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OPTIMIZATION OF SOME TECHNOLOGICAL PARAMETERS FOR FRESH CHILLI PRESERVATION BY CONTROLLED ATMOSPHERE METHOD

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ABSTRACT

The objective of this study was to optimize some parameters of fresh chili preservation technology by controlled atmosphere (CA) with 3 factors of corresponding surveyed domains: temperature (8 - 12 °C), concentration of oxygen (2 - 4 %) and concentration of carbon dioxide (3 - 6 %). Experimental plan includes 9 experiments following 2^3 plan repeating at center with the objective function as indicators of chili quality including total sugar content (%), organic acid content (%) and sensory quality (score). Nine experiments were concurrently conducted on a multifunction CA system in which parameters can be controlled and automatically monitored with good accuracy: temperature ± 0.5 °C, humidity ± 2 %, oxygen concentration ± 0.5 %, carbon dioxide concentration ± 0.5 %. The result was the successful determination of optimal experiment factors including temperature of 10.8 °C, oxygen concentration of 8 %, and carbon dioxide concentration of 6.0 %. The corresponding objective functions were achieved after 35 storage days with 3.65 % of total sugar content, 4.06 % of total organic acids, and good sensory quality (17.29/20 scores).

Keywords: chili, controlled atmosphere, oxygen concentration, carbon dioxide concentration, optimization.

1. INTRODUCTION

Chilli has scientific name as *Capsium* of *Solanaceae* family, with two groups popularly grown as hot chilli *(frutescens L. Capsicum)* and sweet chilli (*annuum L. Capsicum).* Chilli is a climacteric fruit and has common diseases such as bacterial soft rot, gray mold, black mold, and anthracnose, resulting in high rates of decay and rotten after harvest, especially in hot and moist climates. In the world, to date there have been many published studies on efficient chilli CA method, by the effect of inhibiting respiration and restrictiing microorganisms and fungi. Study results show that different species of chillis from different regions are applied different CA storage modes. However, 3 main parameters are not much variable: oxygen concentration from 1 - 4 %, carbon dioxide concentration from 2 - 6 % and temperature from 5 - 12 ^{0}C [1 - 3]. In

Vietnam, apart from for daily consumption, chillis are raw materials for food processing and exports, thus an advanced and safe storage technology as CA is essential in order to maintain stable chilli quality during transportation and processing. Within the scope of this study, experimental results of determination of the optimal mode for fresh chili preservation by CA method are discussed. In particular, the variable domains of the experimental factors such as temperature (8 - 12 ^{0}C), concentration of oxygen (2 - 4 %) and concentration of carbon dioxide (3 - 6 %) are the results conducted under single factor experiment [4].

2. MATERIAL AND RESEARCH METHODOLOGY

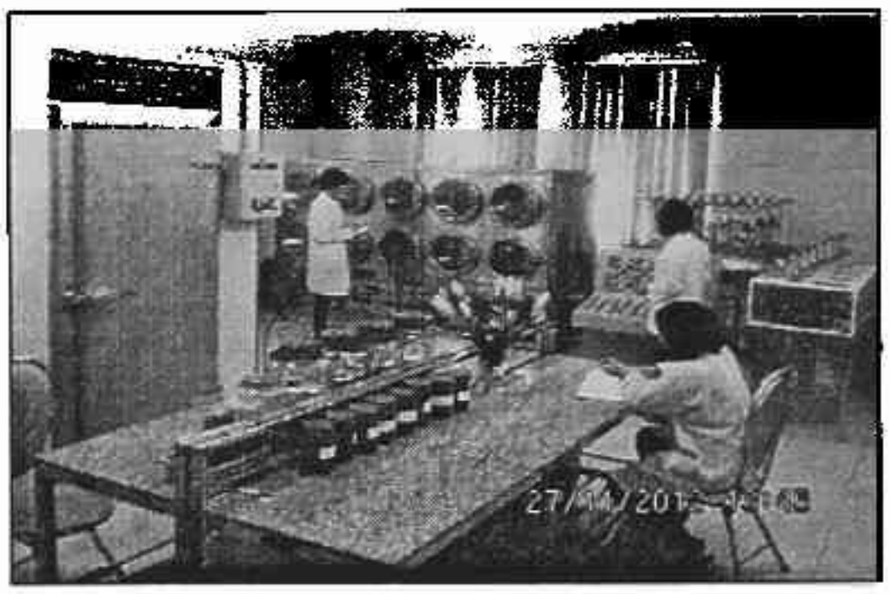
2.1. Material

Indian chilli namely F1 TN 138, grown in Khoai Chau district, Hung Yen province, has 8 - 10 cm length, 0.8 – 1 cm diameter, and 4 – 6 g weight. It was harvested after 85 - 90 days planted.

2.2. Methodology

2.2.1. Equipment used

A multifuntional CA system at the laboratory of Department of Research on Technologies and Equipment for Agricultural Product Preservation, VIAEP was used. It includes 10 CA chambers (Picture 1) with volume of 90 litter/chamber. They can be controlled by PLC system connected to a computer, and this system can update, store, and print experimental figures of 4 main parameters at high accuracy (tempreture ± 0.5 ^{0}C, moisture ± 2 %, oxygen concentration ± 0.5 %, carbon dioxide concentration ± 0.5 %). It also shows warning of C_2H_4 concentration over maximum level.



Picture 1. CA lab.

2.2.2. Plan of experiments

Experiments followed 2^3 total plan and 1 experiment was at center. 3 experimental factors and variable domains were coded as in Table 1. Nine experiments were named as TN_1, TN_2, TN_3, TN_4, TN_5, TN_6, TN_7, TN_8, TN_9, in which TN_9 is the experiment at center and repeated 2 times.

Table 1. Levels and variable domains of experimental factors.

Levels and variable domains	Code	Real figures		
		Temprature X_1 (^{0}C)	oxygen concentration X_2 (%)	Carbon dioxide concentration X_3 (%)
Lower level	-1	8	2	3
Basic level	0	10	3	4,5
Upper level	+1	12	4	6
Variability	1	2	1	1,5

Ten samples of fresh chilli were prepared, semi-processed and ed by embedding on Javel solution 1.5 ml / liter of water for 2 minutes at the temperature of 52 ± 1 ^{0}C. They were naturally drained before taking 3 kg/sample for conducting experiments [4]. After 35 day storage, quality criteria were analised and evaluated, including Y_1 - total sugar content (%), Y_2 - total organic acid content (%), and Y_3 - organoleptic quality (scores). Humidity parameter was fixed for all experiments at 90 ± 2 %.

2.2.3. Method of product quality analising and evaluating

Fresh chilli sampling followed the TCVN 5120 - 90 standard; Quality sensoring analising followed the TCVN 3218:2011, by analising committee assessment according to 2 criteria of colour and apperance. Assessment was individually conducted on a scale of 5 scores, the highest score was 5, and the lowest score was 1. Corresponding important factor: the color got 1.5, and the apperance got 2.5. Classification was based on total scores: good (18.2 to 20), pretty (15.2 to 18.1), medium (11.2 to 15.1), low (7.2 to 11.1), bad ≤ 7.1; Determination of total sugar content followed the TCVN 4594 - 88; Determination of total organic acids followed the TCVN 5483 - 91.

2.2.4. Methods of data processing

Experimental data were processed using statistical software Design - Expert version 7.1 to analyze regression coefficients, surface response, and optimization with expected function algorithm [5].

3. RESULTS AND DISCUSSION

3.1. Results of analising effects of temprature, oxygen concentration, and carbon dioxide concentration on quality of fresh chilli

Data of experiments are summarsired on Table 2. Using regression analysis by statistical software Design - Expert 7.1. check validity of the coefficients and the compatibility of the model. Standard F of three models is determined respectively: 110.54 (Y_1), 45.75 (Y_2), 3489.0 (Y_3) to show that three models are completely statistical with significant reliabilities as 99.1 % ($p < 0.009$), 97.85 % ($p < 0.0215$), 99.7 % ($p < 0.003$), respectively. Results of the validity analysis of regression coefficients tested by standard F with p values < 0.05 can determine coefficients of regression equations corresponding to real variables (1), (2), (3):

Table 2. Experiment data.

TT	X_1	X_2	X_3	Y_1	Y_2	Y_3
TN1	-1	+1	-1	3.61	3.98	17.6
TN2	-1	+1	+1	3.59	3.94	17.9
TN3	+1	+1	-1	3.92	4.22	16.1
TN4	+1	-1	+1	3.73	4.12	16.8
TN5	-1	-1	+1	3.47	3,91	18.5
TN6	+1	-1	-1	3.78	4.14	16.5
TN7	+1	+1	+1	3.86	4.17	16.3
TN8	-1	-1	-1	3.53	3,92	18.1
TN9	0	0	0	3.67	4.08	17.2

3.1.1. Changes in total sugar content

$$Y_1 = 3.00694 + 0.060625X_1 + 0.00375X_2 - 0.010833X_3 + 0.004375X_1X_2 - 0.00125X_1X_3 + 0.0025X_2X_3 \quad (1)$$

From the regression equation (1) through the regression coefficients, it can be seen that the total sugar content is most influenced by temperature, followed by concentration of carbon dioxide, and least by oxygen concentration. The influencing levels are different from those of other fruit and vegetables those are often affected by oxygen concentration higher than carbon dioxide concentration, to prove that chili is a climacteric respirating fruit. However, apart from the factor of low temperature, high carbon dioxide concentration can limit respiration better than low oxygen concentration. Specifically, when temperature and concentration of oxygen increase, total sugar content increases and vice versa. On the other hand, carbon dioxide concentration increasing can reduce total sugar content, while interaction effects among experimental factors are negligible.

3.1.2. Changes in total organic acid content

$$Y_2 = 3.42333 + 0.0525X_1 + 0.025X_2 + 0.01333X_3 + 0.0025X_1X_2 - 0.000833333X_1X_3 - 0.005X_2X_3 \quad (2)$$

From the regression equation (2) through the regression coefficients, it can be seen that the total organic acid content is most influenced by temperature, followed by concentration of oxygen, and least by carbon dioxide concentration. When temperature and concentration of oxygen increase, total organic acid content increases and vice versa. The difference here is that during preservation time, total sugar content increases and total organic acid content also increases, while with other fruit and vegetables, total organic acid content gradually reduces. This result is correspondent with study [6]. On the other hand, organic acid content is most influenced by temperature, which is due to the impact of the activation energy depending on temperature - the condition for biochemical conversion process.

3.1.3. Changes in organoleptic quality

$$Y_3 = 21.29722 - 0.4X_1 - 0.3X_2 + 0.23333X_3 + 0.0125X_1X_2 - 0.00833333X_1X_3 - 0.016667X_2X_3 \quad (3)$$

From the regression equation (3) through the regression coefficients, it can be seen that the quality of chilli sensored is most influenced by temperature, followed by concentration of oxygen, and least by carbon dioxide concentration, while interaction effects among experimental factors are minor. When temprature or oxygen concentration increase, quality of chilli sensored reduces and vice versa. This is understandable because the two factors directly affect on respiration process leading to biochemical changes and sensory quality changes as color, smell, and taste. On the other hand, when carbon dioxide concentration increases, sensory quality tends to increase, though the increase is small.

3.2. Results of optimizing preservation modes for fresh chillis by CA

Results are acquired from doing researches on individual factor and multiple factors, combined review data and analysis during the experiments. Binding conditions satisfy the desire to achieve corresponding experimental factors and objective functions: X_1 - temperature (8 - 12 ^{0}C), important factor: 5, desired value: max; X_2 - oxygen concentrations (2 - 4 %), important factor: 4, desired variable: in domain boundary; X_3 - carbon dioxide concentrations (3 - 6 %), important factor: 3, desired variable: in domain; Y_1 - total sugar content (3.47 to 3.92 %), important factor: 4, desired value: max; Y_2 - concentration of total organic acids (3.91 to 4.22 %), important factor: 4, desired value: min; Y_3 - organoleptic quality (16.1 to 18.5 points), important factor: 5, desired value: max. Optimal modes are identified: storage temperature of 10.8 ^{0}C,

oxygen concentration of 2.08 %, and carbon dioxide concentration of 6 %. Total sugar content is 3.65 %, organic acid content is 4.06 %, and organoleptic quality is 17.29 points, respectively.

Optimal model reaches 52.5 % of general desire, and the specific objectives as temperature, oxygen concentration, carbon dioxide concentration, total sugar content, total organic acid content, and organoleptic quality reach the desired level of 71.14 %; 100 %; 100 %; 40.11 %; 50.72 %; 49.48 %, respectively. They are represented in Figure 2.

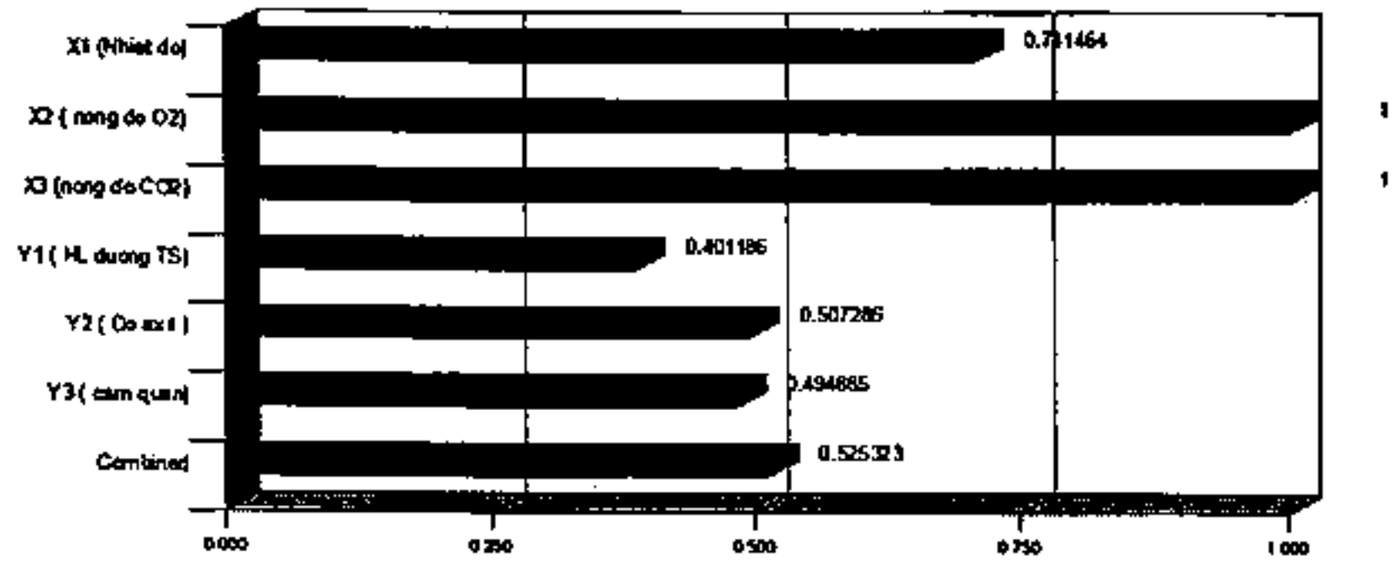


Figure 2. Desired levels reached of optimal model.

From the results of optimization after 35 day storage at 10.8 ^{0}C, oxygen concentration of 2.08 % and carbon dioxide of 6 %, total sugar content is 3.65 % (higher than that of material - 3.51 %) and organic acid content is 4.06 % (higher than that of material - 3.88 %), while the sensory quality gets 17.29 points (minimal decline). Compared with the results of study [7] "temperatures between 5 - 10 ^{0}C, RH 85 - 95 %, in CA condition with 3 - 5 % oxygen and 5 - 10 % carbon dioxide, preservation time is 2 - 3 weeks". However, this new publication is of individual factor research, the best CA mode cannot be achieved, while the results of this study give better CA preservation effectiveness at higher temperature and lower oxygen concentrations. The results of the study [8] "chilli can be preserved in 22 days under the condition of 2 - 8 % carbon dioxide and 4 - 8 % oxygen, at 8.9 ^{0}C, but at 10 % of oxygen and 5 % of carbon dioxide, chilli can be preserved for 38 days". The results of this study shows that fresh chilli during storage has quite unique biochemical changes compared to other fruit and vegetables, that total sugar content and total organic acid content increase at the same time, although under CA conditions the increase is small compared to those in material.

4. CONCLUSION

Results of optimizing factors in chilli preservation by controlled atmosphere (CA) at laboratory level are: determination of appropriate preservation mode with temperature of 10.8 ± 0.5 ^{0}C; moisture of 90 ± 2 %, oxygen concentration of 2.08 ± 0.5 %; carbon dioxide concentration of 6 ± 0.5 %, after 35 days of preservation, the chilli can maintain its good organoleptic quality (17.29/20 scores) to reach requirements of commercial quality with physio-chemical criteria: total sugar content 3.65 % and total organic acid content 4.06 %.

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TÓM TẮT

TỐI ƯU HÓA MỘT SỐ THÔNG SỐ CÔNG NGHỆ BẢO QUẢN QUẢ ỚT TƯƠI BẰNG PHƯƠNG PHÁP KHÍ QUYỂN KIỂM SOÁT (*CONTROLLED ATMOSPHERE*)

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Mục tiêu của nghiên cứu này là tối ưu hóa một số thông số công nghệ bảo quản quả ớt tươi bằng phương pháp khí quyển kiểm soát (CA) với 3 yếu tố thực nghiệm tương ứng miền khảo sát là nhiệt độ (8 - 12 ^{0}C), nồng độ khí O_2 (2 - 4 %) và nồng độ khí CO_2 (3 - 6 %). Kế hoạch thực nghiệm gồm 9 thí nghiệm theo quy hoạch 2^3 có lặp lại tại tâm với hàm mục tiêu là các chỉ tiêu chất lượng của quả ớt gồm hàm lượng đường tổng số (%), hàm lượng axit hữu cơ tổng số và chất lượng cảm quan (điểm). Tiến hành đồng thời 9 thí nghiệm trên hệ thống thiết bị CA đa chức năng có thể điều khiển và giám sát tự động các thông số với độ chính xác (nhiệt độ ± 0,5 ^{0}C, độ ẩm ± 2 %, nồng độ khí O_2 ± 0,5 %, nồng độ khí CO_2 ± 0,5 %). Kết quả đã xác định được giá trị tối ưu của các yếu tố thực nghiệm với nhiệt độ là 10,8 ^{0}C, nồng độ khí O_2 2,08 % và nồng độ khí CO_2 6,0 %. Các hàm mục tiêu tương ứng đạt được sau 35 ngày bảo quản với hàm lượng đường tổng số 3,65 %, hàm lượng axit hữu cơ tổng số 4,06 % và chất lượng cảm quản đạt loại khá (17,29/20 điểm).

Từ khóa: quả ớt, khí quyển kiểm soát, nồng độ khí oxy, nồng độ khí cacbonnic, tối ưu hóa.