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BIOCHEMICAL COMPOSITION OF WHEAT GRAIN AS INFLUENCED BY SOME BEETLES FEEDING

I. INTRODUCTION

Biochemical investigations regarding the composition of cereal grains are usually performed to compare the composition of different varieties or even of different parts of grains (Koźmina, Krietowicz, 1953; Woźna et al. 1958; Mac Masters et al 1964).

The aim of our researches was to examine the changes may occure as a result of feeding by six species of noxious insects: *Sitophilus granarius L.*, *Sitophilus oryzae* L., *Rhizoperta dominica* F., *Tribolium confusum* Duv., *Oryzaephilus surinamensis* L., and *Trogoderma granarium* Ev., in the wheat grain. These works comprised the determiniations of content of starch, protein nitrogen, total lipids and composition of fatty acids in damaged grain, and the results were compared to undamaged grain.

In the experiments the effect of various initial number of beetles, the time of beetle feeding, as well as the influence of larval feeding were examined.

The biochemical investigations paralel to the investigations on the increase of insect population, and intensity of feeding by various species, as well as on the germination of damaged grain were performed. The results of these investigations are presented by Gołębiowska et al. (1976).

II. METHODS

To 100 g of wheat grain of known moisture level were introduced: 50, 100, 200 or 400 beetles of one age for a period of 10 or 20 days. The experiments were conducted in six replications, at 25°C, and relative air humidity of 75%. The control constituted the grain kept in the same conditions, without beetles. After feeding period the beetles were removed, and the dust formed, as well as the grain, and the beetle feeding intensity

was calculated. Then biochemical determinations were made such as: dry matter, starch, total nitrogen and fat content, as well as the fatty acids composition.

The grain dry matter was determined using the weighing method (Brzeski, Kaniuga, 1957). The starch content by polarimatric method, in which the polarisation angle has been determined through the starch solution in concentrated hydrochloric acid (Lintner, Belshner 1950). The total nitrogen equalling to the protein nitrogen was determined by Kjeldahl's technique modified by Neurath and Bayley (1953). The total fat content was determined using the nuclear magnetic resonance on NMR quantity analyser of New Port Instrument Ltd. Fatty acids composition was tested using the gas-chromatography technique (James, 1960, Byczyńska and Krzymański, 1969).

Parameters of chromatographic analysis: Chromatograph apparatus: PYE 104; detector: flame-ionization;
oven temperature 215°C; detector temperature 280°C;
column: 1,5 m with DEGS — 15% on Chromosorb W — 100 120 mesh;
carrier gas: nitrogen — 40 ml/min; Hydrogen: 45 ml/min;
air: 60 ml/min; time of analysis: about 20 min.

The quantitative evaluation of chromatograms was based upon the area enclosed under the peaks (Jakubowski, 1968).

The results were calculated as per cent of each component related to the total fatty acids.

III. RESULTS AND DISCUSSION

1. Influence of *S. granarius* feeding on chemical composition of wheat grain

Material for biochemical analyses proceeded from the experiments in which feeding intensity of insect was investigated. In the first period of researches the influence of *S. granarius* feeding on starch, total protein and total lipid content in healthy and damage grain was compared. Moreover, composition of fatty acids was investigated. In the Table 1 data concerning the content of investigated compounds in undamaged grain, and the differences stated in damages grain expressed in the percent in relation to the control are presented. The differences are marked with the sign „+" in the case of increase of the content of a given compound, and with the sign „—" in the case of its decrease.

The differences in the content of investigated compounds were not high, but they distinctly show the tendency, and the direction of changes

Table 1

Biochemical changes in wheat grain after the feeding of *S. granarius* beetles

Days of feeding	Determined compounds	Content in %	Per cent of changes in relation to the control			
			initial number of beetles			
		0 = control	50	100	200	400
10	Starch	69,9	+0,21	−3,93	−5,51	−5,18
	Protein	13,0	−0,84	+14,13	+14,29	+12,98
	Lipid	2,5	+4,80	+4,00	+7,20	+11,20
20	Starch	68,3	−1,76	−0,18	−4,87	−6,47
	Protein	14,7	−1,84	−0,41	+0,34	+2,31
	Lipid	2,2	+2,27	+6,82	+7,73	+12,73
	Composition of fatty acids:					
	Palmitic	18,4	0,00	+1,09	−5,98	−4,89
	Oleic	18,4	+1,63	−16,30	−14,67	−20,11
	Linoleic	57,3	−2,79	+3,66	+6,28	+8,38
	Linolenic	3,4	−5,88	+2,94	−14,71	+2,94

caused by beetles feeding. The decrease of starch content, and the increase of protein and lipid content were observed. Some influence of intensity of beetles feeding on the changes of grain composition has been stated, no interdependence however between the duration of period of beetles feeding and biochemical changes in the grain has been found. On the ground of analyses of fatty acids in the lipids of grain it can be stated that palnitic, oleic and linoleic acids are the dominant compounds. Linolenic acid occurs in considerably lower amount.

In further experiments the feeding of larvae was taken into account, which made possible to compare the differences occured after the feeding of beetles only and, after the feeding of beetles and larvae, hatched from the eggs laid by these beetles during 10 or 20 days of inhabiting in the grain. The results are presented in Table 2. Comparing such data with the data presented in the Table 1 it can be seen that the differences in the composition of undamaged and damaged grain are considerably higher. The influence of initial number of beetles used for the experiment was also visible. After the feeding of 50 and 100 beetles in 100 g of wheat grain the changes in its composition are not so important. However 200 and 400 beetles caused significant differences, especially in starch content, which considerably decreased. In both cases increase of total protein content is also distinct. The changes in lipid content are of various character, for example after 20 days of feeding of beetles and their progeny the decrease of content of the compound is exceptionally observed.

Table 2

Influence of feeding of beetles and larvae of *S. granarius* on chemical composition of wheat grain

Days of feeding	Determined compounds	Content in %	Per cent of changes in relation to the control			
		Initial number of beetles				
		0 = control	50	100	200	400
10	Starch	68,4	+2,62	−1,26	−15,09	−18,17
	Protein	12,6	+3,09	+11,32	+28,11	+30,48
	Lipid	2,5	−9,68	+2,02	+27,02	+26,21
	Composition of fatty acids:					
	Palmitic	21,7	−3,69	−12,90	−21,66	−17,51
	Oleic	20,9	−10,09	−17,70	−22,49	−20,10
	Linoleic	48,0	+9,17	+29,38	+32,92	+32,71
	Linolenic	2,8	−7,14	+64,29	+42,85	+50,00
20	Starch	61,8	−6,58	−12,28	−26,51	−11,24
	Protein	12,7	+15,28	+26,54	+48,82	+31,65
	Lipid	3,0	−20,93	−23,59	−27,57	−28,57
	Composition of fatty acids:					
	Palmitic	22,0	−0,91	−8,18	−21,36	−29,09
	Oleic	21,8	−12,84	−18,35	−33,03	−35,78
	Linoleic	49,6	+2,82	+12,70	+28,43	+27,62
	Linolenic	2,3	+30,43	+30,43	+60,87	+104,35

Both, after the feeding of beetles only, and of beetles and larvae, similar changes in the composition of fatty acids have been stated. Considerable decrease in content of palmitic and oleic acids, and the increase in content of linoleic and linolenic acids occured.

On the ground of obtained results it can be concluded that:

1. after investigated period of feeding the damages caused by the beetles are lower than the damages occurring, when in the grain larvae feed and develop,
2. beetles and larvae fed mainly on the part of grain rich in the strach,
3. increase in content of total protein and lipids is not only by the decline of starch, but in certain degree also by the contamination of grain with the eggs, larvae, and insect excrements.

Considering the results from the point of view of intensity of changes according to the initial number of beetles it can be seen, that these changes in relation to the control are not directly proportional to the degree of infestation. The samples can be devided into two groups: 1) infestation by 50 and 100 beetles, and 2) infestation by 200 and 400 beetles. Sometimes however, even when initial number of beetles was 200 more distinct

changes occurred, than when such number was 400. It can be explained by the results of investigations upon the feeding intensity of beetles which demonstrated, that in the case of higher population density, the quantity of food eaten by one specimene was lower (Gołębiowska et al., 1976).

In order to obtain more detailed data on the noxiousness of beetles and larvae of *S. granarius*, experiment was made with high number of beetles: 4000 in 2 kg of wheat grain. This grain was investigated after 3 days, when the feeding of larvae could not take place. One part of grain was left till the emergence of next generation, and it was analysed according to the number of emerged beetles. The results are presented in the Table 3.

Table 3

Biochemical changes occurring in wheat grain after 3 days of feeding of 4000 beetles of *S. granarius* in 2 kg grain, and after the feeding of larvae of next generation

Determined compound	Content in control in %	Changes after beetles feeding	Changes after larvae feeding				
			Number of emerged beetles — next generation				
			19	45	65	140	190
Starch	66,6	−0,71	−0,38	−3,47	−3,75	−4,97	−6,59
Protein	14,8	−4,04	−2,09	−2,69	−2,09	−1,28	+0,47
Lipid	2,4	−2,88	+2,89	0,00	−3,70	+0,82	+1,23
Composition of fatty acids:							
Palmitic	18,9	−1,58	−4,91	−1,74	−5,44	−0,69	−4,65
Oleic	11,8	+0,93	+1,87	−3,23	+0,17	−1,53	−6,62
Linoleic	65,8	−1,20	−0,43	−0,42	+0,12	−0,18	−0,27
Linolenic	3,8	+23,22	+18,73	+13,46	+13,46	+5,54	+24,01

The data obtained show, that short, lasting 3 days beetle's feeding in large mass of grain did not cause the changes in its composition even-after the feeding of larvae during their whole development.

In order to supplement the data concerning the changes occurring as the results of grain damaging by *S. granarius* analysis of the composition of dust, formed by the pest, has been made. It has been stated, that dust composition significantly differs from grain composition. The content of starch reached only 36,9%, the nitrogen however, converted to total protein amounted to 54,5%, and lipid content was similar as in the grain 2,6%. These data confirm the suggestion that the beetles and larvae of *S. granarius* need the starch, the fundamental compound of wheat grain. Very high content of total nitrogen in dust shows also the contamination

with animal protein. Baker (1974) in his investigations on the quantity of food eaten by the larvae (on artificial diet) demonstrated, that in the excrements, important quantity of uric acid occurs. Comparative investigations of amino acids composition in healthy grain, as well as after the feeding of 400 beetles in 100 g of wheat grain during 7 days were carried out, using automatic analyser of amino acids (Phoenix USA, model K--500A). Results presented in the Table 4 show the occurrence of some

Table 4

Amino acid composition in the wheat grain: control sample, and after 7 days of feeding of *S. granarius* beetles (400 in 100 g)

Amino acid	Control sample % in relation to the total	Sample after beetle's feeding % to the total	Difference % in relation to the control
Alanine	4,36	3,89	−11,01
Arginine	4,61	4,75	
Aspartic acid	6,54	5,82	−11,16
Cysteine	1,64	0,69	−57,93
Phenylalanine	4,98	5,15	
Glicine	4,14	4,47	
Glutamic acid	30,40	31,09	+2,27
Histidine	2,33	2,55	
Isoleucine	3,70	3,82	
Leucine	7,10	7,45	
Lysine	2,99	3,14	+5,02
Methionine	2,04*	1,29*	−36,76
Proline	10,04	11,56	+15,14
Serine	4,63	3,93	+15,12
Threonine	3,00	3,14	
Thyrosine	2,99	2,44	+18,39
Valine	4,51	4,81	
Total	100,00	99,99	

*) methionone + methionione sulphoxide

differences in the composition of undamaged grain, and of the grain damaged by the beetles. Highest differences were stated in cysteine and methionine content. The content of these amino acids in damaged grain was lower by 57,9% and 36,8% respectively. The content of lysine, deciding on nutritive value of the grain, was about 5% higher.

In order to draw general conclusions, the results obtained in all experiments with initial number of 200 beetles in 100 g of grain, as a most

favourable population density for pest feeding and development, in the Table 5 are presented.

It can be seen from the data, that the feeding of beetles, regardless the time of their exposition, in slight degree influenced biochemical grain composition, however the feeding of larvae was of considerably higher

Table 5

Influence of *S. granarius* beetles feeding and larvae of further generation on biochemical composition of wheat grain

Determined compound	Per cent of changes in relation to the control			
	Beetles		Beetles + larvae	
	10 days	20 days	10 days	20 days
Starch	−5,51	−4,87	−15,09	−26,51
Protein	+14,29	+0,34	+28,11	+48,82
Lipid	+7,20	+7,73	+27,02	+27,57
Composition of fatty acid				
Palmitic		+5,98	−21,66	−21,36
Oleic		−14,67	−22,49	−33,03
Linoleic		+6,28	+32,92	+28,43
Linolenic		−14,71	+42,85	+60,87

importance. Undoubtedly, if the beetles would feed on the grain for a longer time, the changes in grain composition would be significantly more distinct.

2. Influence of *S. oryzae* feeding on chemical grain composition

The influence of feeding of *S. oryzae* beetles on biochemical grain composition was investigated in some experiments, using for this purpose the materials obtained in the researches upon feeding intensity (Gołębiowska et al., 1976). In first experiment the differences occurring as the effect of beetle feeding in rye and wheat grain during 10 days were compared. The results are presented in the Table 6. As it can be seen, beetle feeding in considerably higher degrre caused the changes in biochemical composition of wheat than of rye grain. The course of changes in the content of investigated compounds in wheat grain is similar to that, which was observed after feeding of *S. granarius* beetles. The decrease of starch content has been observed, and the increas in content of total protein and lipids, especially after the feeding of most numerous beetle population.

Table 6

Influence of *S. oryzae* beetles feeding during 10 days on biochemical composition of rye and wheat grain

Kind of cereal	Determined compound	Content in %	Per cent of changes in relation to the control			
		Initial number of beetles				
		0 = control	50	100	200	400
Rye	Starch	59,4	−2,86	+1,45	+2,95	+2,14
	Protein	8,1	−1,99	+1,49	+2,61	+11,04
	Lipid	2,3	−23,68	−0,89	−3,51	+4,39
Wheat	Starch	66,0	+1,39	−4,65	+0,41	−11,09
	Protein	14,0	+1,57	+0,72	+2,93	+8,45
	Lipid	2,4	−3,40	−3,40	+2,98	+20,43
	Composition of fatty acids:					
	Palmitic	24,8	−24,60	−30,24	−33,87	−33,47
	Oleic	24,6	−28,86	−38,21	−39,02	−39,43
	Linoleic	41,7	+37,65	+48,20	+48,21	+46,04
	Linolenic	5,0	−32,00	−38,00	−24,00	−22,00

In rye grain the differences in starch content remain in the limits of analytical error, simultaneous increase of total protein content, and certain increase in lipid content after the feeding of 400 beetles in 100 g of grain, however, lead us to suppose, that in this case the contamination with animal fats took place, in all probability originating from the larvae developing inside tha grain.

In futher investigations the feeding of beetles during 10 days, and then of the larvae developing from the eggs laid by them has been taken into account. The results are presented in the Table 7. It has been stated, that in this case the decrease of starch content, and the increase in protein and lipid content occurred. The differences in content of these compounds are higher when initial number of feeding beetles was higher too. The duration of feeding period also influences the values of changes occurring in grain composition. It can be explained as follows: these beetles laid more eggs, so the number of feeding larvae higher. In general, it has been stated, that dependence of intensity of changes occurring on initial beetle number took place in the case of both *Sitophilus species*. It appeard also in both cases, that feeding of larvae inside the grain causes more considerable changes in grain composition than beetles feeding of short duration.

Table 7

Influence of feeding of *S. oryzae* beetles, and larvae of further generation on biochemical composition of wheat grain

Period of beetles feeding (days)	Determined compound	Content in %	Per cent of changes in relation to the control			
		Initial number of beetles				
		0 = control	50	100	200	400
10	Starch	88,3	+0,45	−1,56	−8,17	−9,50
	Protein	13,6	+5,30	+9,28	+11,34	+17,53
	Lipid	2,6	+1,90	+3,42	+8,00	+3,80
	Composition of fatty acids:					
	Palmitic	17,9	+1,00	+0,89	+3,68	+2,51
	Oleic	11,9	+2,94	+2,69	+5,21	+4,87
	Linoleic	65,7	+0,06	−0,62	−1,69	−1,13
	Linolenic	4,4	−12,44	−2,26	−3,85	−7,24
20	Starch	68,4	+1,51	+0,22	−3,79	−9,94
	Protein	12,5	−0,96	+0,56	+7,82	+18,44
	Lipid	2,8	+4,36	+0,36	+9,09	+6,55
	Composition of fatty acids:					
	Palmitic	15,5	−1,16	+2,78	−0,58	−0,58
	Oleic	15,5	−1,03	−0,45	+5,94	+3,36
	Linoleic	60,7	+2,09	+2,67	+2,57	+2,06
	Linolenic	5,3	−14,83	−8,37	−14,45	−19,20

The results of analysis of dust, formed during the feeding of *S. oryzae* beetles is presented in the Table 8, and these data have been compared with those obtained in the experiments on *S. granarius*. As it can be seen, the results are similar. Analysing the composition of dust, considerably lower starch content than in the grain, and very high content of total nitrogen, have been stated. On the ground of these data it can be

Table 8

Biochemical composition of dust formed after feeding of *S. oryzae* and *S. granarius* beetles and larvae

Determined compound	S. granarius		S. oryzae	
	Beetles	Larvae	Beetles	Larvae
Starch	37,0	14,5	37,0	16,8
Protein	54,5	56,1	44,6	42,4
Lipid	3,6	2,4	2,2	0,7

concluded, that both species assimilate mainly the starch, essential compound of grain.

Irabagon (1959) stated, that the feeding of *S. oryzae* in maize grain caused the increase in protein content in accordance with the increase of grain infestation. Pingale, Rao and Swaminathan (1954) inform however, that the feeding of beetles in wheat grain causes the increase in lipid acidity, and the decrease in thiamine content, but it does not change the content of other compounds, as total nitrogen, and reducing sugars.

3. Influence of feeding of *R. dominica* on chemical composition of wheat grain

For the investigation on chemical composition of wheat grain after the feeding of *R. dominica* beetles, the grain from the experiments on the influence of population density on feeding intensity was used. The results of two experiments carried out in various periods were similar, so in the Table 9 average data are presented. It has been stated in all repli-

Table 9

Influence on changes of biochemical composition of wheat grain after 10 and 20 days of feeding of *R. dominica* beetles

Days of grain exposition	Determined compound	Content in %	Per cent in relation to the control			
		Initial number of beetles				
		0 = control	50	100	200	400
10	Starch	70,4	−2,86	−4,08	−4,21	−4,85
	Protein	12,8	−1,52	−1,27	−1,48	−1,14
	Lipid	3,0	−0,28	−3,02	−1,79	−0,12
	Composition of fatty acids:					
	Palmitic	13,8	+1,84	+7,14	+3,15	+6,09
	Oleic	12,4	+5,73	+0,45	+0,82	+1,87
	Linoleic	68,5	−1,15	+1,80	−1,06	+0,37
	Linolenic	4,6	+11,52	−10,22	−18,89	−4,55
20	Starch	70,9	−2,21	−6,92	−6,73	−3,91
	Protein	13,9	+0,64	+0,80	+1,83	+2,02
	Lipid	3,0	−14,36	−17,15	−20,23	−17,48
	Composition of fatty acids:					
	Palmitic	15,2	−0,56	+4,52	+1,62	+10,37
	Oleic	13,8	+0,30	+2,26	+2,56	+7,24
	Linoleic	66,0	−0,54	−1,43	−1,98	−4,28
	Linolenic	3,9	+16,78	−7,63	+5,27	+8,88

cations, that beetle feeding caused the decrease in starch content from 2,2 to 6,9% in average. No exact dependence of such decrease from the duration of period of beetles feeding can be seen. The influence of initial number of beetles has been more distinct, but not in all experiments in the same degree. No essential changes in protein content have been stated, because the differences observed were variable, and they were contained in the limit of error. The decrease in lipid content is considerably higher after 20 days of insect feeding than after 10 days, howewer only insignificant changes in the fatty acids composition have been observed. The content of palmitic and oleic acids increased, especially after most dense population feeding. In some experiments decrease in linolenic acid content have been observed.

The results of analysis of chemical composition of dust formed after the feeding of beetles and larvae are presented in the Table 10. Starch

Table 10

Biochemical composition of dust formed after feeding of *R. dominica* beetles and larvae

Determined compound	Beetles	Larvae
Starch	54,4	59,5
Protein	19,6	15,0
Lipid	2,8	2,4

content in the dust is considerably lower than in the grain, what proves that both, the beetles and larvae assimilate high quantity of this compound. The content of total nitrogen, however, considerably exceeds in wheat grain, it can be explained by the presence of animal protein in the dust.

4. Influence of feeding of *T. confusum* on chemical composition of wheat grain

Experiments consisted researches on the changes occurring in whole wheat grain as the result of beetles feeding during 10 or 20 days, next after beetles feeding during 10 days in crumbled grain, and after the feeding of beetles and their progeny during the whole development in crumbled grain, and also of researches on the changes caused by larvae feeding considering the groups of larvae according to their size (small, middle, and big) during 10 or 20 days. The results are presented in the Tables 11, 12 and 13.

Table 11

Changes in composition of wheat grain after 10 and 20 days of feeding of *T. confusum* beetles in whole grain

Time of grain exposition (days)	Determined compound	Content in %	Per cent of changes in relation to the control			
			Initial number of beetles			
		0 = control	50	100	200	400
10	Starch	72,9	−3,73	−5,61	−5,38	−6,35
	Protein	13,0	−4,02	−3,40	−5,41	−2,01
	Lipid	2,8	+3,57	+1,07	+4,64	+1,07
	Composition of fatty acids:					
	Palmitic	18,9	−11,11	−7,41	−10,05	−7,42
	Oleic	12,6	+2,36	−0,79	−0,80	−0,78
	Linoleic	62,9	+2,23	+2,54	−3,34	+1,43
	Linolenic	4,5	0,00	−11,11	−11,11	−33,33
20	Starch	72,9	−2,33	−1,34	−1,04	−1,10
	Protein	13,0	+0,85	+3,01	+0,31	−0,39
	Lipid	2,8	0,00	−3,57	0,00	0,00
	Composition of fatty acids:					
	Palmitic	17,0	+4,71	+5,88	0,00	+5,88
	Oleic	12,5	+3,20	+8,00	0,00	−4,00
	Linoleic	65,1	−0,15	−0,15	−0,15	+1,38
	Linolenic	4,5	−6,67	−11,11	−22,22	−11,11

In the experiments in which the beetles fed during 10 days the differences in starch content, in relation to the control, for the combinations with 400 and 200 beetles have been stated. In the experiment lasting 20 days, however, the differences in starch content occurred in all combinations. Comparing these data to the number of progeny for separate groups of insects it can be seen, that in the experiment lasting 10 days the number of progeny in the combinations with 50 and 100 beetles was lower in relation to initial beetle number amounting to 200 and 400. In the experiment lasting 20 days, however, the number of progeny in all combinations was almost the same, regardless initial beetles number. The changes in grain composition are in this case the result of considerably higher number of feeding specimes of second generation. In both experiments the increase in protein content, and certain decrease in lipid content have been stated. The changes of composition of fatty acids, expressed by the decrease in content of linoleic and linolenic acids were also observed.

Earlier described experiments on the distribution of damages on the grain even during first period of insect feeding, and the results of experiments on the germination capacity of wheat grain show, that *T. con-*

Table 12

Changes in composition of wheat grain after 10 and 20 days of feeding of *T. confusum* beetles in crumbled grain

Time of grain exposition (days)	Determined compound	Content in %	Per cent of changes in relation to the control			
		Initial number of beetles				
		0 = control	50	100	200	400
10	Starch	66,4	−0,95	0,00	−3,46	−1,34
	Protein	13,7	1,75	+0,66	+1,24	+1,97
	Lipid	2,7	−10,00	−5,56	−2,59	−6,30
	Composition of fatty acids:					
	Palmitic	17,1	+0,64	−4,10	−4,98	+1,70
	Oleic	13,7	+4,24	+4,16	+3,87	+0,29
	Linoleic	63,7	+0,57	+1,08	+1,74	+0,09
	Linolenic	4,6	−22,61	−20,00	−20,21	−14,35
20	Starch	65,2	+9,18	+7,27	+7,08	+9,86
	Protein	13,2	−4,24	−4,08	−4,61	−4,99
	Lipid	2,5	−18,37	−23,27	−20,41	−21,63
	Composition of fatty acids:					
	Palmitic	19,0	−14,45	−5,27	−1,85	+3,38
	Oleic	16,8	−25,94	−1,55	+31,25	+19,62
	Linoleic	60,0	+10,14	+2,15	−8,99	−7,05
	Linolenic	3,0	+45,21	+12,21	+10,23	+8,25

fusum beetles feed mainly on the part of grain near to the germ. (Gołębiowska et alt., 1976).

The results of researches on the influence of feeding of *T. confusum* larvae differ from those obtained after the feeding of beetles and larvae. No essential changes in the content of starch, protein and total lipid in dry matter, as well as, in the composition of fatty acids have been stated. It is interesting, because after the feeding of both, beetles and larvae of this species, considerable changes in the proportions between separate compounds have been observed. It can be conclude, that the feeding of larvae in crumbled grain causes uniform decrease in all compounds without any choice, whereas the beetles choose the germ and its environment for their feeding. Larvae need more starch, which is proved by lower content of this compound in the dust formed by the larvae than in the dust formed by the beetles.

5. Infuence *O. surinamensis* feeding on chemical composition of wheat grain

Investigation on the influence of beetles feeding on grain composition were carried out similarly to those described above. As the food only crushed wheat grain was used. The beetles were kept in the food during

Table 13

Changes in composition of wheat grain after 10 and 20 days of feeding of *T. confusum* larvae in crumbled grain

Time of grain exposition (days)	Determined compound	Content in %	Per cent of changes in relation to the control		
			Size of larvae		
		Control	Small	Middle	Big
10	Starch	69,1	−1,42	−3,13	−3,42
	Protein	14,1	−1,78	−1,49	−0,36
	Lipid	3,1	−6,39	−0,32	−8,95
	Composition of fatty acids:				
	Palmitic	15,2	+3,95	+1,97	+1,32
	Oleic	15,8	−4,43	−5,06	−2,53
	Linoleic	65,5	−0,61	−0,31	−0,46
	Linolenic	4,5	−13,33	−11,11	−17,78
20	Starch	65,7	−0,11	−0,40	+0,21
	Protein	14,7	−2,46	−2,94	−2,25
	Lipid	2,8	0,00	+4,64	0,00
	Composition of fatty acids:				
	Palmitic	16,8	+4,76	+6,43	−3,22
	Oleic	15,5	+6,27	+6,20	+2,58
	Linoleic	60,7	−1,17	−1,61	+0,77
	Linolenic	5,3	−18,06	−16,16	−3,04

10 or 20 days, and then the grain was left till emergence of progeny (Table 14).

After the feeding of beetles during 10 days changes in the content of protein and total lipid did not occur, only starch content decrease by 4,83% in the combination with 400 beetles, in relation to the control. Results of experiment after 20 days of beetles feeding, and their progeny feeding differ from above mentioned. Considerable decrease in content of total lipid (by about 20%) and decrease in starch content by 3% is observed in the combination with 400 beetles. Together with quantitative changes in the content of total lipid, also changes in composition of fatty acids were observed. Whereas in control samples linoleic acid makes 65,6%, in the grain damaged by 50, 100, 200, and 400, beetles this per cent amounts 64,6; 63,3; 63,0; and 61,5% respectively. The increase of protein content was connected with the number of feeding beetles. Additional experiment with 400 beetles kept in undamaged wheat grain during 20 days was made (Table 15). In this case changes were not so distinct, but their course was the same as in previous experiments, i.e. decrease in starch, lipid, and even in total protein content occurred.

Table 14

Changes in composition of wheat grain after 10 and 20 days of feeding of *O. surinamensis* beetles in crushed grain

Time of grain exposition (days)	Determined compound	Content in %	Per cent of changes in relation to the control			
		Initial number of beetles				
		0 = control	50	100	200	400
10	Starch	66,3	−0,92	−2,37	−4,66	−4,83
	Protein	15,4	+2,08	+3,12	+1,63	+3,25
	Lipid	2,8	−6,47	−8,27	−12,59	−11,15
	Composition of fatty acids:					
	Palmitic	13,7	−0,80	+2,26	+4,60	−0,22
	Oleic	12,33	+31,22	+52,55	+34,23	+41,93
	Linoleic	65,6	−3,59	−6,25	−4,04	−1,61
	Linolenic	8,3	−16,47	−32,33	−26,44	−48,92
20	Starch	67,1	−0,22	−0,22	−1,10	−3,24
	Protein	13,5	+4,00	+7,49	−11,79	+17,20
	Lipid	3,4	−16,96	−19,64	−18,45	−22,23
	Composition of fatty acids:					
	Palmitic	15,0	+1,47	−5,40	−6,80	−6,40
	Oleic	15,0	+8,27	+18,41	+24,15	+24,82
	Linoleic	65,5	−0,93	−2,59	−4,21	−3,75
	Linolenic	4,5	−18,89	−5,33	+3,56	−6,89

Table 15

Changes in composition of wheat grain after 20 days of feeding of *O. surinamensis* beetles in whole grain

Determined compound	Content in % Control	Per cent of changes in relation to the control
		Initial number of beetles = 400
Starch	68,0	−1,69
Protein	13,4	+1,19
Lipid	3,3	−2,73
Composition of fatty acids:		
Palmitic	15,0	−12,14
Oleic	15,0	+0,40
Linoleic	65,5	+1,92
Linolenic	4,5	+11,11

6. Influence of *T. granarium* larvae feeding on chemical composition of wheat grain

Investigations on the influence of feeding of *T. granarium* larvae on composition of wheat grain were carried out in two experiments, using larvae of various sizes. Larvae have been divided into 3 groups: small, middle, and big regardless the number of moults. The feeding of larvae lasted 10 or 20 days, After 20 days of exposition it has been stated that about 16% of larvae terminated their development and pupated. (Gołębiowska et al. 1976). The results of analyses are presented in the Table 16. After

Table 16

Changes in composition of wheat grain after 10 and 20 days of feeding of *T. granarium* larvae

Time of grain exposition (days)	Determined compound	Content in % Control	Per cent of changes in relation to the control		
			Small	Middle	Big
10	Starch	68,5	−12,90	−9,42	−13,19
	Protein	13,0	+2,53	+3,30	+1,15
	Lipid	2,7	−6,30	−3,70	−3,70
	Composition of fatty acids:				
	Palmitic	16,8	−4,29	+0,24	−3,57
	Oleic	14,3	−6,62	−5,23	−6,42
	Linoleic	63,2	+2,42	+0,59	+1,66
	Linolenic	4,7	+3,87	+5,59	−0,43
20	Starch	64,3	+1,45	+1,65	+2,01
	Protein	11,3	+3,64	+2,84	+0,89
	Lipid	2,6	−7,75	−4,26	−0,78
	Composition of fatty acids:				
	Palmitic	16,9	−4,43	−0,71	+0,83
	Oleic	14,0	+6,85	+9,49	+10,78
	Linoleic	63,5	+0,88	−0,90	−0,79
	Linolenic	4,6	−10,61	−14,29	−14,94

10 days the decline in starch and lipid content and insignificant decrease in content of total protein have been stated. After 20 days, however, when a part of larvae just pupated, only decrease in lipid content has been observed, and this decrease was always higher in the case of younger larvae than in the case of the oldest ones.

The changes in the composition of fatty acids were of various charac-

ter. It depended from that if larvae had fed uniformly on whole surface of grain or on the germ only.

Analyses of dust composition formed by larvae show significantly lower content of starch (28,7%) than in the grain, two times higher content of total nitrogen (25,7%), and almost the same content of lipid (2,1%).

IV. CONCLUSION

Investigations upon the influence of beetle feeding on wheat grain composition demonstrated the decrease of starch content in the case of all investigated species. This decrease was in general higher after the feeding of larvae during their whole development than after beetles feeding.

Beetles and larvae feeding of both *Sitophilus* species, as well, as feeding of *T. confusum* and *T. granarium* larvae caused the increase in total protein content. However larvae of *O. surinamensis, T. confusum* and *T. granarium,* feeding caused decrease of lipid content.

In the composition of fatty acids after feeding of *Sitophilus* spp. the decrease in content of palmitic and oleic acids, as well as the increase in content of linoleic and linolenic acids have been observed. On the contrary, after the feeding of *R. dominica, T. confusum,* and *T. granarium* insignificant increase in linolenic acid content has been stated.

Analysis of dust formed by beetles and larvae of all investigated species has showed considerably lower starch content and higher content of total nitrogen. Obtained data show, that investigated beetle species use during the feeding first of all the starch. Moreover, all species, except of *Sitophilus* damage the germ, which is manifested by the decline of total lipid content.

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ИЗМЕНЕНИЯ БИОХИМИЧЕСКОГО СОСТАВА ЗЕРНА ПШЕНИЦЫ ВЫЗВАННЫЕ АМБАРНЫМИ ВРЕДИТЕЛЯМИ

РЕЗЮМЕ

Происследовано влияние питания шести видов амбарных вредителей: *Sitophilus granarius* L., *Sitophilus oryzae* L., *Rhizopertha dominica* F., *Tribolium confusum* Duv., *Oryzaephilus surinamensis* L. и *Trogoderma granarium* Ev.

Для определения изменений какие вызывает питание выше перечисленных вредителей в зерно пшеницы обозначено содержание крахмала, общего белка, липидов а также состав жировых кислот в здоровом зерне и пораженном. В опытах учитывано разное начальное количество жуков (0, 50, 100, 200 и 400 жуков в 100 г зерна) как и длину периода питания (10 или 20 дней). Сравнивано тоже влияние питания жуков и личинок.

Обнаружено разницы между эффектом питания жуков и личинок, а также влияние величины популяции вредителей. Наблюдано тоже разницы возникающие под влиянием питания жуков и личинок.

Jadwiga Krzymańska, Zofia Gołębiowska

ZMIANY SKŁADU BIOCHEMICZNEGO ZIARNA PSZENICY WYWOŁANE ŻEROWANIEM SZKODNIKÓW MAGAZYNOWYCH

STRESZCZENIE

Przebadano wpływ żerowania sześciu gatunków owadów należących do szkodników magazynowych: *Sitophilus granarius* L.; *Sitophilus oryzae* L.; *Rhizoperta dominica* F.; *Tribolium confusum* Duv.; *Oryzaephilus surinamensis* L. i *Trogoderma granarium* Ev.

Dla określenia zmian jakie powoduje żerowanie wyżej wymienionych szkodników w ziarnie pszenicy wykonywano oznaczenia zawartości skrobi, białka ogólnego, lipidów oraz składu kwasów tłuszczowych w ziarnie zdrowym i porażonym. W doświadczeniach uwzględniono różną początkową ilość chrząszczy (0, 50, 100, 200 i 400 chrząszczy w 100 g ziarna) jak również długość okresu żerowania (10 lub 20 dni). Porównywano też wpływ żerowania chrząszczy i larw.

Stwierdzono różnice pomiędzy skutkami żerowania różnych gatunków, a także wpływ wielkości populacji szkodników. Obserwowano również różnice zachodzące pod wpływem żerowania chrząszczy i larw.