SPECTRAPHOTOMETRIC MODELING OF GREENHOUSE-FILM PROPERTIES

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INTRODUCTION

The development of greenhouse agriculture is a very important problem mainly for rural areas of densely populated Moldova. Construction of new greenhouses and maintenance of existing contribute to the growth of gross agricultural output, as well as improve food security, land management, helps to create additional jobs in related industries. The most important industry, which develops in parallel with greenhouse's industry, is the production of greenhouse-films. Conscientious producers of greenhouse-film would combine the high quality with reasonable price, also, stability of the film with the possibility of its recycling. Thus, the production of greenhouse-films with desired properties is an important scientific and practical problem, which has the technological, economic and environmental components [1].

1. STABILITY OF GREENHOUSE FILMS TO UV RADIATION

One of the main factors affecting the stability of polyethylene and polypropylene films is their resistance to solar radiation [2]. It is well known that X-Ray (1-10 nm) and far-ultraviolet (FUV, 10-200 nm) radiation is completely retained in the atmosphere. Nevertheless, the energy of the "near" ultraviolet (NUV, 200-400 nm) passes through the atmosphere is enough to break some chemical bonds in the polymer chain, which leads to aging of polymers, the loss of their durability and transparency [3, 4]. Methods of protecting the films from the photochemical degradation are based on the absorption, disappearance, reflection, or bathochromic shift of the shortwave radiation. Also found that in addition to the direct effects of excessive ultraviolet radiation, it increases the activity of chemical toxins of different nature, thus becoming a synergistic stress factor [5]. At the same time, plants are genetically adapted to the entire spectrum of light, reaching the Earth's surface. Based on these assumptions, we can conclude that both the presence and absence of a large quantity of ultraviolet radiation is harmful to plants, including greenhouse-plants. In addition, the ultraviolet portion of the spectrum affects the state of insect pests. Therefore, the complete absence of UV light may contribute to the accumulation of insects in greenhouses covered with films, protecting from UV radiation [6]. Thus, the problem of "right" films production has important applied aspects.

2. EXPERIMENTAL METHODS

Various samples of films (serial, advertising and trial), manufactured in 2008-2009 were studied. The electronic absorption spectra of UV-modified films were recorded by spectrophotometer "DR-5000" (*"Lange"*, USA) in the range of 190-1100 nm, with no cells, compared with air or with the corresponding film without modifying additives. Spectra of transmission were recalculated and reconstructed using *Formula 2* by means of "Microsoft Office Excel".

3. RESULTS AND DISCUSSION

3.1. Registration of spectra

For all studied films was observed very strong absorption in the range of 190-200 nm, exceeding the maximum sensitivity of the instrument (3.5 absorbance units, which corresponding of transparency lower than 0,032% (look *Formula 2*). At the wavelengths over 600 nm all of the spectra are linear. Therefore is advisable to lead the absorption and transmission spectra in the range of 200-600 nm. Qualitative spectra were obtained for films with a thickness of 75-80 microns. The spectra of films with a thickness of 100-120 microns are characterized by a large dispersion of visible radiation (appears low transparency in the ranges over 600 nm) and the presence of many spectral noise. Films with the UV-filtering additives "UV 8600" (***A***) and "UV

0007" (***B***) (*"Tosaf"*, Israel) were obtained on the extruder "Covema-120" *("Covema"*, Italy) from high-pressure polyethylene A22FMA002 (*"Aprechim"*, Romania). Both additives provide significant absorption in the range of 200-250 nm (Figure 1). Nevertheless, there are observed a substantial transparency in the form of two peaks at 265 and 310 nm even at the high concentrations (5-10%) of filtering additives in the film with a thickness of 120 microns. Greenhouse-films with the addition of ***A*** were more transparent to UV rays than film with equal percentages of additives ***B***.

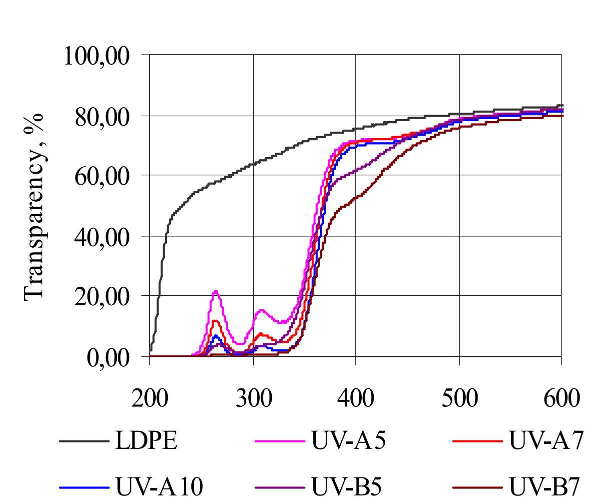

Figure 1. The transmission spectra of greenhouse-films.

Significant differences in the spectra of additives are observed near the 380-480 nm, where the ***B*** retards the light stronger, than ***A***. Interestingly, this effect is not visually noticeable on the absorption spectra (Figure 2). It should be noted that this absorption, probably, is undesirable for the plants, since it leads depletion of the short-wave part of the visible spectrum, with high-energy rays.

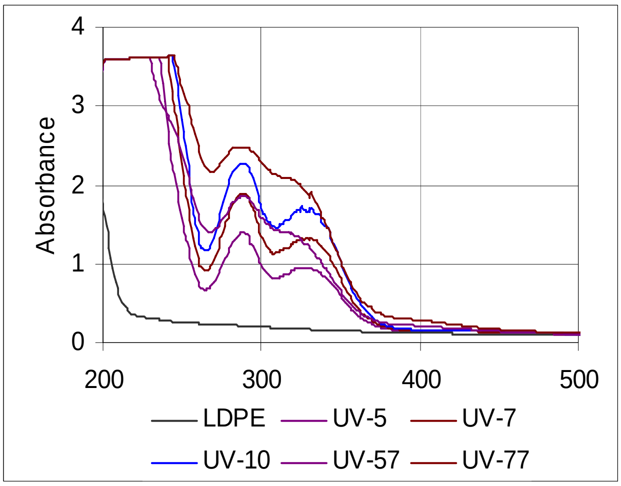

Figure 2. The absorption spectra of greenhouse films

3.2. Using spectral data for producing of films with required transparency

It is interesting problem to calculate the required doses of additives for UV filtration, without manufacturing of the film, thus reducing the costs for the production of a small test samples. This will be possible on the basis on spectra of the samples with known thickness and concentration of the filtering additives. It is advisable to use the peak of transparency (respectively, a "collapse" of the absorbance) in the ultraviolet spectrum. For the additives ***A*** and ***B*** it is 265 and 268 nm, respectively. To develop a mathematical model of the films with a given transparency, we are used the classical expressions for the calculating of absorbance (***A***, no dimension), and of the transparency (***T***, %) [7]:

$$A = \varepsilon \cdot C \cdot L \qquad (1)$$

$$T = 10^{2-A} \qquad (2)$$

$$\lg T = 2 - A \qquad (3)$$

Here: ***ε***, *%*$^{-1}$, is extinction coefficient. ***C***, *%*, is concentration of optical active substances. ***L***, *cm*, is thickness of the light absorbing stratum.

Subscript index "1" denoted by the variables ***L***, ***C*** and ***T*** for the existing film with the recorded spectrum, and the subscript index "2" for the films with desired properties. Substituting *Formula 1* to *Formula 3*, we obtain:

$$\lg T_1 = 2 - \varepsilon \cdot C_1 \cdot L_1 \qquad (4.a.)$$

$$\lg T_2 = 2 - \varepsilon \cdot C_2 \cdot L_2 \qquad (4.b.)$$

Combining, we obtain:

$$\frac{\lg T_2}{\lg T_1} = \frac{2 - \varepsilon \cdot C_2 \cdot L_2}{2 - \varepsilon \cdot C_1 \cdot L_1} \qquad (5)$$

Reducing the extinction coefficient:

$$\frac{2 - \lg T_2}{2 - \lg T_1} = \frac{C_2 \cdot L_2}{C_1 \cdot L_1} \qquad (6)$$

From the *Formula 6* we obtain *Formula 7* for calculating of the concentration of additives, required to produce the new film with the preset value of transparency, T_2:

$$C_2 = \frac{2 - \lg T_2}{2 - \lg T_1} \cdot \frac{C_1 \cdot L_1}{L_2} \quad (7)$$

Obtained results have very good convergence. For example, the calculation of the amount of additive ***A***, necessary for producing a film with thickness of 80 µм and desired transparency of 12.22%, gives 11.7, 10.5 and 10.2 percent, respectively, on the basis of spectral data for 120 micron film, with real concentrations of A, equal to 10%, 7% and 5%, respectively.

3.3. Which of these additives is more effective for the practical use?

It is interesting to find out which of the used additives is most effective. Here is shown the calculations of the amount of additives ***A*** and ***B***, which are required to produce 100-micron film with desired values of transparency, 10 and 15%:

$$C_{2,10\%}(A) = \frac{2 - \lg 10}{2 - \lg 12.22} \cdot \frac{7 \cdot 120}{100} = 9.2$$

$$C_{2,10\%}(B) = \frac{2 - \lg 10}{2 - \lg 0.69} \cdot \frac{7 \cdot 120}{100} = 3.9$$

$$C_{2,15\%}(A) = \frac{2 - \lg 15}{2 - \lg 21.33} \cdot \frac{5 \cdot 120}{100} = 7.4$$

$$C_{2,15\%}(B) = \frac{2 - \lg 15}{2 - \lg 4.06} \cdot \frac{5 \cdot 120}{100} = 3.6$$

These calculations shows that to achieve the same effect in the film must be entered in 2.1-2.4 times less additive ***B*** than additive ***A***. It is obvious that reducing the concentration of additives can compensate the previously marked absorption in the range of 380-450 nm, which is a positive factor for the quality of a light, passing through the film.

4. CONCLUSIONS

1. The optimum thickness of films used for the spectrophotometric studies, is 70-80 microns, without cells, in comparison with air;
2. To design a given film thickness and transparency it is sufficiently the presence of one film, containing the same filter additive;
3. The mathematical model allows us to replace multiple test extrusion in the production of films with a given transparency in the UV-range;
4. The additive ***B*** is 2 times more efficiently, than ***A***. Therefore, the difference in ***ε*** for these additives at 380-450 nm does not affect substantially the quality of the spectrum in the visible range, and the quality of light in the greenhouses, respectively.

Bibliography:

1. *Moldavian Tomatoes: greenhouse's and not typical. Independent Moldova, 17.05.2006.*
2. Selivanov, I. *Barrier for the ozone holes. Rural Life, 11.04.2000.*
3. Zaikov, G.E. *Degradation and Stabilization of Polymers. New York, Nova Science Publishing, 1999. – 296 p.*
4. Compan, M.E., Aksyanov, I.G. *"Narrowband luminescence of polyethylene and polytetrafluor-ethylene in the near-UV region of the spectrum". Physics of Solid Body, Vol. 51, no. 5, 2009. – p. 1024-1027.*
5. Preston, B.L., Snell, T.W., Kneisel, R. *"UV-B exposure increases acute toxicity of pentachloro-phenol and mercury to the rotifer Brachionus calyciflorus". Environmental Pollution, Vol.106, No. 1, 1999. – p. 23-31.*
6. Mutwiwa, U.N., Borgemeister, C., von Elsner, B., Tantau, H.-J. *"Effects of UV-Absorbing Plastic Films on Greenhouse Whitefly". Journal of Economic Entomology, Vol. 98, No. 4, 2005. – p. 1221-1229.*
7. *Chemical Encyclopedia in 5 volumes. Volume 1. Moscow, Soviet Encyclopedia, 1988, 623 pages. – p. 14.*

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