EFFECT OF THE IRRADIATION OF COTTON SEEDS WITH PULSES OF CONCENTRATED LIGHT ON THE COMPOSITION OF THE COTTONSEED OIL

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The presowing irradiation of cotton seeds with pulses of concentrated light (PCL) causes a change in a number of indices of the oil. When the seeds are stored, oxidative processes in them are intensified. In the oil of the harvested seeds some indices are restored.

Depending on the dose and conditions of irradiation, the radiation treatment of seeds causes various effects. High doses of ionizing radiation (UV light, x-radiation, γ-radiation, etc.) initiate complex processes in plant seeds which lead to deep biochemical changes. The lipid components of seeds undergo changes due to radiation more readily than the proteins and carbohydrates. After irradiation, oxidative, hydrolytic, decarboxylation, and polymerization processes in the lipids are intensified, a consequence of which is the formation of products which are toxic for the plant cell [1, 2].

However, the radiation treatment of the seeds of agricultural crops with small doses under appropriate conditions also has a favorable effect on the quality of the seeds: The presowing irradiation of cotton seeds with certain doses of gamma rays stimulates germination and the development of the plants, leading to increased crop yield [3]. Irradiation of the seeds of this crop with the optimum doses of pulses of concentrated light (PCL) has the same effect [4].

The influence of PCL on the composition of cottonseed oil has not been studied. We give the results of an investigation of the composition of the oil of industrial sample of seeds of the cotton plant of variety Tashkent-1 irradiated with PCL. Unirradiated seeds were used as control.

Pubescent seeds from the first reproduction and those which had been freed from fibrous residues (naked seeds) were irradiated before sowing in an apparatus developed by one of the authors of this paper. The source of light in it was xenon lamp the radiation spectrum of which is close to that of sunlight [5]. The physicochemical and chemical indices reflecting the composition of the main components of the seeds and of the oil isolated from them were determined by the usual methods. The fatty acids obtained by the hydrolysis of the oil were studied by GLC.

After irradiation, the pubescent seeds from the first reproduction (1977) were sown under field conditions in parallel with controls, and the same indices were determined for the seeds of the 1978 harvest. Pubescent and naked seeds of the second reproduction were irradiated again and were resown. Samples of the irradiated seeds and seeds of the 1979 harvest were investigated similarly. For each sample the indices were determined in duplicate or triplicate. The results are given in Table 1.

On comparing the indices of the irradiated pubescent seeds of the first reproduction with the control sample, it can be seen that after irradiation the weight of the seeds had fallen (by 6.1%) and so had the moisture content, the decrease in the moisture content of the kernels (1.6%) being greater than that of the whole seeds (0.8%). The irradiated seeds contained 1% more oil. The oil of these seeds contained a smaller amount of the biologically valuable linoleic (18:2) acid (by 3.1%), the amount of phosphatides was almost halved, the density of

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TABLE 1. Indices of the Irradiated and Control Cotton Seeds of Variety Tashkent-1

Index	Seeds of the first reproduction						1978 harvest		Seeds of second reproduction				1979 harvest	
	pubescent			naked			pubescent		pubescent		naked		pubescent	
	C*	PCL		C	PCL		C	PCL	C	PCL	C	PCL	C	PCL
		1	2		1	2								
Seeds														
Weight of 1000 seeds g	108,7	102,1	104,1	93,4	96,1	95,5	96,2	97 3	104,8	100,5	100,9	101,3	102,2	99,7
Moisture content, %	6,8	6,0	6,8	6.6	5,4	6 3	6,1	7,3	7,4	7,2	6,6	6,5	7,9	7,3
Oil content, %	20,5	21,6	20,7	23 7	23,6	23,3	18.6	18,1	18,9	20,4	24,1	23,6	20,0	20,7
Free gossypol, %	0,79	0,80	0,53	0,89	0,92	0,65	0,69	0,61	0,7	0,65	1,10	0,90	0,40	0,40
Kernel														
Moisture content, %	5,5	3,9	3,8	5,2	4,9	4,5	5,4	5,0	3,4	3,4	5,4	5,0	5,6	5,6
Oil content, %	34,2	35,1	34,7	36,5	36,3	35,9	34,0	34 1	34,1	34 1	35,6	35,8	35,3	35,2
Oil														
Density, g/cm³	0,9292	0 9143	0,9242	0,9213	0,9109	0,9137	0,9191	0,9229	0,9043	0,9312	0,8974	0,9197	0,9201	0,9130
Refractive index, n_D^{20}	1,4730	1,4720	1,4730	1,4730	1,4720	1,4745	1,4720	1,4720	1,4720	1 4740	1,4735	1,4745	1,4735	1,4735
Color at 35 yellow	21,0	25,0	24,0	21,0	20,0	24,0	21,0	21,0	20,0	18,0	19,0	18,0	12,0	12,0
Acid No., mg KOH/g	4,0	5,6	4,0	6,8	8,0	5,2	2,8	7,6	3,4	4,6	4,2	3,8	7,1	6,9
Phosphatides, %	0,56	0,32	0,45	0,51	0,47	0,48	0 47	0,37	1,41	1,40	1,56	1,19	0,45	0,6
Acids, % by GLC														
14:0	0,6	0,6	0,6	0,3	0,1	0,6	0,7	0,6	0,7	0,4	0,9	0,5	1,0	1,2
16:0	26,6	28,0	26,9	22,8	26,2	26,6	25,2	22,3	22,8	19,1	25,8	25,5	19,0	19,5
16:1	—	—	—	—	—	—	—	—	—	—	—	—	0,60	1,3
18:0	2,5	2,0	2,6	1,3	1,6	2,4	2,3	2,5	2,3	1,8	1,8	1,8	1,6	2,2
18:1	16,4	18,7	18,1	15,6	17,8	17,7	18,2	16,6	14,6	12,8	8,5	15,9	12,6	13,6
18:2	53,5	50,4	51,4	59,7	54,3	52,3	53,0	57,9	59,6	65,9	53,0	56,0	65,2	62,2
Low-molecular-weight	0,4	0,3	0,4	0,3	—	0,4	0,6	0,1	—	—	—	0,3	—	—

the oil was somewhat lower, the color was somewhat higher (by 4 units) and the acid No. was higher (by 1.6 mg KOH/g).

The fall in the weight of the seeds (taking the changed moisture content into account) with no change in oil content shows some changes in the protein fraction of the irradiated seeds, as is observed in the gamma-irradiation of cotton seeds [1]. The increase in the acid No. of the oil — which is a measure of the free fatty acids — is due to the activation of hydrolytic processes as a consequence of an intensification of lipase activity. The induction in cotton seeds irradiated with PCL of the synthesis and activity of a lipase has been reported by Azimov and Rakhimov [6].

As was to be expected, in the irradiated naked seeds the moisture content of the seeds had fallen more than the moisture content of the kernels and the weight of the seeds had increased by almost 3% (in comparison with the control). The relative content of the 18:2 acid in the oil of the naked seeds after irradiation had decreased by a greater amount than in the pubescent seeds.

Linoleic acid is the most unsaturated acid of cottonseed oil, and therefore it is the first to be involved in oxidative processes, and this is reflected on its content in the oil.

Since the amount of 18:2 acid in the naked seeds of the first reproduction after irradiation with PCL was lower than in the pubescent seeds, it must be assumed that the removal of the residual fiber from the cotton seeds, leading to some increase in the weight of the irradiated seeds, simultaneously reduces their radiation resistance.

When the irradiated seeds were stored for four months (sample 2, see Table 1), the above-mentioned indices continued to change. The decrease in the amount of a natural oxidation inhibitor — gossypol — in the stored seeds as compared with the control was particularly appreciable.

When the irradiated (and the unirradiated) seeds were stored, similar changes took place in the total lipids due to processes of autooxidation and hydrolysis. The intensity of these processes depends on the conditions of storage.

In cotton seeds with a high (more than 8%) moisture content the autooxidation of the unsaturated acids and the hydrolysis of the neutral fat take place faster, as a result of which the acid No. and the amounts of 18:2 acid and free gossypol change to a greater extent [7]. Since the storage of unirradiated seeds with a moisture content of less than 7% scarcely changes the composition of the oil, the deterioration of the indices of irradiated seeds during storage can be ascribed to the known phenomenon of the after-effect of irradiation [1].

In the pubescent seeds harvested in 1978 from seeds that had been irradiated with PCL before sowing, the seeds increased in weight in comparison with the control, but this increase was probably the result of different conditions in the vegetation period.

The conditions of the 1978 season were more favorable for the synthesis of proteins, and not fat, in the seeds than those of 1977. This can be seen from a comparison of the control seeds of the 1978 harvest with those of the first reproduction: The weight of 1000 seeds in the harvest sample from the pubescent seeds was 12.4 % smaller and their absolute oil content 2.2% smaller than in the case of the pubescent seeds of the first reproduction.

In the harvested pubescent seeds the amount of phosphatides remained low but the acid No. had not fallen in comparison with the control. The color of the oil was restored. The amount of 18:2 acid was not only restored but actually exceeded the amount of this acid in the control by 5%.

An increase in the amount of 18:2 acid was also observed in the pubescent seeds of the second reproduction after the second irradiation, but in the seeds of the 1979 harvest its amount again proved to be lower than the norm, by 3%.

The amount of phosphatides in the seeds of the second harvest had recovered.

Thus, according to the results of the investigation, the presowing irradiation of cotton seeds with PCL causes certain changes in the oil which are partially restored in the oil of the harvested seeds.

EXPERIMENTAL

The seeds were selected after the collection of the raw cotton in the 1977, 1978, and 1979 seasons from the fields of the Leinizm kolkhoz (communal farm) in the Yanglyul' region of Tashkent province. The samples were irradiated in an apparatus with the following parameters: dimension of the focal plane 2 m × 0.1 m; period of oscillations 2 sec^{-1}; optimum dose of irradiation of cotton seeds before sowing $2.8 \cdot 10^8$ erg/cm^2 – $4.3 \cdot 10^8$ erg/cm^2; density of the energy of the xenon arc tubes of the lamps (source of light) in ultraviolet region 4.3, in the visible region 1.4, and in the infrared region 9.2 times greater than the energy density of the solar radiation incident upon the reflected surface of the irradiator.

The indices were determined by standard methods [8]. Gossypol was determined in samples of seed by the p-anisidine method [8].

Gas–liquid chromatography was performed on a Khrom-4 chromatograph with a flame ionization detector using a column 2.5 m long and 4 mm in diameter filled with 17% of Reoplex 400 on Chromaton N-AW-DMCS at a column temperature of 198°C.

SUMMARY

1. The presowing irradiation of cotton seeds with PCL causes, in addition to changes in their weight and moisture content, an increase in the amount of free fatty acids in the oil, a fall in the density of the oil, and a decrease in the amounts of phosphatides and linoleic acid in it.

2. When the irradiated seeds are stored oxidation processes in the oil are intensified.

3. In the oil of harvested seeds subjected to preliminary irradiation with PCL the amount of linoleic acid is partially restored.

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