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Research Article

Study on the Key Indexes of *Carambola* Quality Safety under Logistics Environment of Different Temperature

[1, 2]Lei Wang, [3]Ruhe Xie and [3]Yifeng Zou
[1]School of Traffic and Transportation Engineering, Central South University, Changsha 410075, China
[2]School of Logistics, Guangdong Mechanical and Electrical College, Guangzhou 510515, China
[3]Research Center for Logistics and Transportation, Guangzhou University, Guangzhou 510006, China

Abstract: By using layered factor analysis method, the key indexes of quality safety of *Carambola* are determined. The whole logistics process from picking, storing, transportation to selling is simulated in the experiment. At the same time, the key indexes are detected and analyzed under different temperature in logistics environment. The results indicate that both temperature and package have certain effect on the quality of *Carambola*. As shown in the study, the following conclusions are made. The temperature has a certain effect on *Carambola*'s weight loss. The higher the temperature, the greater the weight loss. The impact of temperature change on the sugar degree of *Carambola* and the P.H. value was little. The higher the temperature, the quicker the *Carambola*'s hardness decreases. It will be better to keep *Carambola* in a low-temperature environment with package that will slow down the decay speed.

Keywords: *Carambola*, key index, logistics, quality safety, temperature

INTRODUCTION

Carambola is native to tropical regions of Southeast Asia. It is one of the famous fruit in southern China and mainly distributed in the Guangdong area. The nutritional value of *Carambola* is high, because it contains protein, fat, sugar and other beneficial ingredients on human health. However, it is very difficult to make *Carambola* retain freshness in the process of transportation and sale because *Carambola* is a kind of impatience storage, easy to damaged and rotten fruit. When the temperature is high, fruits are perishable. As the length for preservation of *Carambola* is only a week at room temperature, transportation and sale of *Carambola* is difficult in other regions. If the temperature is too low, the value of the goods will be lost because of cold damage (Chen *et al*., 2010; Jiang, 1999; Yang *et al*., 2009). At present, studies on the *Carambola* quality changes in different temperature logistics environment at home and abroad is rarely (Hong *et al*., 2000; Li and Huang, 1996). The vast majority of studies have focused on *Carambola* quality change in a kind of condition. By determining the key index of *Carambola* quality safety, the effects are analyzed on the change of quality of postharvest *Carambola* under different temperature logistics environment (Lam and Wan, 1987; Yusof and Chiong, 1997; Ren *et al*., 2006). Therefore, it can provide a new way for storage, transportation, sales and preservation of *Carambola*.

Determination of the key indexes of quality safety of *Carambola*: Used for reference evaluation elements in previous studies customer preference behavior of *Carambola* and synthesized some literatures and customer interview, the preference model of *Carambola* that the moisture, acidity, sweetness and brittlement are measured variables is proposed. The questionnaire survey of consumers is made to verify the model. The layered factor analysis method is used to study different variable and the reliability of the questionnaire is tested by internal consistency coefficient. Questionnaire data for statistical analysis tools is SPSS 20.0. In the process of factor analysis, the Principal Components method is used to factor extraction. Varimax orthogonal rotation method is for factor rotation and the feature values greater than 1 factor are selected.

When the factor analysis was performed on the sweetness of values, KMO value is 0.850 and Bartlett test value is 0.000. It is shown that the sample is fit to do factor analysis. The characteristic value of 1 factor extracted is greater than 1 and the cumulative explained variance is 57.952%.

When the factor analysis was performed on the moisture of values, KMO value is 0.686 and Bartlett test value is 0.000. It is shown that the sample is fit to

Corresponding Author: Ruhe Xie, Research Center for Logistics and Transportation, Guangzhou University, Guangzhou 510006, China

Table 1: The degree of fitting parameters of the measurement model of customer purchase behavior

Index of fitting	Value
x^2/df	2.900
RMSEA	0.060
Upper limit of confidence interval RMSEA 90%	0.073
NFI	0.950
NNFI	0.960
PNFI	0.810
CFI	0.970
IFI	0.970
RFI	0.940
GFI	0.850
AGFI	0.810
PGFI	0.800

do factor analysis. The characteristic value of 1 factor extracted is greater than 1 and the cumulative explained variance is 68.75%.

When the factor analysis was performed on the brittlement of values, KMO value is 0.826 and Bartlett test value is 0.000. It is shown that the sample is fit to do factor analysis. The characteristic value of 1 factor extracted is greater than 1 and the cumulative explained variance is 65.40%.

When the factor analysis was performed on the acidity of values, KMO value is 0.847 and Bartlett test value is 0.000. It is shown that the sample is fit to do factor analysis. The characteristic value of 1 factor extracted is greater than 1 and the cumulative explained variance is 67.30%.

Reliability and validity testing: According to the analysis of exploratory factor, 4 factors and 19 measurement index are obtained. The large sample data is inputted into SPSS 20.0 and tested sequentially. The results show that the 4 factors all indexes of the CICT (Corrected Item-Total Correlation) were greater than 0.5. Cronbach's Alpha value which is above 0.8 is far more than 0.6 requirements. Therefore, the measurement table of the purchase behavior of customer is passed by reliability testing. Moreover, the LISREL software is used to First-Order Factor Analysis in order to test structure validity. The verification result show that the majority of the goodness of fit indexes is within an acceptable range. So, the model structure is reasonable. The degree of fitting parameters of the measurement model of customer purchase behavior is shown in Table 1.

Two order factor model of customer purchase behavior: Based on the rationality and validity of the customer purchasing behavior model, 4 dimensions of customer purchase behavior is the synthesis of a factor to do the analysis of higher order factor. Two order factor model goodness of fit with first-order model is roughly same. Tests show that the two order model fit is better that can reflect the relationship between the first order factors.

According to the analysis of confirmatory factor data of the two stage, the percentage method of the completely standardized total effects total effects coefficient of measurement index is used to measure index weight. At the same time, the importance of each dimension in the customer purchasing behavior can be calculated also. The result is shown in Table 2.

The measurement formula Customer purchase behavior is settled as follows:

$$BE = \sum W_i X_i \quad (1)$$

BE is the customer purchase behavior, W_i is the evaluation index and X_i is the index value. According to the analysis results, the importance of the customer purchase behavior in all the dimensions are ranked from small to large as follows: moisture, acidity, sweetness and brittlement.

Table 2: The index weight of customer purchase behavior

Measure index	Total effect of complete standardization	Measure index weight	Latent variable	Factor loading coefficient	Latent variable weight
1	0.66	0.054	Sweetness	0.81	0.25
2	0.62	0.051			
3	0.59	0.048			
4	0.62	0.051			
5	0.62	0.051			
6	0.66	0.054			
7	0.64	0.052			
8	0.67	0.055	Moisture	0.84	0.27
9	0.70	0.057			
10	0.63	0.051			
11	0.65	0.053			
12	0.64	0.052	Brittlement	0.87	0.22
13	0.71	0.058			
14	0.68	0.056			
15	0.60	0.049			
16	0.77	0.063	Acidity	0.83	0.26
17	0.53	0.043			
18	0.75	0.061			
19	0.51	0.042			
Total	12.25	1.000		3.35	1.00

MATERIALS AND METHODS

Experimental preparation: The *Carambola* used in the experiment is produced in China's Guangdong area. The selection of raw materials is demanded that is no ripening, uniform size, no pests and mechanical damage (Li and Dai, 1999; Ye and Lin, 2009; Lau *et al*., 2000; Choi *et al*., 2011). The weight of sample is 25 kg and each group of 5 kg. *Carambola* picked after one hour are transported to the cold chain logistics research laboratory. The experimental equipment include YP3001N electronic balance, PHS-3C type pH acidometer, GY-2 type sclerometer, LRH-150 type biochemical incubator and HG-100 transport simulation platform, etc. Some experimental equipment is shown in Fig. 1.

The method and process of the experiment: *Carambola* is a kind of washy and juicy fruit. So, sterilization of pretreatment needs to be circumspect (An *et al*., 2006; Oliveira *et al*., 2012; Sherlock and Labuza, 1992). Firstly, the fruit surface of *Carambola* is cleaned with flowing water and then the water on the surface is dried with clean cloth. The purpose is to wash away the dust, the sediment, a large number of microorganisms and residual chemicals attached to the surface of *Carambola*. Secondly, before experiment, clean *Carambola* is stored for 30 min in refrigerator that is kept at zero degrees Celsius. The experiment was divided into A, B, C and D group, respectively. In the process of experiment, the method of comparison of control variables is used and the actual transportation, sale and storage environment is simulated. The process of experiment is shown in Fig. 2.

Contrast experiment:

A group: Five kilogram of fresh *Carambola* precooled and sterilized is placed in freezer for 48 h to storage experiment. The freezer temperature is set as 5°C. Then, refrigerated transport experiment is performed for 24 h. The refrigerator car temperature is set as 1°C After the end of cold chain transport, sale of simulation experiment is performed on 2 to 3 days. The display cabinet is set as 1°C from the beginning of the experiment, parameters of each detection index are tested once every 24 h until the pulp is metamorphic. The color change of *Carambola* pericarp of A group at different stages is shown in Fig. 3.

B group: Five kilogram of fresh *Carambola* precooled and sterilized is placed in freezer for 48 h to storage experiment. The freezer temperature is set as 5°C Then, refrigerated transport experiment is performed for 24 h. The refrigerator car temperature is set as 5°C After the end of cold chain transport, *Carambola* is divided into B1 (2.5 kg) and B2 (2.5 kg) two groups for experiment.

(a) Display case

(b) LRH-150 type biochemical incubator

(c) GY-2 type sclerometer

(d) Saccharimeter

(e) PHS-3C type pH acidomete

Fig. 1: Some experimental equipment in study

B1 group: Sale of simulation experiment is performed on 2 to 3 days. The display cabinet is set as 5°C From the beginning of the experiment, parameters of each detection index are tested once every 24 h until the pulp is metamorphic. The color change of *Carambola* pericarp of B1 group at different stages is shown in Fig. 4.

B2 group: Sale of simulation experiment is performed on 2 to 3 days. The display cabinet is set as 15°C From the beginning of the experiment, parameters of each detection index are tested once every 24 h until the pulp is metamorphic. The color change of *Carambola* pericarp of B2 group at different stages is shown in Fig. 5.

C group: Five kilogram of fresh *Carambola* precooled and sterilized is placed in freezer for 48 h to storage experiment. The freezer temperature is set as 5°C then; the transport experiment at room temperature is performed for 24 h. The car temperature is set as 30°C after the end of transport experiment, sale of simulation experiment is performed on 2 to 3 days. The display cabinet is set as 30°C from the beginning of the experiment; parameters of each detection index are tested once every 8 h until the pulp is metamorphic. The color change of *Carambola* pericarp of C group at different stages is shown in Fig. 6.

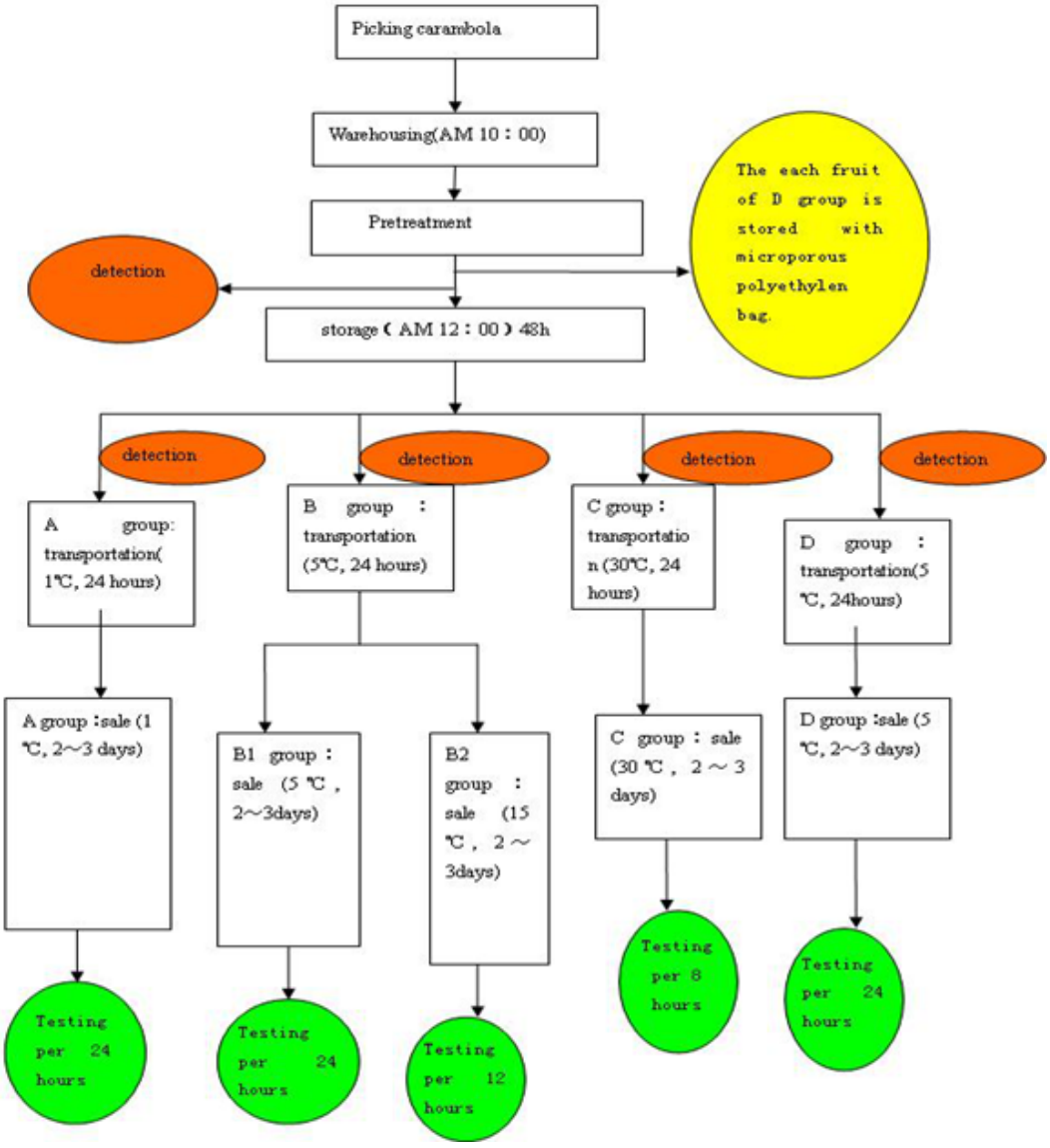

Fig. 2: The process of the experiment

Fig. 3: The color change of *Carambola* pericarp of A group at different stages

Fig. 4: The color change of *Carambola* pericarp of B1 group at different stages

Fig. 5: The color change of *Carambola* pericarp of B2 group at different stages

Fig. 6: The color change of *Carambola* pericarp of C group at different stages

Fig. 7: The color change of *Carambola* pericarp of D group at different stages

Table 3: The weight loss experiment result of *Carambola*

Weight loss (%)	0 h	24 h	48 h	72 h	96 h	120 h	144 h	168 h
A group	0	0.09	0.24	0.40	0.19	1.01	0.38	
B1 group	0	0.09	0.24	0.19	2.49	0.04	0.39	
D group	0	0.09	0.24	0.02	0.04	0.29	0.12	0.24

Table 4: The weight loss experiment result of *Carambola*

Weight loss (%)	0 h	24 h	48 h	72 h	84 h	96 h	108 h	120 h	132 h	144 h
B2 group	0	0.09	0.24	0.19	0.72	0.44	0.67	0.89	1.65	1.16

Table 5: The weight loss experiment result of *Carambola*

Weight loss (%)	0 h	24 h	48 h	56 h	64 h	72 h	80 h	88 h
C group	0	0.09	0.24	0.41	1.21	1.91	2.10	2.65
Weight loss (%)	96	104	112	120	128	136	144	152
C group	2.85	3.20	8.76	4.18	3.39	8.68	7.25	7.27

D group: Five kilogram of fresh *Carambola* precooled and sterilized that is packaged with micropore polyethylene freshness bag is placed in freezer for 48 h to storage experiment. The freezer temperature is set as 5°C then; refrigerated transport experiment is performed for 24 h. The refrigerator car temperature is set as 5°C after the end of cold chain transport, sale of simulation experiment is performed on 2 to 3 days. The display cabinet is set as 5°C from the beginning of the experiment; parameters of each detection index are tested once every 24 h until the pulp is metamorphic. The color change of *Carambola* pericarp of D group at different stages is shown in Fig. 7.

RESULT ANALYSIS

Because each detection samples are not the same, the absolute number analysis method cannot be good for comparative analysis and brings difficulties to the change comparison between the indexes. In this study, the relative number analysis method is used.

The weight loss analysis: The weight loss result of *Carambola* about A, B1 and D group, respectively that is obtained by calculated experimental data is shown in Table 3. The result of B2 and C group are shown in Table 4 and 5.

The weight loss change curve is shown in the Fig. 8. In the figure, the abscissa was the simulation time and the vertical axis is weight loss. The 5 lines represent the 5 experimental groups.

It can be seen from the experiment results that the weight loss of *Carambola* did not change obviously at 5°C condition. However, the weight loss of *Carambola* did change obviously at 30°C condition. The result shows that the weight loss is significantly affected by

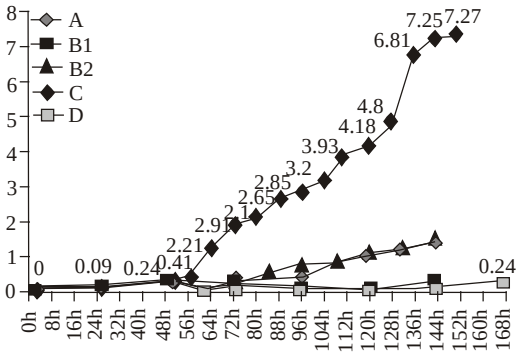

Fig. 8: The weight loss change curve of *Carambola*

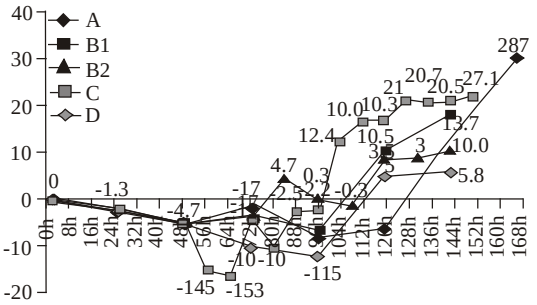

Fig. 9: The PH value change curve of *Carambola*

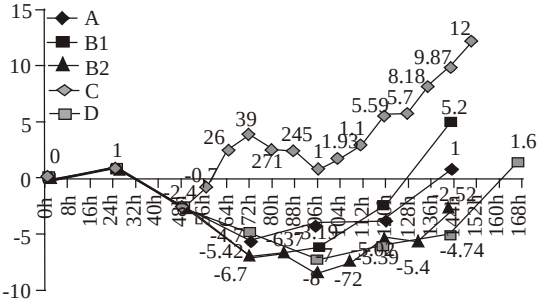

Fig. 10: The sugar degree change curve of *Carambola*

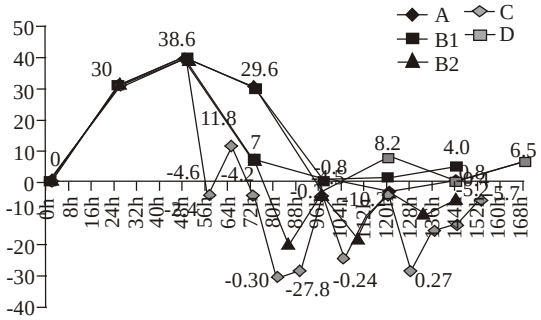

Fig. 11: The hardness rate change curve of *Carambola*

temperature. The higher the temperature, the greater the weight loss.

The PH value analysis: The change rate of PH value curve graph is obtained by calculated experimental data. The result is shown in the Fig. 9. In the figure, the abscissa is the simulation time and the vertical axis is the change rate of PH value. The 5 lines represent the 5 experimental groups.

The PH value is rang of 4.08~5.29 from several groups of experimental results. So, *Carambola* is a weak acid. Although the change rate of PH value as one falls in each experimental group, the general trend is rising. The rising trend shows that *Carambola* has been acid in the whole process of storage. In the transportation and storage process, different temperature had little effect on the pH value of *Carambola*. The PH value maintained relatively stable.

The sugar degree analysis: The change rate of sugar degree curve graph is obtained by calculated experimental data. The result is shown in the Fig. 10. In the figure, the abscissa is the simulation time and the vertical axis is the change rate of sugar degree. The 5 lines represent the 5 experimental groups.

The sugar degree is rang of 9.3~9.8 from several groups of experimental results. The change rate of sugar degree of *Carambola* in each group experiment is on the rise. The sugar degree of *Carambola* is related with the sweetness. The sugar degree increases with the mature fruit of *Carambola*. It is consistent with the cold chain logistics rule that the change rate of sugar degree in control at 10% is not obvious in the process of cold chain logistics of food. The data in the table showed that different temperature had little effect on the sugar degree of *Carambola* in the transportation and storage process and the sugar degree maintained relatively stable. The purchase intention survey of consumer shows that much sweeter *Carambola* is welcomed by consumers.

The hardness analysis: The change rate of hardness curve graph is obtained by calculated experimental data. The result is shown in the Fig. 11. In the figure, the abscissa is the simulation time and the vertical axis is the change rate of hardness. The 5 lines represent the 5 experimental groups.

It can be seen from the graph that the hardness of fruit stored at 5°C increases rapidly in the 48 h and the highest point of growth is to reach 38.6%. After reaching a peak, the change rate of hardness decreased rapidly because of the change of temperature and the hardness becomes small. The change rate of hardness at room temperature from C group is reduced to minus thirty percent. So, the hardness becomes small with the rising temperature and the passage of time. It shows that the temperature and time affect the quality of *Carambola*.

CONCLUSION

Throughout the 5 set of experiments, because the *Carambola* of D group had always been at the suitable

temperature condition of 5°C under refrigeration and external packaging protection, the indexes of D group did not change significantly till the end of the experiment and the quality of *Carambola* was best preserved. However, while the comparison group was at the 30°C preservation conditions, indexes changed obviously and fruit matured quickly. The quality of *Carambola* was worst preserved. In the process of simulation experiment, two samples of *Carambola* rot because the temperature is too high. Although the detection indexes of the A group at one degree centigrade with only minor changes, two samples of *Carambola* were frozen and the cool injury events occurred. The quality of *Carambola* had been worse after thawing. It shows that the refrigeration temperature is not as low as possible in the process of *Carambola* preservation. At the same time, only when the *Carambola* is placed in the appropriate temperature 5°C and packed effectively, the quality of *Carambola* can be better preserved.

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