

A SYNTHETICAL STUDY OF THE IDENTIFICATION OF TEA-LEAVES GRADES OF QUALITY WITH SENSE ORGANS

Luo Yongtai
(Tianjin Urban Construction Institute)
Liu Naishen
(The Second Commercial Bureau of Tianjin)
Zhao Zhanyi
(Tianjin Jeyuan Waterworks)

ABSTRACT

It has been a long time since the traditional process came into use for the identification of tea-leaves grades of quality with sense organs in China. However, there are a lot of changeable factors and wider subjective errors, so the identification accuracy has been unsatisfactory. This paper presents a new practical and systematic process, which is formed with the Analytic Hierarchy Process (AHP) and the Fuzzy Synthetical Evaluation Process. The tea-leaves grades of quality identified with this new process are objective and reliable. It is also suitable for the identification of food with sense organs.

I. PROBLEMS

Now in China, for the identification of tea-leaves grades of quality, the examination with sense organs is the main traditional process, in which the judges compare the tea-leaves' appearance, fragranciness, flavour, colour of tea-water, and swelled-up tea-leaves with those of the sample, give their corresponding evaluations, then sum up their opinions on each aspect and finally determine the tea-leaves grades and subdivided grades. However, there are no clear unified standards for the criteria. And the existing ones are too sweeping. Moreover, the judges may hold different biases and views. Therefore, the results differ between the judges greatly. In addition, there is a deviation of the judgement from the real quality. In view of the above-mentioned facts, a new practical and systematic process of identification is presented in this paper. AHP is first adopted in the new process, in which the hierarchical structure of judgement is set up, and the priorities of the subdivided criteria are rationally determined, and the various results of judgement are synthesized by the Fuzzy Synthetical Identification Process.

II. The Set-up of the Hierarchical Structure and the Determination of the priorities of the Various Criteria by AHP

I. The Hierarchical Structure of the Criteria of Tea-leaves Grades of Quality

On the basis of the Standards GH 016-84 issued by The State Commerce Department of the P.R.C. and the rich experience gained through years' of judging tea-leaves by the judges and technicians, the criteria of tea-leaves grades of quality can be divided into four levels.

Level A is the goal level of Tea-leaves Grades of Quality.

Level B is the requirement level of Appearance (B1) and Inner Quality (B2).

For D8 and D9 in Colour of Tea-water (C3), the matrix of pairwise comparisons is

$$H_{C3-Di} = \begin{pmatrix} 1 & 0.45 \\ 1/0.45 & 1 \end{pmatrix}$$

where $i=8, 9$

For D10, D11 and D12 in Swelled-up Tea-leaves (C4), the matrix of pairwise comparisons is

$$H_{C4-Di} = \begin{pmatrix} 1 & 2.4 & 4 \\ 1/2.4 & 1 & 1.7 \\ 1/4 & 1/1.7 & 1 \end{pmatrix}$$

where $i=10, 11, 12$

According to Power Method, the maximal eigenvalue (λ_{max}) and the corresponding priorities of the various matrixes of pairwise comparisons can be extracted:

$$H(B1-Di): \lambda_{max}=4.016 \quad W_{D1}=0.749 \quad W_{D2}=0.076 \quad W_{D3}=0.076 \quad W_{D4}=0.099$$

where $i=1, 2, 3, 4$

$$H(B2-Ci): \lambda_{max}=4.000 \quad W_{C1}=0.502 \quad W_{C2}=0.374 \quad W_{C3}=0.062 \quad W_{C4}=0.062$$

where $i=1, 2, 3, 4$

$$H(C2-Di): \lambda_{max}=2.000 \quad W_{D6}=0.667 \quad W_{D7}=0.333$$

where $i=6, 7$

$$H(C3-Di): \lambda_{max}=2.000 \quad W_{D8}=0.310 \quad W_{D9}=0.690$$

where $i=8, 9$

$$H(C4-Di): \lambda_{max}=3.000 \quad W_{D10}=0.600 \quad W_{D11}=0.251 \quad W_{D12}=0.149$$

where $i=10, 11, 12$

The consistency of each of the matrixes of pairwise comparisons with the totality has been verified, so the priorities of the criteria in each level can be calculated, shown in Table 2.

Table 2

Level	Criterion	Priority
B	B1	0.200
	B2	0.800
C	C4	$0.800 \times 0.502 = 0.401$
		$0.800 \times 0.374 = 0.299$
		$0.800 \times 0.062 = 0.050$
		$0.800 \times 0.062 = 0.050$
D	D1	$0.200 \times 0.749 = 0.150$
	D2	$0.200 \times 0.076 = 0.015$
	D3	$0.200 \times 0.076 = 0.015$
	D4	$0.200 \times 0.099 = 0.020$
	D5	0.401
	D6	$0.299 \times 0.667 = 0.199$
	D7	$0.299 \times 0.333 = 0.100$
	D8	$0.050 \times 0.310 = 0.016$
	D9	$0.050 \times 0.690 = 0.034$
	D10	$0.050 \times 0.600 = 0.030$
	D11	$0.050 \times 0.251 = 0.013$
	D12	$0.050 \times 0.149 = 0.007$

3. The Determination of the Judgement Standards for Each Criterion

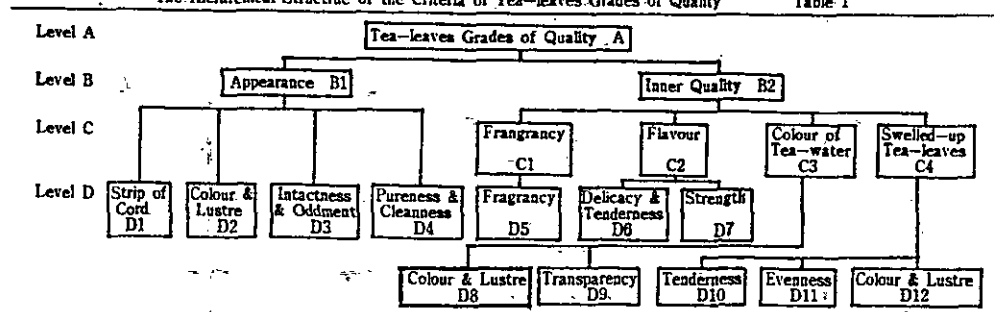
Following the determination of the priority of each subdivided criterion, the standards of giving marks are to be determined for the subdivided grades of each criterion with several stipulations concerned. The standards are shown in Table 3.

Level C is the subrequirement level, in which Inner Quality (B2) is subdivided into Fragrance (C1), Flavour (C2), Colour of Tea-water (C3) and Swelled-up Tea-leaves (C4)

Level D is the criterion level, in which Appearance (B1) is subdivided into Strip of Cord (D1), Colour & Lustre (D2), Intactness & Oddment (D3) and Pureness & Cleanness (D4), Fragrance in Level C is directly used as a criterion (D5) in the lowest level, Flavour in Level C is subdivided into Delicacy & Tenderness (D6) and Strength (D7), Colour of Tea-water in Level C into Colour & Lustre (D8) and Transparency (D9), Swelled-up Tea-leaves in Level C into Tenderness (D10), Evenness (D11), and Colour & Lustre (D12).

The hierarchical structure of the criteria is shown in Table 1. These criteria are convenient to determine the specific standards of judgement and decrease the errors of sense organs in judgement.

The Hierarchical Structure of the Criteria of Tea-leaves Grades of Quality Table 1



2. The Determination of the Priority of Each Criterion

On the basis of the Standards issued by The State Commerce Department of the P.R.C., in Level B, the ratio between the importance of Appearance (B1) and that of Inner Quality (B2) is 1:4, so the priority of B1 is 0.20, or $WB_1=0.20$, the priority of B2 is 0.80, or $WB_2=0.80$.

In accordance with the principle of the scale of AHP, the experts concerned, who are engaged, get the following matrixes of pairwise comparisons between the criteria in Level C and Level D.

For D1, D2, D3 and D4 in Appearance (B1), the matrix of pairwise comparisons is

$$H_{B_1-D_i} = \begin{pmatrix} 1 & 9 & 9 & 9 \\ 1/9 & 1 & 1 & 7/10 \\ 1/9 & 1 & 1 & 7/10 \\ 1/9 & 10/7 & 10/7 & 1 \end{pmatrix}$$

where $i=1, 2, 3, 4$

For C1, C2, C3 and C4 in Inner Quality (B2), the matrix of pairwise comparisons is

$$H_{B_2-C_i} = \begin{pmatrix} 1 & 1.344 & 8 & 8 \\ 1/1.35 & 1 & 6 & 6 \\ 1/8 & 1/6 & 1 & 1 \\ 1/8 & 1/6 & 1 & 1 \end{pmatrix}$$

where $i=1, 2, 3, 4$

For D6 and D7 in Flavour (C2), the matrix of pairwise comparisons is

$$H_{C_2-D_i} = \begin{pmatrix} 1 & 2 \\ 1/2 & 1 \end{pmatrix}$$

where $i=6, 7$

In addition to the above-mentioned criteria, peculiar smells should be considered as a specific criterion. If the tea-leaves have no peculiar smell, the total will not be affected. If the tea-leaves have a peculiar smell, the specific criterion can be dealt with in the two following cases.

Table 3

Criterion	Degree	Score
Strip of Cord D1	tight, heavy, solid, with noticeable sharp points	100
	tight, with less noticeable sharp points	94
	tight and solid	75
	less strong and solid	63
	a little untight and loose	50
Colour & Lustre D2	untight and loose	31
	green and sleek	100
	less green and sleek	84
	green and a little sleek	67
	yellow and green	50
Intactness & Oddment D3	green and yellow	34
	green and yellow with a little loose	17
	even and regular	100
	even and complete	67
	less even and complete	50
Purity & Cleanliness D4	complete	34
	less complete	17
	tight and thin	100
	with a few tender veins	90
	with some tender veins	80
Fragrancy D5	with veins and leaflets	70
	with more leaflets	50
	with leaflets and thick veins	40
	fresh and strong	100
	less fresh	95
Delicacy & Tenderness D6	scent and mellow	90
	weak	80
	tender, scented and delicious, lasting	100
	less tender and scented	98
	much less tender and scented	95
Strength D7	pure	90
	less pure	88
	less plain	80
	plain	70
	fresh and delicious	100
Colour & Lustre D8	fresh and mellow	98
	mellow	97
	mellow and gentle	90
	gentle	80
	plain and weak	70
Transparency D9	bright yellow	100
	dark yellow	80
	green and yellow	70
	dark	60
	limpid	100
Tenderness D10	less limpid	90
	bright	80
	less bright	70
	turbid	50
	tender	100
Evenness D11	less tender	90
	pliable and tough	85
	thick and overgrown	60
	most even	100
	more even	90
Colour & Lustre D12	even	80
	less even	70
	least even	60
	soft green	100
	yellow green	90
	dark green	80

a) No Value of Drinking

For instance, if there is a camphor ball smell or other serious pollution of waste gases in the tea-leaves, one cannot drink them. They are harmful to one's health. Selling of such tea-leaves is not permitted and judgement is not needed either.

b) With Light Peculiar Smells, but Still Drinkable

For such tea-leaves, the total will be reduced according to the various degrees in Table 4.

Table 4

Dgree	Score
a smell of smoke	-21
a light smell of smoke	-19
a burnt smell	-17
a light burnt smell	-14
other peculiar smells	-12

The model of the hierarchical structure of the identification of tea-leaves quality can be adjusted on the basis of the actual conditions in different areas. In judgement, for each item of criterion, the value of the priority and the standards of giving marks can also be adjusted, in order to grade the same fumigated tea-leaves into different grades in the said area according to certain marks. Moreover, the subdivided grades of the same grade can be graded according to certain scores.

AN EXAMPLE

Tianjin laid in a stock of tea-leaves of Grade II from Fujian. In dry state, it looks good in appearance. The strips of cord are tight, heavy, solid and with noticeable sharp points. The colour is green and sleek. The appearance is tight, thin, even and regular. In wet checking, the sweet scent is mellow. The flavour is tender, scented and delicious, lasting, without any peculiar smell. The colour of tea-water is green and yellow, less bright. The swelled-up tea-leaves are less even, soft and tender. The colour of swelled-up tea-leaves is green and yellow. Try to determine its grade.

Making a check against the above-mentioned standards of giving marks, the given scores and total are shown in Table 5.

Table 5

Criterion	Priority	Score	Priority×Score
D1	0.150	100	15.00
D2	0.015	100	1.50
D3	0.015	100	1.50
D4	0.020	100	2.00
D5	0.401	90	36.09
D6	0.199	100	19.90
D7	0.100	100	10.00
D8	0.016	70	1.12
D9	0.034	70	2.38
D10	0.030	85	2.55
D11	0.013	80	1.04
D12	0.007	90	0.67
Total	1.000		93.75

Conclusion: The stock of tea-leaves belongs to the medium subdivided grade in Grade II.

III. The Fuzzy Synthetical Evaluation

There are two approaches to synthetically evaluate the various results of the judges by means of Fuzzy Theory.

1. The Composite Algorithm with Fuzzy Matrixes

Let it be supposed that the set of the evaluation factors is

$$U = (u(1), u(2), \dots, u(m))$$

its corresponding priority is

$$A = (a(1), a(2), \dots, a(m))$$

Assuming that the set of the evaluation criteria is

$$V = (v(1), v(2), \dots, v(s))$$

its corresponding evaluation matrix is

$$R = \begin{pmatrix} r(11) & r(12) & \dots & r(1s) \\ r(21) & r(22) & \dots & r(2s) \\ \dots & \dots & \dots & \dots \\ r(m1) & r(m2) & \dots & r(ms) \end{pmatrix}$$

When considering the synthetical evaluation of The Stressed Main Factor Type (Wang Guangyuan, 1984), the Composite Algorithm with Fuzzy Matrixes may be adopted, that is

$$C = A \cdot R = (a(1), a(2), \dots, a(m)) \cdot \begin{pmatrix} r(11) & r(12) & \dots & r(1s) \\ r(21) & r(22) & \dots & r(2s) \\ \dots & \dots & \dots & \dots \\ r(m1) & r(m2) & \dots & r(ms) \end{pmatrix}$$

$$= (C(j))_{1 \times s}$$

where

$$C(j) = \max \min(a(k), r(kj)) \\ = \bigvee (a(k) \wedge r(kj))$$

According to the principle of the maximal degree of membership, when $C(i) = \max\{c(1), c(2), \dots, c(m)\}$ the evaluation result is $V(i)$.

AN EXAMPLE

Let it be supposed that the evaluation field of jasmine tea-leaves is U .

$$U = \{\text{Appearance } (u(1)), \text{ Fragrancy } (u(2)), \text{ Flavour } (u(3)), \\ \text{Colour of Tea-water } (u(4)), \text{ Swelled-up Tea-leaves } (u(5))\}$$

Assuming that the priority is

$$A = (0.2, 0.4, 0.3, 0.05, 0.05)$$

and the set of evaluation criteria is

$$V = \{\text{Deg. I } (v(1)), \text{ Deg. II } (v(2)), \text{ Deg. III } (v(3)) \\ \text{Deg. IV } (v(4)), \text{ Deg. V } (v(5))\}$$

In our own organization, the score intervals of the degrees are shown in Table 6.

Table 6

Degree	Score
I	91—100
II	81—90
III	71—80
IV	61—70
V	51—60

There are ten judges giving the scores for the various criteria, shown in Table 7. (unit: person)

Criterion	Degree				
	I	II	III	IV	V
Appearance	0	1	4	3	2
Fragrance	0	2	4	2	2
Flavour	0	1	5	4	0
Colour of Tea-water	0	0	4	4	2
Swelled-up Tea-leaves	0	0	5	4	1

Dividing each value in Table 7 by 10 (the total of the judges), the evaluation matrix is

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

therefore

$$C = A \cdot R = (0.2, 0.4, 0.3, 0.05, 0.05) \cdot \begin{pmatrix} 0 & 0.1 & 0.4 & 0.3 & 0.2 \\ 0 & 0.2 & 0.4 & 0.2 & 0.2 \\ 0 & 0.1 & 0.5 & 0.4 & 0 \\ 0 & 0 & 0.4 & 0.4 & 0.2 \\ 0 & 0 & 0.5 & 0.4 & 0.1 \end{pmatrix}$$

$$= (0, 0.2, 0.4, 0.3, 0.2)$$

further, owing to

$$\max\{0, 0.2, 0.4, 0.3, 0.2\} = 0.4$$

Conclusion: This stock of jasmine tea-leaves belongs to Degree III, that is, $v(3)$ (Score 71~80).

It should be deserved extra attention that this algorithm must presuppose that it doesn't lose effectiveness. The discussion on the algorithm is without going into detail.

2. The Algorithm of Common Matrix Multiplication

When considering the joint effects of the various factors, with adopting The Weighted Average Type. The Algorithm of Common Matrix Multiplication may be used, that is

$$C = A \cdot R = (a(1), a(2), \dots, a(m)) \cdot \begin{pmatrix} r(11) & r(12) & \dots & r(1s) \\ r(21) & r(22) & \dots & r(2s) \\ \dots & \dots & \dots & \dots \\ r(m1) & r(m2) & \dots & r(ms) \end{pmatrix}$$

$$= (C(j))_{1 \times s}$$

where

$$(C(j)) = \sum_{k=1}^m a(k) \wedge r(kj)$$

AN EXAMPLE

There are five judges, whose authoritativenesses differ. The priorities of their authoritativenesses are

$$B = (0.3, 0.2, 0.2, 0.15, 0.15)$$

The priorities of the five criteria of the stock of tea-leaves are the same as those in the above example:

$$A = (0.2, 0.4, 0.3, 0.05, 0.05)$$

In Table 8 are the scores given by each judge for the criteria.

Table 8

Judge	Criteria				
	Appearance	Fragrancy	Flavour	Colour of Tea-water	Swelled-up Tea-leaves
1	83	90	85	85	84
2	92	88	83	96	90
3	87	80	84	90	78
4	71	82	77	80	86
5	86	81	84	74	72

Try to determine its grade.

In the light of the meaning of the example, we have

$$C = B \cdot R = (0.3, 0.2, 0.2, 0.15, 0.15) \cdot \begin{pmatrix} 83 & 90 & 85 & 85 & 84 \\ 92 & 88 & 83 & 96 & 90 \\ 87 & 80 & 84 & 90 & 78 \\ 71 & 82 & 77 & 80 & 86 \\ 86 & 81 & 84 & 74 & 72 \end{pmatrix}$$

$$= (84.25, 85.05, 83.05, 85.80, 82.50)$$

$$A \cdot C^T = (0.2, 0.4, 0.3, 0.05, 0.05) \cdot \begin{pmatrix} 84.25 \\ 85.05 \\ 83.05 \\ 85.80 \\ 82.50 \end{pmatrix}$$

$$= 84.20 \text{ (score)}$$

Conclusion: The stock of tea-leaves belongs to Grade II.

Both the priorities of the judges' authoritativenesses and those of the various criteria are considered in this approach. Therefore, the result tallies with the actual situations better.

SUMMARY

- 1 The systematic process for the identification of tea-leaves presented in this paper can be conveniently developed into special soft ware, with which the evaluation by man-machine interaction will become a reality.
- 2 Each area should set up the standards of the criteria for the identification of tea-leaves, and those of the division of grades and subdivided grades.
- 3 The process presented in this paper can be used for the similar identification of food with sense organs and for other similar synthetical evaluations.

REFERENCES

- Thomas L. Saaty, "The Analytic Hierarchy Process". McGraw-Hill Inc. New York, 1980
- Wang Guangyuan, "On the Essence of a Few Mathematical Models for Synthetical Evaluation". Fuzzy Mathematics, Volume 4, 1984
- Wang Peizhuang, "Fuzzy Set Theory and its Applications". Shanghai Science and Technology Publishing House, 1984
- Zhao Huanchen, Xu Shubo, He Jinsheng, "AHP-A New Simple and Easy Process of Police-Making". Science Publishing House, September, 1986