）
			61.0-71.0
			50.0-60.0
			49.5
		protein content	28.5（percentage）
			23.5-28.4
			19.3-23.4
			19.2

2.6 Determination of Weights and Fuzzy Membership Functions System of Quality index evaluation for Carya cathayensis

Quality index evaluation of Carya cathayensis should consider the indexes of organoleptic, palate, physiochemical and sanitation safety, of which sanitation safety index is selected as the basic evaluation index. Considering its national compulsory standardization, the sanitation safety index is not taken into account in this work. In addition, the palate index is not taken into account owing to its variety with different individuals.

(1) Main factor level set U is divided into two groups, namely
$U_1 = \{u_1, u_2\}$, $U_2 = \{u_3, u_4, \cdots u_7\}$

(2)Setting a judgment set $V = \{v_1, v_2, v_3, v_4\}$.
where v_i ($i = 1, \cdots, 4$) represent super,1th level,2th level and 3th level, respectively.

(3) Determination of Judgment matrix
To obtain the index values of organoleptic and physiochemical by adopting the proposed method in[13]. Firstly, the membership values of single-factor are gained. Then, we determine the index value of evaluation in the same under the hierarchy of AHP[16-17]. To determine the matrix by pair-wise comparison method for the relative importance, we give the weight value of a combination for factors according to the expert experiences. Finally, we can obtain the priority of the layer of main factors.

Weights of the main factor Layer is drawn from expert experiences according to the importance of the main elements in grading evaluation.

Determination of the judgment matrix A and B_i ($i = 1, 2$) uses the following procedure: firstly, the pairwise comparison of their importance is conducted according to different expert experiences; then, the weights are determined by solving the characteristic value; finally, the matrix elements are given by using standard 1-9 scale method.

According to the above procedure, the judgment matrixes are given as follows:

$$A = \begin{bmatrix} 1 & \frac{1}{3} \\ 3 & 1 \end{bmatrix} \tag{1}$$

and

$$B1 = \begin{bmatrix} 1 & 0.143 & 0.33 & 0.2 \\ 7 & 1 & 3 & 5 \\ 3 & 0.33 & 1 & 0.33 \\ 5 & 0.2 & 3 & 1 \end{bmatrix}, \quad B2 = \begin{bmatrix} 1 & 5 & 3 \\ 0.2 & 1 & 0.33 \\ 0.33 & 3 & 1 \end{bmatrix} \tag{2}$$

2.7 Membership functions for quality indexes evaluation of Carya cathayensis
According to the statistical results of six economic properties (i.e. nuts diameter, average fruit weight, shell thickness, kernel ratio, nucleolus fat content and protein content) for 803 kinds of Carya cathayensis made by GUO Bao-lin, the fuzzy membership functions of each factor are given as follows:

Membership Function of Size:

$$C(\chi_1) = \begin{cases} 0 & \chi_1 \le a_1 \\ \dfrac{x_1 - a_1}{a_2 - a_1} & a_1 \prec \chi_1 \prec a_2 \\ 1 & \chi_1 \ge a_2 \end{cases} \tag{3}$$

where $a_1 = 16.80$, $a_2 = 23.00$, respectively.

Membership Function of Shell Thickness:

$$C(\chi_2) = \begin{cases} 1 & \chi_2 \le a_1 \\ 1 - \dfrac{\chi_2 - a_1}{a_2 - a_1} & a_1 \prec \chi_2 \prec a_2 \\ 0 & \chi_2 \ge a_2 \end{cases} \tag{4}$$

where $a_1 = 0.62$ and $a_2 = 1.26$, respectively.

Membership Function of Quality:

$$C(\chi_3) = \begin{cases} 0 & \chi_3 \le a_1 \\ \dfrac{\chi_3 - a_1}{a_2 - a_1} & a_1 \prec \chi_3 \prec a_2 \\ 1 & \chi_3 \ge a_2 \end{cases} \tag{5}$$

where $a_1 = 2.30$ and $a_2 = 3.70$, respectively.

Membership Function of Kernel rate:

$$C(\chi_4) = \begin{cases} 0 & \chi_4 \le a_1 \\ \frac{x_4 - a_1}{a_2 - a_1} & a_1 \prec \chi_4 \prec a_2 \\ 1 & \chi_4 \ge a_2 \end{cases} \tag{6}$$

where $a_1 = 42.80$ and $a_2 = 53.20$, respectively.

Membership Function of Nucleolus Fat Content:

$$C(\chi_5) = \begin{cases} 0 & \chi_5 \le a_1 \\ \frac{x_5 - a_1}{a_2 - a_1} & a_1 \prec \chi_5 \prec a_2 \\ 1 & \chi_5 \ge a_2 \end{cases} \tag{7}$$

where $a_1 = 65.50$ and $a_2 = 49.50$, respectively.

Membership Function of Protein Content:

$$C(\chi_6) = \begin{cases} 0 & \chi_6 \le a_1 \\ \frac{x_6 - a_1}{a_2 - a_1} & a_1 \prec \chi_6 \prec a_2 \\ 1 & \chi_6 \ge a_2 \end{cases} \tag{8}$$

where $a_1 = 28.50$ and $a_2 = 19.20$, respectively.

2.8 Total Sequencing Level and Consistency Checking
(1)Hierarchy single sorting and Consistency Check

From the above mentioned, the gained judgment matrixes maybe cause some problems, for example, $a_{ij}a_{jk} \neq a_{ik}$. To avoid such case, we should make a consistency check.

The eigenvector AW, which corresponds to the maximum (absolute value) eigenvalue of the judgment matrix A, is calculated in the proceeding of Hierarchy single sorting. To gain the weight w_i, the column of judgment matrix A or B should be normalized. For ease of presentation, we take $A = (a_{ij})_{n\times m}$ for an example. After A being normalized, we get $A' = (a'_{ij})_{n\times m}$ given as:

$$A' = \begin{pmatrix} a_{11} \big/ \sum_{i=1}^{n} a_{i1} & \cdots & a_{1m} \big/ \sum_{i=1}^{n} a_{im} \\ \vdots & \ddots & \\ a_{n1} \big/ \sum_{i=1}^{n} a_{i1} & \cdots & a_{nm} \big/ \sum_{i=1}^{n} a_{im} \end{pmatrix} \tag{9}$$

Then the weight w_i is given as:

$$w_i = \sum_{j=1}^{m} a'_{ij}, i = 1,2,..., m, \tag{10}$$

According to the values of Table 1, the eigenvector of AW is given as:

$$AW = (0.25, 0.75)^T \tag{11}$$

Then AW corresponds to $\lambda_{\max}$, given as:

$$\lambda_{\max} = n\sum_{i=1}^{n}\frac{(AW)_i}{nw_i} = 1.995 \quad (12)$$

So, random consistency is entirely consistent. By the same token, other parameters are given as follows:

$$BW\ 1 = (0.06, 0.58, 0.13, 0.23),\quad C_R = \frac{\lambda_{\max} - n}{n-1} / R = \leq 0.1 \quad (13)$$

$$BW\ 2 = (0.64, 0.10, 0.26),\ C_R = \frac{\lambda_{\max} - n}{n-1} / R = 0.028 \prec 0.1 \quad (14)$$

(2) Total ranking and its consistency test

Total ranking:

$$(0.25, 0.75)\begin{pmatrix} 0.06 & 0.58 & 0.13 & 0.23 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0.64 & 0.10 & 0.26 \end{pmatrix}$$
$$= (0.015, 0.145, 0.033, 0.058, 0.480, 0.075, 0.195) \quad (15)$$

Consistency index:

$$C_R = \sum_{i=1}^{m} a_i C_i \Big/ \sum_{i=1}^{m} a_i R_i = 0.06 \prec 0.1 \quad (16)$$

So, we can get Carya cathayensis quality evaluation results.

RESULTS AND DISCUSSION

The results of each sample are shown in Table 2.

Table 2: Values of various indexes

Value brands \ index	Size（mm）		kernel rate（%）		Shell thickness（mm）		Quality（g）		nucleolus fat content （%）		protein content（%）	
	AVG	STD	AVG	STD	AVG	STD	AVG	STD	AVG	STD	AVG	STD
DongLin	22.43	1.140	0.520	0.031	0.8653	0.200	3.403	0.209	0.618	0.008	25.8	0.249
LongJing	22.51	1.429	0.487	0.053	0.7040	0.193	3.361	0.418	0.634	0.009	22.8	10.6
LinKang	22.75	1.340	0.509	0.047	0.700	0.17	3.565	0.378	0.637	0.004	27.3	5.13

And the scores of every index are shown in Table 3.

Table 3: Results of every index

Score Brand	Size（mm）	kernel rate（%）	Shell thickness（mm）	Quality（g）	nucleolus fat content （%）	protein content（%）	total score
DongLin	0.908	0.885	0.617	0.714	0.769	0.709	0.746
LongJing	0.921	0.567	0.865	0.686	0.869	0.387	0.738
LinKang	0.960	0.779	0.875	0.832	0.868	0.871	0.883

We set the total score over 0.85 for premium, 0.7 for level 1, 0.6 for level 2 , 0.5 for level 3. Therefore, we can be drawn conclusion from the table, The sample of “DongLin” is premium, the sample of “LongJing” and “LinKang” are level 1 , the conclusion isn’t same of the traditional methods.

Compared with the existing grading standards of Carya cathayensis, the fuzzy hierarchical classification method takes into account the impact of sensory, chemical and other walnut grading weights. Which is better reflect the quality of walnut quality, It is more effective and more reasonable evaluation method.

CONCLUSION

The current evaluation standards of Carya cathayensis have been put into practice for more ten years. However, along with the development of cultivation and processing technology, new varieties continue to come out, these standards in certain ways are not suitable, and should be revised and adjusted. This paper proposes a new classification method based on the fuzz rules. The proposed method takes fully into account the comprehensive characteristics, and it is more scientific and effective. Finally, the proposed method is applied into the evaluation of Carya cathayensis. From the experimental results, three different brands can be graded and evaluated, and the results are satisfactory. Maybe it can provide another effective method for evaluation of Carya cathayensis.

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