Evaluation on Home Storage Performance of Table Grape based on Sensory Quality and Consumers' Satisfaction

Ma Changyang [1,2], Fu Zetian [2], Xu Mark [3], Mira Trebar [4], Zhang Xiaoshuan [2*]

[1] *Pharmaceutical college, Henan University, Kaifeng, P. R China, 475004*

[2] *Beijing lab for Food quality and safety, China Agricultural University, Beijing, P. R China, 100083*

[3] *Portsmouth Business School, University of Portsmouth, Portsmouth, Hampshire PO1 3DE, UK*

[4] *University of Ljubljana, Tržaška 25, SI-1000 Ljubljana, Slovenia*

[*] *Corresponding author. Address: China Agricultural University. 209#, No. 17 Qinghua Donglu, Haidian district, Beijing 100083, P.R.China. Tel.: +86 010 62736717.*

E-mail addresses: zhxshuan@cau.edu.cn, zhxshuan@sohu.com (X. Zhang).

Abstract:

With continuous rise of table grapes consumption and increased public awareness of food safety, the quality control of grapes in storage after purchase is not sufficiently examined. Home storage constitutes the last and important stage in grape supply chain. Literature review shows that few researches on grape quality focus on the home storage stage compared with numerous researches reported on the quality control during postharvest and transportation process. This paper reports the performance evaluation of grape quality at home storage and consumers' satisfaction using integrated sensory evaluations. The internal attributes, including Texture, Taste and Odor of the table grapes and the appearance indices, Color and Cleanliness are examined. Key results show that during home storage, all the internal attributes decrease rapidly as time goes on, and cleanliness and color appear to be deteriorating in a lower speed. A comprehensive quality index was created to measure the quality of table grape which has high correlation with the Overall acceptability perceived by consumers.

Key words: Table Grape, Sensory Evaluation, Home Storage, Consumer Satisfaction, Quality Control

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1. Introduction

With the improvement of living standards and enhancement of public's quality consciousness, table grape is becoming one of the popular fruits consumed worldwide; the consumption has steadily increased for its favorable taste and rich nutrition. According to the statistics from United States Department of Agriculture, both the global production and consumption of grapes for 2012 are about 17.11 and 17.00 million metric tons (MT), a three percent increased compared with the previous year (USDA 2012).

As one kind of the highly perishable berries with their low pH, higher moisture content and nutrient composition, the fresh fruits of the table grape are very susceptible to attack by pathogenic fungi causing rots (Moss 2002; Tripathi and Dubey 2004), especially during the hot harvest season. More postharvest technologies and supply chain management strategies are developed and applied to quality control so as to avoid potential loss (Costa et al. 2011; Sabır et al. 2011; Ciccarese et al. 2013). Among those technologies, cold chain and its control technologies emerged as the vital and broadly adopted technology to preserve the safety and quality of grapes. A cold chain can be defined as a logistics environment (covering storage, handling, and transport) maintained within specified temperature ranges (Higgins et al., 2009). Currently maintaining a cold chain should extend to a consumer's home (Jevšnik et al. 2008, Ovca et al. 2009, Joshi et al., 2010). This means that the household storage process is perhaps one of the most critical stages of the cold chain (Baar et al. 2005; James et al. 2008). Researchers suggest that domestic storage is the weakest link in the entire chilled-chain with inadequate temperature control and handling (Jevšnik et al. 2008; James et al. 2008). Many home refrigerators used as the cold storage are running at higher than recommended temperatures (James et al. 2008). There is few research about performance evaluation on the quality of table grape at home storage.

Sensory qualities can be regarded as mediators of food preferences and intake, thus playing a prominent role in quality assessment (Brueckner 2010). Sensory evaluation can provide important and useful information to the food industry and food scientists about the sensory characteristics of food (Debjani et al. 2011). It is a convenient and rigorous method to detect the quality of food. It has been widely adopted (e.g. Cyprian et al 2008; Simpson et al. 2012) although it has lower accuracy than the physics and chemistry experiment in some aspects. (Sipos et al. 2011) For example, Mohapatra et al. (2011) employed sensory approach to estimate the shelf life of fresh products. Sensory evaluation, with appropriate descriptors, is the most reliable approach to measure consumer preference and satisfaction (Pecore and Kellen 2002; Di Miceli et al. 2010) which have remarkable effect on their purchase behavior.

This paper aims to analyze the changes of sensory quality attributes of table grapes at home storage, evaluate consumer satisfaction and examine the relationship between the sensory attributes and consumer's satisfaction of the fruit. The remainder of the paper is organized as follows. Section 2 describes experiment and data collection and process methods. Section 3 discusses the empirical results. The conclusions are summered in the final section.

2. Materials and methods

2.1Experimental material preparation

The kyoho grape was chosen as the representative Table Grape variety for its relatively high production and wide distributions in China (Mu and Feng 2010). Taking into account initial quality, the grapes were directly purchased and picked up from a grape production base in Changli, Hebei province of China, and transported by the wholesaler to the university laboratory in 3 hour at August 2012. Upon arrival, all of the grapes were coded and stored in a household refrigerator (Haier BC-117 FC with 0.39kw • h/24h chiller) immediately and was monitored by an improved temperature transducer (SHT 11), which could record the temperature online and transmit to the pre designed data base via wireless sensor network. During the storage, the refrigerator was opened and closed according to the designed scenarios to mimic different daily usage situations people often do at home.

From the first arriving day to the 10^{th} day, 30 berries from over 15 clusters were sampled with 30 fresh berries of the same variety to the evaluation trial randomly at 10:00am each day. Before operating the sensory evaluation, the samples were coded with random numbers and kept at a clean room to bring up the temperature of grape.

The evaluation trial was performed by a sensory evaluation team consisting of 10 panelists who have a good background and knowledge of the details of sensory evaluation and have been trained about table grapes for one week. During the evaluation, all the 10 panelists had tasted the samples and completed a short questionnaire covering the quality indicators independently. The experiment was carried out in a special room with individual booths and basic requirements for sensory experiment.

2.2 The Sensory Evaluation

The experiment procedure for the sensory evaluation was adopted from Heintz and Kader's work (1983). Sensory attributes of the table grape consist of Color, Cleanliness (Berry Bloom), Odor, Taste and Texture. Overall acceptability is also used to give a comprehensive score for each sample.

Appearance is one of the major factors the consumer uses to evaluate the quality of fruit and vegetables, and measurement of optical properties has been one of the most successful instrument techniques for assessing quality (Abbott 1999). Color is a direct sensory characteristic making it attractive and pleasant to eat for consumers. Table grapes range in color from pale greens, through light yellows, golden colors, to the pinks, reds, and nearly black. Meanwhile, Hygiene condition of food is a significant indicator of the safety of the fruit in the extrinsic indicators.

Berry surface Bloom, a thin layer of wax-like material coating the outer surface of the berry (Webb 1981), is of equal importance to the berry shape and the color as indicators of the health and hygiene of the grape, but Berry Bloom always give the consumers' wrong impression that the berry has been lightly and uniformly dusted or frosted.

Odor and taste are indispensable attributes to the sensory quality of food. Grape is a popular fruit for its specific Odor, Taste and Texture. Though Sensory characteristics of the fruit vary according to the species, a number of similar characteristics in different Table grapes can be presented to stimulate the purchasing and consume desire of the consumers. For example, it is more attractive to consumers if the grape with intense perfume and plump, juicy, sweet and sour flesh.

Acceptability assessment was used to understand the influence of single characteristics on overall liking, and represents as an indicative value of threshold acceptability for consumers (Di Miceli et al. 2010; Ghosh et al. 2012).

This research uses the 9-point Hedonic scale based on previous research (Chouksey et al. 2013) for the evaluation experiment. Table 1 shows the score criterion. 1 means Dislike Extremely; 2=dislike very much; 3=dislike moderately; 4=dislike slightly; 5=neither like nor dislike; 6=like slightly; 7=like moderately; 8=like very much; 9 = Like Extremely.

(Table 1 inserted here)

2.3 The weight of each indicator of the sensory attributes

In order to gain an aggregative indicator measuring the sensory quality of table grape, 10 experts with knowledge of the grape quality jointed the evaluation team to weigh each quality index using Delphi method (Molnár 1995; Wilson and Moffat 2010).Delphi method is particularly useful for achieving a consensus among experts given a complex problem (Chan et al. 2001). In this method, all the panelists were asked to conduct a multiple comparisons about relative importance of the five indices: Color, Cleanliness (Berry Bloom), Odor, Taste and Texture, and completed a questionnaire about the indices' weighting. The score 4~0 means the index given is very important for the over quality of grape, compared with the other ones; 3~1 shows

that the first is little bit more important than the second, and 2~2 means that both indices are equally important. 0~4, 1~3 are deduced respectively. Using the questionnaires' data, the weight of each index are calculated and listed in Table 2.

(Table 2 inserted here)

The figures in Table 2 shows the weights of the Taste, Odor and Texture are all around 0.25, this is higher than that of the Color and Cleanliness which implies that the internal attributes are more important to the grape quality than the appearance indices. In the appearance indices, Color whose weight is 0.17 appears more important than the Cleanliness (Berry Bloom) Grape Bloom with the weight of 0.07. The lower weight of clearness may be the fact that consumers believe any unsafe elements on the skin of the fruit can be removed by washing. It may also be explained that many consumers were not familiar with the Grape Bloom indicator, so many of them misunderstand it or show no interest in it.

2.4 Data analysis

Microsoft Excel 2007 and SPSS Statistics 17.0 were used to conduct the statistical analysis, and the results are reported in the next section.

3. Results Analysis and Discussions

3.1 Temperature fluctuations during home storage

Temperature abuse is an important factor affecting the preservation and storage of perishable products. Figure 1 illustrates the ambient temperature fluctuation at home storage during the experiment period, the coldest temperature in the refrigerator is about -1℃. The temperature reached the high value when the refrigerator was opened to sample. Except that, the temperature was fluctuated and not in the stable people expected.

(Fig.1 insert here)

The storage temperature was recommended to be within 0 ± 1℃ in order to maintain quality (Deng et al. 2007; Brady and Morris 2009). Though the lowest temperature keeps in bottom of the recommended temperature range, many times the temperature during the storage period is obviously higher than the range. According to James et al.'s (2008), many refrigerators were running at higher than recommended temperatures. For this reason, the preservation and storage of the fruit at home storage may have the worse quality than that in the professional cold warehouse.

3.2 Changes of quality over time

Person correlation method is applied to quantitatively analyze the changes of the detailed sensory quality over time, and the result is listed in the first line of the table 3.

The result reveals that all the indices deteriorate significantly at the 0.01 significant level with time during the period, except Color with a negative parameter. The correlation coefficients of Taste, Odor and Texture are all less than -0.600, which means the three indices decrease rapidly as time goes on, while the Cleanliness (0.360) decreases in a relatively low speed. The correlation coefficient of Color with time (-0.165) is less than 0. The correlation coefficient of Overall acceptability is -0.557 revealing that the accumulative time can reduce the consumers' satisfaction in grape fruit rapidly and significantly.

(Table 3 inserted here)

It is well known that the storage of agro-products is a gradual deterioration process. During the storage, all the three palate attributes and Cleanliness have significant and negative correlation with duration at home, but the Cleanliness deterioration is in relative lower speed. The Cleanliness changes of grape depend a great deal on many other storage factors, and it will not change too much if storage condition is stable and clean. The Color or the pigments of grape fruit which would changes when stored in some environments such as hot, pH (Deng 2006), have the lowest correlation with time. The reason could be the short storage period and a comparatively cold environment which causes too less color degradation of skin to be sensed with eyes.

For the more detailed research about quality changes of grape, multi-comparison of variables and time was carried out using Least Significant Difference (LSD） method and the results are presented in Table 4. The result of Appearance factors shows that mostly of them with the same marked letter along with time indicating that the majority can't be able to distinguish from each other clearly. Moreover, there are some fluctuations of the indices' changes with time. Compared with the Appearance, all the Intrinsic factors and Overall acceptability have continuous notable deterioration over time, especially in the early part of the storage.

(Table 4 inserted here)

The sensory attributes for the grape are shown in Figure 2. The radar graph shows that each spoke of the chart represents one of the indices' score. All the scores of the indices are decreasing with time, and the differences of their scores become more and more obvious. Though there is little difference among the indices in the first day, in the 5th and 10th day, the attributes Texture, Odor and Taste have much lower scores than that of the Color and Cleanliness. The Overall acceptability in the 5th day is close proximity to 5, which suggests that it's better to consume the grape before it being stored 5 days at home in case of the unacceptable taste.

(Fig.2 inserted here)

3.3 The relationship between the quality indices and Overall acceptability during the storage.

Since the Overall acceptability and quality indices decrease rapidly, correlation analysis is operated for the actual relationship between them. The results listed in bottom line of the table 3 show that Taste has the most highly positive correlation with Overall acceptability. This is followed by Odor, Texture, and Cleanliness which are all significant at the 0.01 level except Color with the lowest correlation parameter at the 0.05 level. The result about the Color comes as a surprise as most consumers prefer a visually appropriate product in the case of grape. This could be due to the fact that the color of grape deteriorates much more slowly (-0.165) while Overall acceptability decreases rapidly (-0.557) during the short storage period. The Cleanliness has a higher correlation with Overall acceptability (0.570) than the Color (0.255), this could be the higher deterioration ratio of cleanliness.

3.4 Factor analysis of indices

Principal Component Analysis (PCA) is a widely used multivariate analytical statistical technique that can be applied to quantitative descriptive data to reduce the dependent variables. (Ghosh and Chattopadhyay 2012) In this paper, Principle component analysis is used to extract a set of values of linearly uncorrelated variables from observations of possibly correlated variables, this aims to reveal the internal structure of given variables. This paper uses the factor analysis technique to identify the principle components from the five variables and the results are presented in the Figure 3.

(Fig.3 inserted here)

The results show that only the first two components with Eigen values exceeding 1 are extracted which can explain a total of 80.64％ of the variance. The results reveal that PC-1 with the loading of 59.62％ is almost a combined value reflecting all the five variables, while PC-2 with 21.02％ loading mainly reflects the Color and Cleanliness. In the Component 1 (PC-1), all the five variables' loading are higher than 0.500 positively, and Taste, Texture and Odor whose loading are all higher than 0.800. However in PC-2, only the Color (0.783) and Grape Bloom (0.391) have a positive loading. The results reveal that the intrinsic factors appear to be more important in the quality indices, though the quality is jointly determined by the five indices.

The results show that Texture, Taste and Odor have much in common, regardless the changes over time or loadings distributed in the PC-1 and PC-2.This means there is a connection among the three intrinsic indices obtained and the indices can be possibly synthesized into one single internal index. Whereas Color and Cleanliness

can remain as relatively independent variables, due to lower weights to the quality and lower deterioration speed.

3.5 overall quality changes and relationship with Overall acceptability

As discussed above, the grape quality factors include visual factors -Color, cleanliness, and palate factors such as texture and taste, etc. In this study, these factors are combined into a single measurement of composition that universally correlates with perceived quality, i.e. Comprehensive Quality of table grape was proposed by combining Color, Cleanliness, Taste, Odor and Texture with their weights. Fuzzy Synthetic Evaluation is a method to combine many detailed attributes into a single comprehensive index, which has been used in similar studies (Sowlat 2011; Gharibi et al. 2012). This method is adopted to calculate the Comprehensive quality.

$$CQ = \begin{bmatrix} C_1 & B_1 & O_1 & TA_1 & TE_1 \\ C_2 & B_2 & O_2 & TA_2 & TE_2 \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ C_n & B_n & O_n & TA_n & TE_n \end{bmatrix} \begin{bmatrix} C_w \\ B_w \\ O_w \\ TA_w \\ TE_w \end{bmatrix} = \begin{bmatrix} CQ_1 \\ CQ_2 \\ \vdots \\ CQ_n \end{bmatrix} \quad \text{Eq 1}$$

Where, C_i, B_i, O_i, TA_i, TE_i, and CQ_i are the scores of Color, Cleanliness (Berry Bloom), Odor, Taste, Texture and Comprehensive quality of *i*-th questionnaire respectively. C_w, B_w, O_w, TA_w and TE_w are the weight of the five indicators for the aggregative quality.

(Fig.4 inserted here)

The grey line in the Figure 4 reveals that the Comprehensive Quality score decrease rapidly over time, especially during the first few days. Compared with the black line indicating the Overall acceptability from the evaluation trial, it shows that the two indices are of high similarity in terms of the value and trend. Further examined further Person correlation analysis, a correlation of 0.83 between the Overall acceptability and the Comprehensive quality is obtained at the significant level of 0.01 which confirms the similarity between them quantitatively.

The results above suggest that the Overall acceptability is an appropriate indicator to monitor the aggregative quality of grape which is similar to results of Mohapatra et al's (2011) research on white button mushrooms. In the next sections, the research will employ the Overall acceptability as an effective measure to predict aggregated quality of the table grapes.

3.6 Overall acceptability change with time

Even the most healthful foods are not routinely accepted and regularly consumed if they have poor sensory properties according to the consumer point of view (Park et al.

2005; González-Aguilar et al. 2010). Given that the Overall acceptability is an adequate indicator of grape quality, 11 models in the Curve Estimation are applied to fit the curve of quality index. Only 4 regression models listed below: quadratic, cubic, logarithmic and power equation whose goodness-of-fits are higher than 0.900.

Logarithmic: Overall acceptability $=7.194-1.263 \cdot ln(t+1)$, $R^2=0.948$; Eq 2

Quadratic: Overall acceptability $=7.820-0.757t+0.042t^2$, $R^2=0.951$ Eq 3

Cubic: Overall acceptability $=7.777-0.719t+0.034t^2+4.99e-04t^3$, $R^2=0.976$ Eq 4

Power: Overall acceptability $=7.349t^{-0.227}$, $R^2=0.936$. Eq 5

Where t is the storage duration.

Considering the complexity form of 4 regression models and their inverse functions, the logarithmic equation logarithmic model with primary quality of 7.194 is chosen as the quality change curve of grape. The inverse function which is the duration function of the grape is formulized as Eq 6.

$t=\exp[(7.194 - \text{Overall acceptability})/1.263]$. Eq 6

The dotted line in Figure 4 which is drawn through the Eq 2 shows the fitness of an estimated trend of Overall acceptability. The sensory quality changes and the longest storage time of the grape at home storage can be predicted from the quality change function. Following the duration function Eq 6 and the acceptable boundary (Overall acceptability=5), the result is that it will take 4.46 days to reduce the quality score from 7.194 to 5.00. This implies that the maximum storage period, for the case of Kyoho grape at home storage is about 4.46 days after being purchased to home from direct wholesaler.

4. Conclusion

Cold chain is suggested as the foundational technologies to control the quality for the fresh agro-products, domestic storage of chilled food is the weakest link in the entire cold chain. This paper reported an evaluation of the quality of kyoho grape at home storage by using the sensory analysis and a number of results are concluded below:

1). Refrigerator temperature fluctuation is the key factor accelerating the deterioration of the quality of home storage, including the frequency of door opening and temperature control setting of refrigerator itself.

2). The sensory indices can be used as an effective measure of quality deterioration using appearance indices - Color, Cleanliness and internal indices, -Taste, Odor and Texture. During the storage, the deterioration speed of all the internal indices is higher than the Appearance indices. Nevertheless Color has the lowest deterioration speed. The score of the Overall acceptability decreases significantly (-0.557).

3). Through the Delphi method, the weight of each quality attribute is obtained. The

results show that the three internal attributers account for a large share of weight, followed by Color and Cleanliness. Furthermore, the correlation between the each indices and Overall acceptability is examined by using Person correlation analysis, and the results revealed a similar pattern of correlation between the indices' weight to the overall acceptability, however, the two Appearance indices show lower correlation.

4). A single aggregative comprehensive quality index is attended by using the Fuzzy Synthetic Evaluation, this index has high correlation with the Overall acceptability obtained from the evaluation questionnaires. This indicates that the changes of consumers' satisfaction to the grape are closely linked to its comprehensive quality measure, which suggests the Overall acceptability is an appropriate indicator to monitor the grape quality.

5). Through the Curve Estimation of the Overall acceptability, it is revealed that the maximum storage period of the Kyoho grape at home is about 4.46 days after being purchased to home from direct wholesaler.

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Figure1

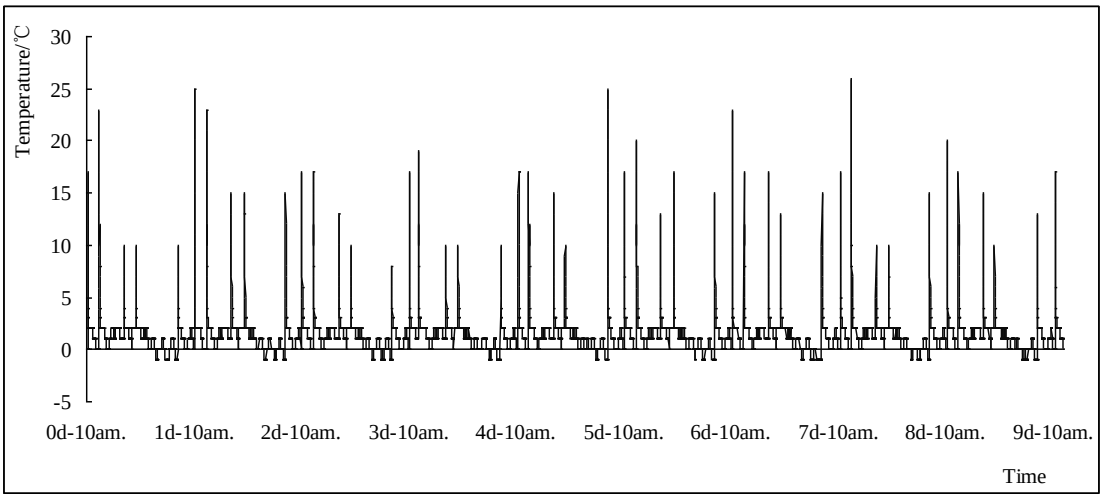

Fig 1 Temperature fluctuations in the refrigerator

Figure2

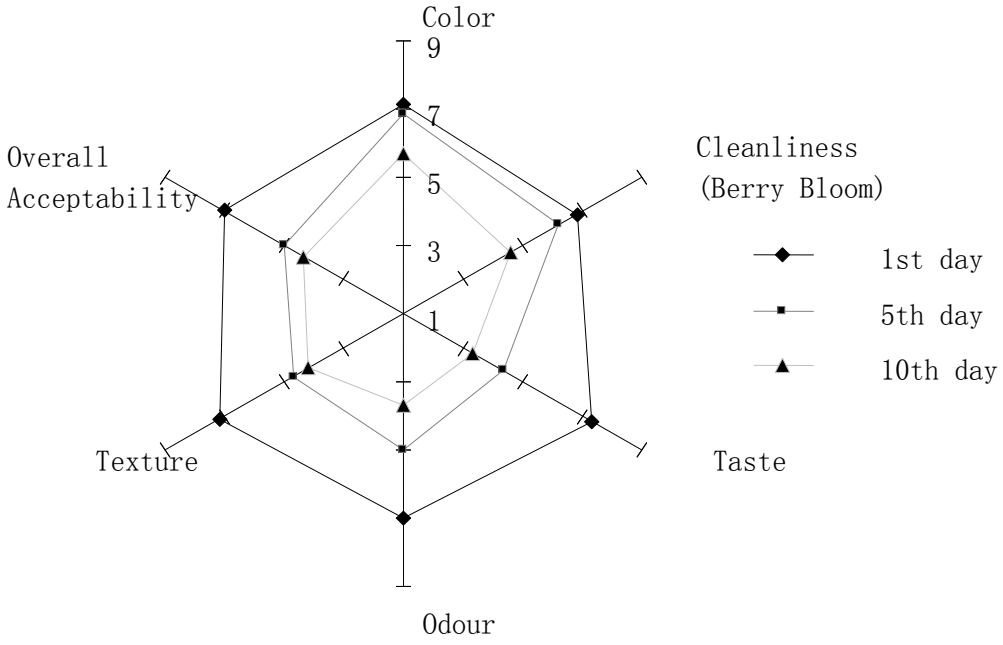

Fig 2 Radar chart of the sensory attributes of the grape with different storage times

Figure3

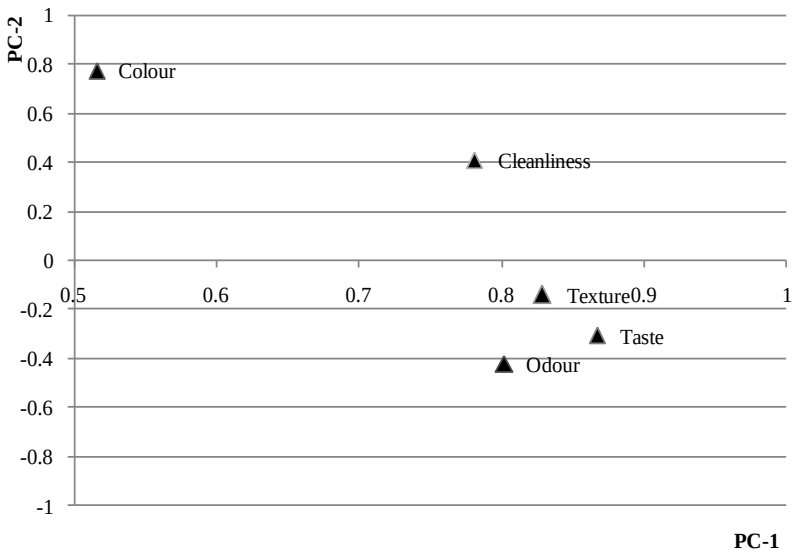

Fig 3 Principle opponent analysis of the quality indices (two Components are extracted)

Figure4

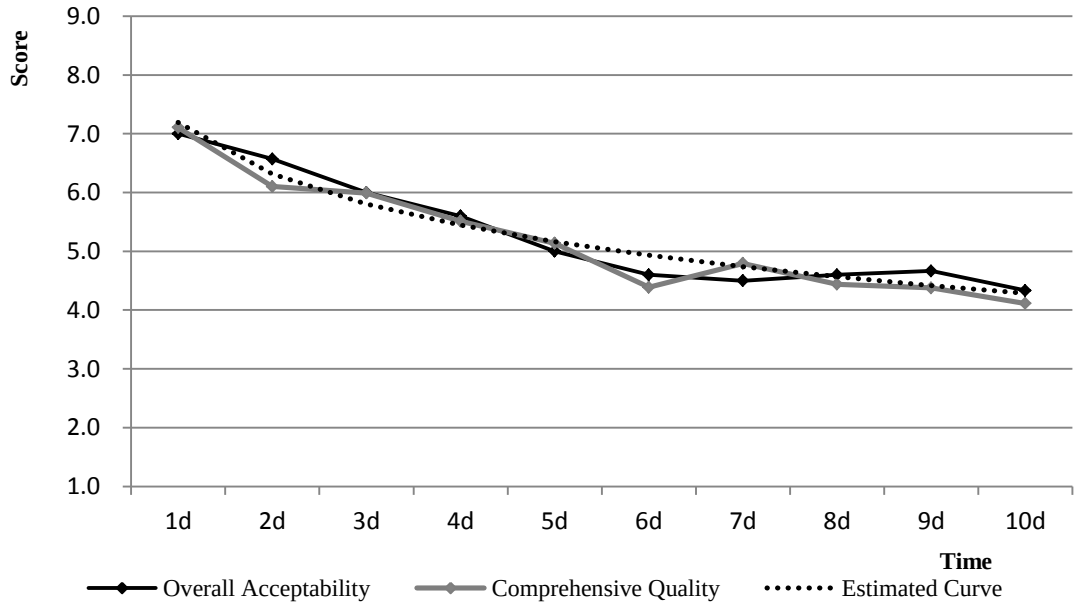

Fig 4 The Overall acceptability score, Comprehensive quality and Estimated Curve

Table Lists

Table 1 The criteria adopted in the sensory evaluation experiment

Quality Parameter	Description of Attributes (kyoho)	Score
Color	Blackish-purple, Uniform	7-9
	Red, streaky	4-6
	Green	1-3
Cleanliness (Berry Bloom)	Bloom evenly and fully distributed, dry and clean	7-9
	Bloom is thin and streaky with some residues	4-6
	The skin is moist and dirty with rare Bloom	1-3
Odour	Intense characteristic perfume	7-9
	Faint fragrance	4-6
	None fragrance and with some awful odour	1-3
Taste	pleasantly Sour and sweet in taste	7-9
	Unpleasant sweet sour ratio	4-6
	Sourness of taste	1-3
Texture	Soft and plump, juicy	7-9
	Excessively Soft and juiceless	4-6
	Coarse dry pulp	1-3
Overall Acceptability	From Dislike Extremely to Like Extremely	1-9

Table 2 The weight of each sensory variable using Delphi method

	Color	Cleanliness (Berry Bloom)	Taste	Odour	Texture
weight	0.17	0.07	0.25	0.26	0.25

Table 3 Correlation of variables

	Color	Cleanliness (Berry Bloom)	Taste	Odour	Texture	Overall Acceptability
Time	-0.165	-0.360**	-0.657**	-.620**	-0.610**	-0.557**
Overall acceptability	0.255*	0.570**	0.847**	0.743**	0.622**	1.000**

** and *indicates the significant level at 0.01 and 0.05 respectively

Table 4 Multi comparison of variables and time

Storage Time	1d	2d	3d	4d	5d	6d	7d	8d	9d	10d
Appearance factors										
Color	7.13^{abc}	6.50^{abcd}	7.38^{ab}	6.20^{bcd}	6.83^{abcd}	5.80^{cd}	8.00^{a}	6.60^{abcd}	6.67^{abcd}	5.67^{d}
Cleanliness(Berry Bloom)	6.81^{a}	5.69^{abc}	6.13^{ab}	5.00^{bc}	6.17^{ab}	4.60^{bc}	5.38^{abc}	4.30^{c}	5.50^{abc}	4.58^{bc}
Intrinsic factors										
Taste	7.25^{a}	6.13^{ab}	5.63^{bc}	5.60^{bcd}	4.33^{cde}	4.20^{cde}	4.10^{cde}	4.00^{de}	3.67^{e}	3.33^{e}
Odour	7.00^{a}	5.75^{ab}	5.60^{ab}	5.38^{ab}	5.00^{bc}	3.40^{cd}	3.25^{cd}	3.60^{cd}	3.17^{d}	3.67^{d}
Texture	7.13^{a}	6.25^{ab}	5.75^{bc}	5.20^{bcd}	4.67^{cd}	4.50^{d}	4.20^{d}	4.25^{d}	4.40^{d}	4.17^{d}
Overall acceptability	7.00^{a}	6.57^{a}	6.00^{ab}	5.60^{abc}	5.00^{bc}	4.60^{bc}	4.50^{bc}	4.60^{bc}	4.67^{bc}	4.33^{c}

The numbers listed in table are the average scores of each sensory variable after certain storage period, and the number on the same line with the same symbol means there are no significant different at the 0.05 significant level between the variable with different time.