Research on the Analysis of Wax Effect in Cold Storage Based on AHP and Interval-Valued Fuzzy TOPSIS Method

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Abstract: In looking for different types of large-scale activities of food sanitation supervision and security modes, improving the efficiency of food hygiene protection, this paper establishes the evaluation index system for sports food hygiene, and proposed the sports food hygiene evaluation model based on the Analytic Hierarchy Process (AHP) and the interval fuzzy TOPSIS method. AHP is used to determine the evaluation indexes' weight, by means of fuzzy theory to build interval fuzzy matrix for calculating the positive and negative ideal solution and proximity, and based on proximity compare sports food hygiene. The effects of wax treatment on alleviating chilling injury and quality changes of pineapple fruit (cultivar 'Paris') during cold storage were examined. It was effective in maintaining firmness and decreasing treatable acidity of harvested pineapple fruit, suggesting that this wax treatment is a useful technique to alleviate chilling injury and maintain fruit quality during the cold storage.

Keywords: AHP, food storage, interval-valued fuzzy TOPSIS method, wax effect.

1. INTRODUCTION

With the development and popularization of food logistics technology, especially its broad applications in important branches of national economy, the problem of food storage has been standing out in the information society. According to the International Federation of Robotics (IFR), "A service robot is a robot which operates semi or fully autonomously to perform services useful to wellbeing of human and equipment." With the city's exhibiting economic development, the frequency of large-scale major events organized around increased significantly, and the size is getting bigger, new issues to food hygiene safeguards have arisen. To ensure food safety pro activities of large reception units, health oversight agencies usually do prior supervision before big events occur. During the event, two supervisors are sent to each host hotel to implement in-store full supervision and take appropriate safeguards to ensure the effect of food hygiene measures. Admittedly, this protection mode to ensure food hygiene and quality, to ensure the smooth conductance of important activities played a major role. This protection mode involves a lot of manpower and health oversight agencies, affecting the conduct of other public health surveillance work.

Currently, the evaluation methods of sports food mainly include hygiene Analytic Hierarchy Process (AHP), fuzzy evaluation, peer review method and set pair analysis method [1]. TOPSIS is a multi-objective decision analysis method commonly used in the decision-making methods, due to its

simple calculation, reasonableness, subjective factors, and other characteristics, besides its applications being more widely used [2].

In this paper, interval fuzzy theory and TOPSIS method are combined using AHP to analyze and calculate evaluation indexes weight, and reviews set is determined by the interval comment fuzzy theory. an interval fuzzy evaluation matrix is established, and by means of distance programs with positive and negative ideal solution, proximity is determined as the evaluation standard, making the evaluation results more objective and realistic.

Waxing has been applied to reduce postharvest diseases and chilling injury in many horticultural crops, including nectarine, table grape and strawberry [3, 4]. However, few studies have reported waxing as a method to alleviate chilling injury of pineapple fruit during cold storage. The objective of this study is to investigate if waxing can extend the storage life of pineapple fruit by alleviating chilling injury during cold storage [5].

2. FOOD HYGIENE SUPERVISION MODE

To search for events of food hygiene safeguard model suited to China's national conditions, in order to improve the efficiency of law enforcement, the rational use of resources, is the purpose of health surveillance. Through combining the necessity of food hygiene supervision and protection, and food poisoning risk level methods, the food hygiene supervision mode and its effects on large-scale sports activities were studied.

(1) Assess the level of risk of food poisoning for reception unit.

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Table 1. Assess the level of risk of food poisoning for reception unit.

Level	Points	Level of Risk
A	> 90	low
	80~ 90	middle
	< 80	high
B	> 95	low
	85~ 95	middle
	< 85	high
C	>= 90	middle
	< 90	high

Table 2. Food hygiene supervision and protection mode.

Classification	Risk Level	Recommend Protection Mode
Class 1	low	Full supervision
Class 2, 3		Prior supervision, Circuit Supervision or Prior supervision & Circuit Supervision
Class 1	middle	Full supervision or Full supervision & Circuit Supervision
Class 2, 3		Full supervision or Prior supervision & Circuit Supervision
Class 1, 2, 3	high	Proposal to abolish the reception qualifications

According to the reception unit within a year period, food poisoning, food hygiene administrative punishment, food hygiene report complaints and tableware, Lucai qualified rate and other factors to quantify the score, have been combined with large-scale activities to quantify the reception unit of food hygiene supervision classification, The risk of food poisoning in the reception unit is divided into low, intermediate and advanced (Table **1**). The risk of food poisoning as advanced units should be advised to cancel events or collective distribution reception meal eligibility, in order to establish and determine eligibility reception unit events that is a more scientific method to quantify.

In practice, the reception unit for large-scale activities used percentile score to quantify the risk of food poisoning, the higher the score, the lower the risk of food poisoning. Quantitative score content and implementation standards are as follows:

Food poisoning (35 points): in 1 year occurred once food poisoning incident or occurred more than two times or more than 100 people got food poisoning incidents were deducted respectively 20 points, 35 points.

Food hygiene administrative penalties (20 points): By one year 1 time or more than 2 times administrative penalties were deducted respectively 15 points, 20 points.

Food hygiene report complaints (15 points): By one year one or two times to report complaints, and verified, deducted respectively, 10 points, 15 points.

Tableware, Lucai sampling results (30 points): By 1 year tableware, Lucai qualified sampling were 95% (excluding 100%), 90%, 85%, <85%, deduct respectively, 5 points, 10 points, 20 points and 30 points. Such as Lucai detection of pathogens cutlery deducts 30 points. By one year not making tableware, Lucai health testing, deducts 20 points.

 (2) Determined integrated sports food hygiene supervision mode

Classification of sports food hygiene supervision reflects the importance and impact of social activities. The food poisoning risk level is measured in terms of reception units. Therefore, combining the two for comprehensive determination of the food hygiene supervision mode, should be undertaken for reception units. Not only determining the pattern of food hygiene safeguards can be more scientific, but also ensure that health safeguards focus on improving the efficiency of food hygiene safeguards.

Table **2** shows the proposed food hygiene supervision and protection mode after a comprehensive evaluation, according to the necessity of sports food hygiene supervision and food poisoning risk level classification. For the reception units after assessing the case of high-risk food poisoning, health oversight agencies must receive a written proposal to cancel the eligibility committee.

Select 9 hotels for food hygiene supervision quantify rating, where each 3 are assigned A, B, C-level units. When implementing Prior supervision, Circuit Supervision, Prior

Table 3. Tableware, Lucai sampling pass rate of different types of food hygiene supervision and protection mode.

Supervision Mode	Tableware			Lucai		
	Level A	Level B	Level C	Level A	Level B	Level C
Daily sampling	100.0	94.1	84.3	98.3	90.0	83.9
Prior supervision	100.0	96.7	86.7	96.7	93.3	90.0
Circuit Supervision	100.0	96.7	86.7	100.0	93.3	90.0
Prior supervision & Circuit Supervision	100.0	100.0	90.0	100.0	96.7	93.3
Full supervision	100.0	100.0	100.0	100.0	100.0	96.7
Full supervision & Circuit Supervision	100.0	100.0	100.0	100.0	100.0	96.7

supervision & Circuit Supervision, Full supervision, Full supervision & Circuit Supervision, collect 10 Table **3** wares and 10 kinds of Lucai for each unit. Test items for tableware are coliform (fermentation), pathogens. Test items for Lucai are the total bacterial count, coliform bacteria and pathogens. Evaluation according to the appropriate national health standards implementation of advance copies obtained a Lucai outside failed sampling qualified rate of tableware and Lucai to be 100%. While the level B and C units in different mode of food hygiene safeguards cutlery, Lucai sampling pass rate indicates that, by using Full supervision and Full supervision & Circuit Supervision, Tableware and Lucai sampling qualified rates obtained are the same. But the different effects of both with prior supervision, using protection Tour supervision model were statistically significant. In addition, using Prior Supervision and Circuit Supervision, the sampling qualified rates are the same for tableware and Lucai. Prior supervision & Circuit Supervision is better than that Prior supervision and Circuit Supervision. But the difference is not statistically significant.

3. AHP AND THE INTERVAL FUZZY TOPSIS METHOD BASED EVALUATION MODEL

Evaluation factors set is a collection of sports food hygiene evaluation indexes [6, 7]. Because sports food hygiene evaluation indexes are divided into several levels, therefore, the evaluation factors set contains multiple levels:

$$U = \{U_1, U_2, ..., U_i, ..., U_n,\}, i = 1, 2, ..., n$$

$$U_i = \{U_{i1}, U_{i2}, ..., U_{ij}, ..., U_{inj},\}, j = 1, 2, ..., n_i$$

Where n is the number of elements in U, n_i is the number of elements in U_i.

The right of each index is set in the form of judgment matrix in AHP. a_{ij} is the importance for index i relative to index j, using a scale of 1 to 9 represents listed in Table **4**, and satisfy the conditions: $a_{ij} > 0$, $a_{ij} = 1 / a_{ji}$, $a_i = 1$.

Judgment matrix constructed is

$$A = \begin{bmatrix} a_{11} & a_{12} & ... & a_{1n} \\ a_{21} & a_{22} & ... & a_{2n} \\ ... & ... & ... & ... \\ a_{n1} & a_{n2} & ... & a_{nn} \end{bmatrix} \tag{1}$$

Re-set by root method can be respectively one level indicators weight set w and two level indicators right w_i.

$$w = [w_1, w_2, ..., w_i, ..., w_n]^T \tag{2}$$

$$w_i = [w_{i1}, w_{i2}, ..., w_{ij}, ..., w_{inj}]^T \quad j = 1, 2, ..., n_i \tag{3}$$

By formulas (2) and (3) can be obtained two level indicators relative weights:

$$w^* = [w_1^*, w_2^*, ..., w_j^*, ..., w_m^*]^T \tag{4}$$

Where $w_j^* = w_i * w_j$.

Because of the subjective nature of the experts at the scoring, it is impossible to determine when the pairwise comparison of complete consistency, namely the existence of estimation error, should be undertaken. To avoid too large error, one needs to verify the consistency of judgment matrix, namely calculating and judging matrix's random consistency ratio (CR). Only when CR <0.1 the consistency of judgment matrix can be accepted.

When evaluated on the basis of sports food hygiene, taking into account the vagueness and subjectivity index, semantic judgment is established which ensures the specifications are divided into low, average, high standards and high-five grades [8]. We may use the interval fuzzy numbers to represent the five semantic variables, as shown in Table **5**.

The initial interval fuzzy matrix is build based on two t indexes by reviews set.

Table 4. Measurement and meaning of 1 ~ 9.

Level of Importance	a_{ij}
Two factors are equally important	1
One is slightly more important than the other one	3
One is significantly more important than the other one	5
One is mightily more important than the other one	7
One is uncommonly more important than the other one	9
One is slightly less important than the other one	1/3
One is significantly less important than the other one	1/5
One is mightily less important than the other one	1/7
One is uncommonly less important than the other one	1/9
Two factors' value	2,4,6,8,1/2,1/4, 1/6,1/8

Table 5. Evaluation set.

Criteria for Judging	Interval Fuzzy Number
Low	(0 , 0.2)
Lower	(0.2 , 0.4)
Normal	(0.4 , 0.6)
Higher	(0.6 , 0.1)
High	(0.8 , 1)

$$X = \begin{bmatrix} x_{11} & x_{12} & \dots & x_{1m} \\ x_{21} & x_{22} & \dots & x_{2m} \\ \dots & \dots & \dots & \dots \\ x_{k1} & x_{k2} & \dots & x_{km} \end{bmatrix} \tag{5}$$

Where the x_{ij} is the semantic value of the i-th plan and the j-th evaluation index

The X standardization:

$$R = \begin{bmatrix} r_{11} & r_{12} & \dots & r_{1m} \\ r_{21} & r_{22} & \dots & r_{2m} \\ \dots & \dots & \dots & \dots \\ r_{k1} & r_{k2} & \dots & r_{km} \end{bmatrix} \tag{6}$$

Where $r_{ij} = x_{ij} / A_i$.

According to the right weight and initial evaluation indexes of fuzzy matrix, weighted intervals established standardized fuzzy matrix:

$$\tilde{V} = [v_{ij}] k * m \tag{7}$$

Where $i = 1, 2, ..., k; j = 1, 2, ..., m$; $v_{ij} = x_{ij} * w_j$.

4. THE RELATIONSHIP BETWEEN WATER ACTIVITY, WAX AND FOOD STORAGE

With water activity index gradually applied in the food industry-standard production, especially in recent years, the United States, Japan and other countries have developed water activity indicators as food inspection programs. Determination of water activity has received more and more attention by China's food processing enterprises.

Water activity values (aw) is an important factor affecting the physical properties of color, flavor and shelf life of food, etc., that is to control the growth of microorganisms in the food is the most intuitive and important objective. Since water activity value that reflects the content of the water contained in food can be exchanged with the outside of that part of the water; therefore, the presence of such water will di-
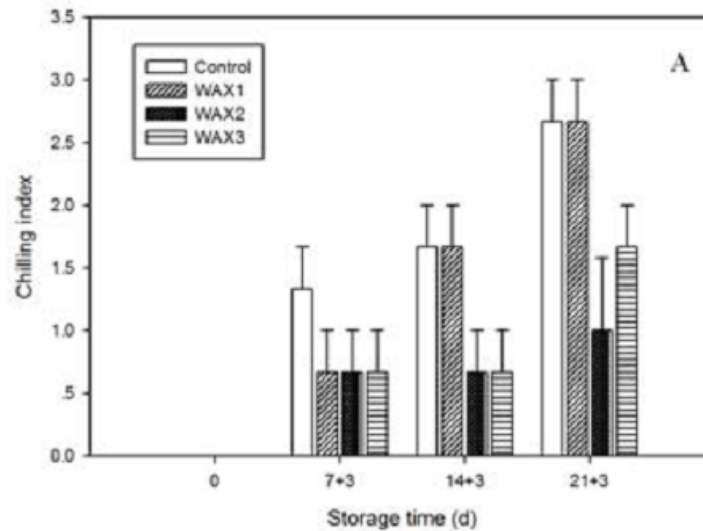
Fig. (1). Effects of different wax treatments on chilling index (**A**).

rectly affect the storage life of food and other physical indicators, such as color, smell, taste and so on.

In food production, water activity is one of the important parameters. It provides non-sticky water chemistry information, which is an important parameter determining the quality of food production enterprises. If there is high water activity food and inadequate refrigeration, the product will have the risk of deterioration. Water activity value equals to 1 or extending the pantry of a major consideration, especially for bread products, sweets, cheese, coffee, dairy products, dried fruit, flour, cereals, meat, dried fruit, edible oil, rice, sausage, instant food, spices, tea, spices and other food storage have a significant impact. For example, a Shandong dehydrated vegetable production enterprises in the export business negotiates with a German importer for providing only moisture content for shelf value of the product, which finally results in abortion of this transaction. The reasoning by foreign investors is that the moisture content cannot be an effective ingredient determining its product shelf life.

Since 1979, the US Food and Drug Administration (FDA) has been providing water activity value of the different types of food. FDA also provides recommendation that food industry should use water activity measurement system to measure water activity food.

The production enterprises are gradually paying attention to the effect of water activity values for food and other physical properties of food. In order to preserve the unique taste, color and flavor of canned vegetables and fruits, production companies control water activity values within a certain range, not only to extend the shelf life of food but also to retain its freshness and flavor.

Water activity values measurement demands measuring humidity sensor requirements of measurement instruments. The accuracy of response is obtained using direct accuracy of measuring instruments. A wide range of Related products of choice are now on the market by the companies. Germany launched Testo 650 which is a precision water activity

measurement system. Its measurement accuracy is 0.01aw. It can be widely used in instant noodles, vegetables, beef jerky and condiments, such as for processing production line.

In recent years, as China's foreign exports is growing in food, for a considerable part of the country food for the exports purpose imposed more stringent restrictive laws and regulations, such as Japan, the European Union and so on. Because water activity values for food is one of the most important indicators impacting the food shelf life, China has also begun to accelerate the work on water activity of the national food standards. Especially in 2006, AQSIQ commissioned a well-known foreign-service company, for a joint effort of two high-level national food laboratories, jointly participating in the development of this indicator for national standards. Currently, the standard has basically taken a shape, and soon it will be promulgated. It is believed that the implementation of this standard will not only help narrow down the gap between China's food quality standards and international standards, but also improve the manufacturing enterprises to enter the supermarket threshold.

The food treated with wax exhibited significantly lower levels ($P<0.05$) of CI compared to that of the control fruit after 21 d at 7 $^{\circ}$C and 3 d at 25 $^{\circ}$C, suggesting that wax prevented the chilling injury. The lowest chilling index was observed in the WAX2-treated food, which was 55% lower than that in the control food (Fig. **1**). Loss of firmness is one of the main factors limiting the quality and shelf-life of fruits and vegetables. Flesh firmness in the wax-treated food was higher than that in the control food, indicating that waxing delayed the decline of firmness (Fig. **2**).

Treatable acidity levels in the treated food were lower than those in the control during the later storage, indicating that wax treatment decreased the treatable acidity levels of food and fruit after chilling stress. The treatable acidity level of WAX2-treated food was the lowest in all groups (Fig. **3**).
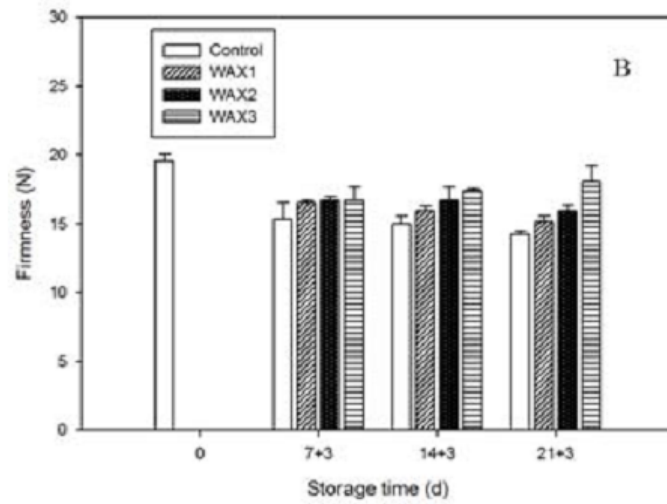
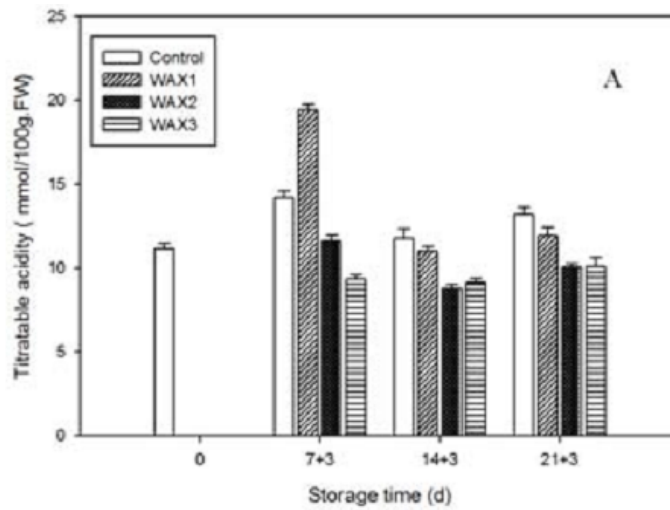**Fig. (2).** Effects of different wax treatments on chilling firmness (**B**).

Fig. (3). Effects of different wax treatments on treatable acidity (**A**).
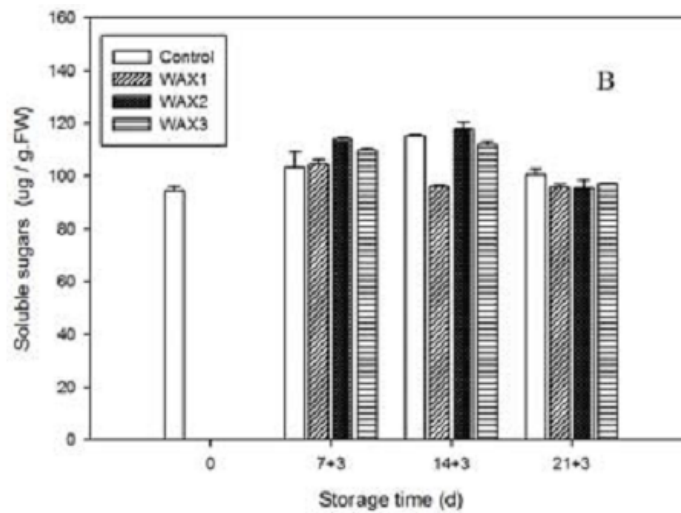

Fig. (4). Effects of different wax treatments on soluble sugar (**B**).

There was no significant difference in the level of soluble sugar between treated and the control groups during the storage, so wax treatment might not affect soluble sugar level of food and fruit (Fig. **4**). Taken all above results, the WAX2-treatment was shown as the optimal treatment.

CONCLUSION

In this paper, interval fuzzy theory and TOPSIS method are combined using AHP to analyze and calculate evaluation indexes weight; reviews set is determined by the interval comment fuzzy theory; intervals fuzzy evaluation matrix is established; and by means of distance programs with positive and negative ideal solution, proximity is determined as the evaluation standard, making the evaluation results more objective and realistic.

Water activity measurement is most commonly used in the food and pharmaceutical industry, to determine food shelf life and physical properties such as color, taste and aroma. Water activity has the main significant importance for bread products, candy, cheese, coffee, dairy products, fruit drying, flour, cereals, meat, vegetables, cooking oil, rice, sausages, instant food, seasoning, spices and tea. Since 1979, FDA U.S.A provides a wide range of food water activity value. FDA proposed guidelines recommend water activity measurement system, such as Testo 650 water activity measuring instrument. Water activity measurement however, must meet the strict requirements of applications. The main criterion is the accuracy of humidity parameters in the system. Testo 650 is high precision water activity measurement system with accuracy up to 0.01aw.

The present study indicates that the wax treatment of food and fruit could be a potentially useful method to alleviate chilling injury, and to maintain food and fruit quality by retarding dehydration, and providing a selective barrier to moisture loss and gas exchange, which leads to a reduction of general metabolism rate and an improvement of food and fruit textural quality.

CONFLICT OF INTEREST

The authors confirm that this article content has no conflicts of interest.

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