The content of photosynthetic pigments and the light conditions in the fruits and leaves of sweet pepper

Jan Pilarski¹,², Maciej Kocurek¹

¹The Franciszek Górski Institute of Plant Physiology, Polish Academy of Sciences, Niezapominajek 21, 30-239 Kraków, Poland,
²Institute of Biology, Świętokrzyska Academy, Świętokrzyska 15, 25.406 Kielce, Poland,
e-mail: j.pilarski@zfr-pan.krakow.pl

Key words: chlorophyll, carotenoids, leaf optical properties, fruit optical properties, absorbance, reflectance, transmittance, leaf, fruit, sweet pepper

Abstract

Investigations were carried out on the fruits of sweet pepper at its two development stages: on green fruits, on mature red and yellow fruits and on leaves. The content of the photosynthetic pigments and the optical properties were examined.

In the green fruits when compared with leaves the content of the photosynthetic pigments is smaller by 40 to 50 % and the value of the ratio: chlorophyll a/b is lower. Chlorophyll is absent in mature fruits, while the content of carotenoids is a few times higher.

The optical properties of green fruits and of the leaves in the PAR (photosynthetically active radiation) range are the same. In the range 700 - 1100 nm the green fruits show smaller reflectance and transmittance and a few times greater absorbance of irradiation which contributes to the warming up of the seed bag, while small absorbance of leaves in this range protects them against overheating.

In mature fruits, in the PAR range, the reflectance and transmittance are higher, while the absorbance of irradiation in comparison with that of green fruits is smaller. In the range 700 – 1100 nm the changes are rather small and refer to the increase of reflectance and reduction of absorbance, while the transmittance of irradiation remains unchanged.

Introduction

The photosynthetic pigments: chlorophylls and carotenoids, are permanently or temporarily present in all overground parts of plants. In the fruits of pepper they are found in most cultivars. Such fruit, in the course of maturing changes its colour from green into e.g. red, orange, yellow, brown, violet. During maturing there occur changes in the content of the pigments and the content of the carotenoid pigments responsible for the change of the colour of mature fruit increases (Deli et al. 1996).

Green fruits are photosynthetically active (Atkins et al. 1960, Flinn et al. 1977) and their participation in \( \text{CO}_2 \) fixation may amount to 25 - 50 % of \( \text{CO}_2 \) assimilation of leaves (Moreshet and Green 1980). The photosynthetic activity of the green fruits of pepper was stated by Czarnowski (1994, 1995). The large surface area of the fruit at the final stage of its development forms a considerable portion of the assimilation surface of the plant and thereby has a marked share in photosynthetic binding of \( \text{CO}_2 \).

The fruit of sweet pepper is a bag of a fleshy pericarp, built mainly of mesocarp containing the photosynthetic pigments. Irradiation, transmitted
through some millimetres thick layer of the pericarp wall, is necessarily subjected to great changes both as regards its amount and the spectral composition. There are no literature reports available concerning the light conditions in the pericarp of sweet pepper. The aim of the present study was to examine the content of the pigments and the light conditions of the pericarp of sweet pepper.

Material and methods

Investigations were carried out on fruits and leaves of sweet pepper (Capsicum annuum L.), cultivar Cesario - red in the maturity phase, and on the cultivar Kerala - yellow in the maturity phase. The material was collected from plants grown in plastic tunnels.

Determination of spectral properties reflectance $-(R)$ and transmittance $(T)$ of fruits and leaves were measured using the LI-1800 spectroradiometer with $-12 S$ external integrating sphere, in the range $400 – 1100 \text{ nm}$ (Baldini et al. 1997, Knapp and Carter 1998). The absorptance $(A)$ were calculated from the formula $A = 1 - R - T$.

The content of the pigments in green fruits and in leaves was determined in $80 \%$ acetone, and that in mature fruits - in $100 \%$ methanol by the method of Wellburn (1994).

The measurements were made on five to ten repetitions and the results are presented as their arithmetic means with the standard deviations (SD).

Results

The thickness of the pericarp wall was $8 \pm 1.5 \text{ mm}$, and that of the leaves $0.60 \pm 0.1 \text{ mm}$. The content of the chlorophyll pigments and of the carotenoids are listed in Table 1. In the green fruits and in the leaves the content of the pigments in both cultivar was similar, hence the presented results are the mean values for both cultivar. In the green fruits the content of chlorophyll was smaller by about $40 \%$, and that of carotenoids - by about $50 \%$ in comparison with the leaves. The chlorophyll a/b ratio in the leaves was higher than in the green fruits, and the chlorophylls/carotenoids ratio was higher in the green fruits. In mature fruits the content of chlorophyll was almost equal to zero, whereas the content of carotenoids in red fruits was increased almost $14$ times, and in yellow fruits $6$ times, hence the ratio: chlorophylls/carotenoids showed very little value ($0.005$ and $0.028$).

The results of spectral measurements of the optical properties of fruits and leaves are listed in Table 1. In the range of $400 – 1100 \text{ nm}$ the optical properties of green fruits and leaves were very similar, and the differences between them were below $1 \%$. The irradiation incident on the fruit or the leaf, being reflected from the surface $(7 \%)$, is mainly absorbed $(92 \%)$ and its transmittance through the pericarp or leaf was very small $(1.2 - 1.4 \%)$. The greatest absorptance was in the range $400 – 500 \text{ nm}$ $(94 \%)$ and $600 – 700 \text{ nm}$ $(93 \%)$; it was smaller in the range $500 – 600 \text{ nm}$ $(89 \%)$. The greatest reflectance was in the range $500 – 600 \text{ nm}$ $(8.17 \%)$; in the other ranges it was somewhat smaller (about $6 \%$). Transmittance of irradiation in the range $400 - 500 \text{ nm}$ was nearly equal to zero; it was somewhat higher in the range $500 – 600 \text{ nm}$ $(3 \%)$, and in the range $600 – 700 \text{ nm}$ it amounted almost to $1 \%$. Considerable differences between the leaves and green fruits were observed in the range near IR $(700 - 1100 \text{ nm})$.

The leaves showed high reflectance $(54.9 \%)$, rather small absorptance $(5.8 \%)$, the result of which was that transmittance of this irradiation through the leaves was almost equal to $40 \%$, while in the fruits the reflectance and transmittance were only half as high as in the leaves and their absorption was equal to $55 \%$.

In the course of fruits maturing and the change of colour there take place great changes in the optical properties of the fruits. In red fruits, when compared with the green, in the PAR range the reflectance was greater $(2.7 \times)$, as well as transmittance $(5.7 \times)$, while absorptance was smaller $(15 \%)$. This was the result of great changes in the range $600 - 700 \text{ nm}$, where reflectance was increased $6$ times, transmittance - $17$ times, and absorptance was reduced by half. In the range NIR $(700 - 1100 \text{ nm})$ the changes were smaller and they referred to the increase of reflectance $(11 \%)$ and transmittance $(3 \%)$, and reduction of the absorptance of irradiation $(14 \%)$.