British Biotechnology Journal
12(3): 1-5, 2016, Article no.BBJ.23865
ISSN: 2231–2927, NLM ID: 101616695

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Changes of Lycopene, Beta-carotene, Glucose, GA_3 and ABA Contents in Different Parts of Tomato

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Authors' contributions

This work was carried out in collaboration between all authors. Authors YY and BZ designed the study. Author YY performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author QW managed the analyses of the study and the literature searches. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/BBJ/2016/23865
Editor(s):
(1) David W. M. Leung, School of Biological Sciences, University of Canterbury, New Zealand.
(2) Kuo-Kau Lee, Department of Aquaculture, National Taiwan Ocean University, Taiwan.
Reviewers:
(1) Cao Bihao, South China Agricultral University, China.
(2) Dilip R. Panthee, North Carolina State University, USA.
Complete Peer review History: http://sciencedomain.org/review-history/13465

Short Research Article

Received 26th December 2015
Accepted 15th February 2016
Published 26th February 2016

ABSTRACT

Aims: This research studied the dynamic changes of main pigments, glucose, GA_3 (Gibberellic acid) and ABA (Abscisic acid) contents in different parts of tomato fruit during the ripening stage, and provided references for the further research for the coloring mechanism of tomato fruits.
Study Design: When the second cluster of tomato fruits reached green mature stage, fruits were labeled and sampled. The fruits from each ripening stage were sampled and dissected to individual parts for measuring the contents of lycopene, beta-carotene, glucose, GA_3 and ABA.
Place and Duration of Study: Horticultural College, between February 2014 and March 2015.
Methodology: The contents of lycopene, beta-carotene, glucose, GA_3 and ABA were determined by HPLC (High Performance Liquid Chromatography).
Results: The contents of lycopene and glucose increased during the ripening of tomato fruits, and the contents of β-carotene increased after slightly decreased. At the red Ⅱ stage, the maximum

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contents of lycopene and glucose were in the peripheral pericarp, and the maximum content of β-carotene was in pectin. The contents GA_3 decreased during ripening stage, and the minimum content of GA_3 was in peripheral pericarp at the red Ⅱ stage. The change of ABA contents which stayed in a low level in all parts was like a bimodal curve during the whole ripening stage.

Conclusion: Accumulation of lycopene and β-carotene was accompanied by the increasing of glucose and ABA contents, and by the decreasing of GA_3 content.

Keywords: Tomato; different parts; pigments; sugar; hormone.

1. INTRODUCTION

Fruit coloration is one of the important indicators to measure the commodity value of the fruit. And the changes of pigment in tomato fruits may affect the color from green to red, mainly including the decrease of chlorophyll content and increase of carotenoid content [1]. Carotenoids synthetic belongs to one of isoprenoids metabolism in plants. Lycopene, β-carotene, GA_3 and ABA are all the transformation products of GGPP (geranylgeranyl pyrophosphate) which is the first direct precursor substances in plant isoprenoid pathway [2]. Glucose molecule which is the direct product of photosynthesis is transformed to GGPP [3]. The accumulations of the sugar and the biological synthesis of carotenoids are regulated and controlled by endogenous hormones [4,5]. Many scholars tried to discuss the mechanism of carotenoids accumulation by the metabolizing changes of sugar and endogenous hormones. The research on Cara Cara Navel Orange [6] indicated that the accumulation of carotenoids had an intimate connection with sugar and endogenous hormones metabolizing. This had settled a base for the further knowing about the mechanism of fruits pigments accumulation. Many researchers only focused on the changes of the pigments contents in different fruits development stages, but seldom paid attention to the changes of the pigments type and contents in different parts of the fruits. The connection between the main pigment and metabolizing products in different parts is hardly reported. This research studied the changes of the main pigments, glucose, GA_3 and ABA contents in different parts during the ripening of tomato fruits, which will supply references for the further research about tomato fruits coloring mechanism.

2. MATERIALS AND METHODS

2.1 Plant Materials

Jinguan tomato (*Solanum lycopersicum*) seeds were sown and seeds were transplanted to a solar greenhouse of Shenyang Agricultural University with array pitch of 50 cm and row spacing 35 cm. Other management was the same as the field management [7].

There were 3 clusters (each cluster has 4 fruits) per plant. When the fruits of second cluster reached green mature, green mature fruits were labeled and sampled. Ten fruits from each ripening stage were sampled and dissected to individual parts, mixed and then stored at -80℃ in isolated condition.

Partition of ripening stages: Green mature stage, mature fruit with green color; Breaker stage, slightly colored red (<10％); Turning stage, light red, colored red (10％～30％); Pink stage, nearly red, 30～60％ colored; Red Ⅰ stage, fully colored with firmness; Red Ⅱ stage, dark red without firmness.

Partition of fruit parts: according to the anatomical structure, tomato fruits were divided into 4 parts, peripheral pericarp, dissepiment, pectin (including seeds) and axis.

2.2 Methods

Extraction and analysis of lycopene and β-carotene were made by HPLC according to Ma [8]. The contents were assayed as described by Wang [9]. Extraction and analyses of GA_3 and ABA were made by HPLC according to Dobrev and Kaminek [10]. Standards of β-carotene, inter standard β-apo-8'-carotenal, glucose, GA_3 and ABA were obtained from Sigma.

3. RESULTS

3.1 Changes of Lycopene and Beta-carotene Contents in Different Parts of Tomato

The dynamic changes of lycopene contents in four parts of tomato fruits during ripening were shown in the Fig. 1. At the green mature stage, lycopene was not detectable. Lycopene began to

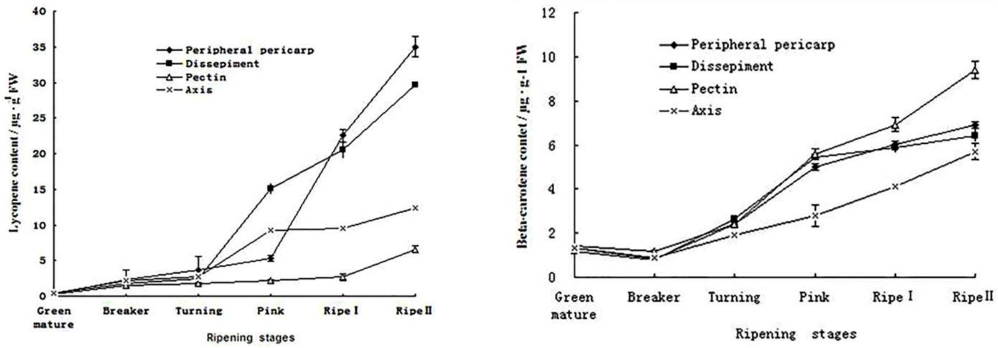

Fig. 1. Changes of lycopene and beta-carotene contents in different parts of tomato

appear and accumulated with the ripening process. Till the red Ⅱ stage, the lycopene contents reached to the maximum. The lycopene content in peripheral pericarp was the maximum of 35.02 $\mu g \cdot g^{-1}$ FW in full mature fruits, followed in dissepiment and axis, and lycopene content in pectin was the minimum.

The contents of β-carotene decreased slightly in the four parts after green mature stage, then the content of β-carotene increased slightly along with the ripening process, finally reached the maximum at the red Ⅱ stage. The content of β-carotene was maximal in pectin (36% higher than that in peripheral pericarp), less in peripheral pericarp, the least in axis.

3.2 Changes of Glucose Contents in Different parts of Tomato

The contents of glucose in different parts increased gradually during ripening and reached to the maximum at the red Ⅱ stage. And the content of glucose was the maximum in peripheral pericarp, less in axis and pectin, the least in dissepiment. At the red Ⅱ stage, trend of glucose content was familiar with those at the green mature stage (Fig. 2).

3.3 Changes of GA_3 and ABA Contents in Different Parts of Tomato

As shown in the Fig. 3, the content of GA_3 began to decrease rapidly at the green mature stage, then decreased slightly and reached to the minimum. At the green mature stage, the maximum content of GA_3 was in axis, less in pectin, the least in the peripheral pericarp and dissepiment. At the red Ⅱ stage, there were little differences of GA_3 contents between axis and pectin. The least was in peripheral pericarp.

Changes of ABA contents in different parts during ripening were like a bimodal curve. The contents of ABA reached to the minimum at the turning stage and reached to the maximum at the red Ⅱ stage. The content of ABA was maximal in peripheral pericarp, less in axis and dissepiment, and the least in pectin.

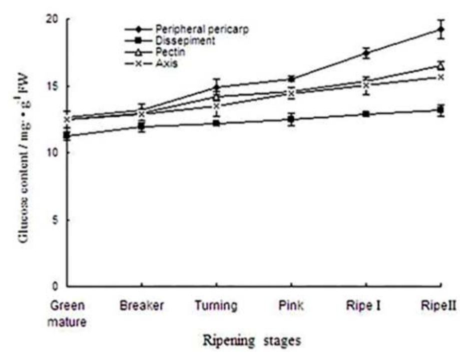

Fig. 2. Changes of glucose contents in different parts of tomato

4. DISCUSSION

The results of this experiment indicated that the main pigments contents in tomato fruits were different and they had different change rules during ripening process. The contents of lycopene and β-carotene were very low at the green mature stage. The content of lycopene increased gradually with ripening process. After that, the content of β-carotene decreased at first and then increased. The possible reason might be that β-carotene would quickly transform to downstream products such as violaxanthin, neoxanthin or ABA [11]. The accumulation of lycopene in tomato fruits might involve in the gene expression of *PSY* (the gene of Phytoene synthase) and *PDS* (the gene of Phytoene desaturase) which lies in upstream on the way of

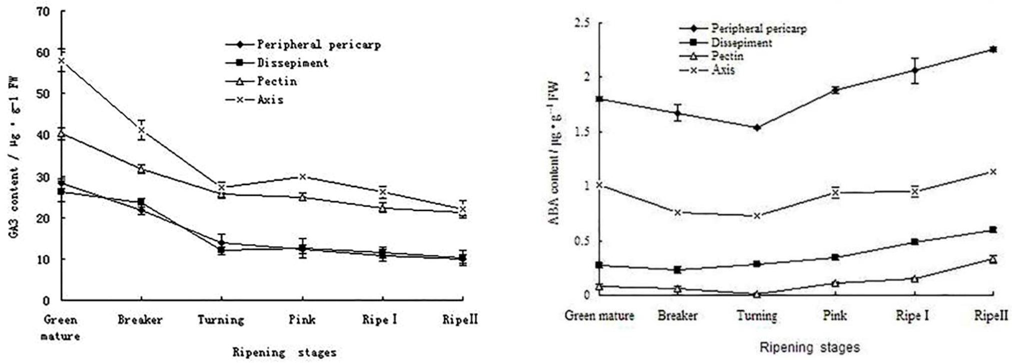

Fig. 3. Changes of GA_3 and ABA contents in different parts of tomato

composing lycopene enhanced but the gene expression of *LYCB* (the gene of Lycopene-β-cyclase) and *LYCE* (the gene of Lycopene-Ɛ-cyclase) faded which control lycopene transformed to carotene at the turning color stage [12]. Lycopene accumulation was regulated and controlled by the expressing level of a series of carotenoids synthetic genes during development process [13]. Different parts of tomato fruits had different carotenoids contents. Lycopene mainly existed in the peripheral pericarp and β-carotene mainly existed in pectin. This was probably because enzyme activities were different at the fruits development stage in different parts. So the genes of enzyme maybe have connection with temporal and spatial expression.

The content of glucose was the maximum in peripheral pericarp at the red Ⅱ stage. This indicated that different parts had the same competitive ability to the leaf assimilation products in the early ripening process. After that, the leaf assimilation products reduced in the later ripening process. Products of photosynthesis from leaf to the inner parts also reduced, so the glucose contents in other parts were obviously lower than that in peripheral pericarp.

The accumulations of lycopene and β-carotene were accompanied by the decreasing of GA_3 content and the increasing of ABA content, indicated that endogenous GA_3 negatively regulated to the accumulations of lycopene and β-carotene, but ABA had a positive regulation. Fray [14] with his partners transferred *PSY* into tomato, which the *PSY* was the key enzyme gene in the pathway of carotenoid biosynthesis. The content of carotenoids increased and the GA_3 content reduced because carotenoids and GA_3 probably were all the transformation products of GGPP. We presumed that the GA_3 content reduced and ABA content increased were likely to be the reason for the accumulation of lycopene and β-carotene.

5. CONCLUSION

The contents of lycopene increased during the ripening of tomato fruits, and the contents of β-carotene increased after slightly decreased. At the red Ⅱ stage, the maximum lycopene content was in the peripheral pericarp, and the maximum β-carotene content was in pectin. The maximum content of glucose was in peripheral pericarp. And the content of GA_3 decreased rapidly in the early ripening stage, after that began to decrease gradually, reached the minimum at the red Ⅱ stage. The minimum content of GA_3 in mature fruit was in peripheral pericarp. The change of ABA contents which stayed in a low level in all parts was like a bimodal curve during the whole ripening stage.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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