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The influence of compost on carbohydrates and minerals content in the mushrooms (*Agaricus bisporus*)

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Abstract

A study of the effect of different composts: horse manure and broiler chicken manure and the influence of flushes during the growing cycle on the carbohydrates and mineral composition of mushrooms (*Agaricus bisporus*) was carried out. In this study the strain Somycel 11 was used. It was found that mannitol, glucose and fructose contents in mushrooms growing on broiler chicken manure were significantly higher than on horse manure. Noticeable differences of macro- and microelement contents were observed, depending on the size of the fruit-body, flushes and type of compost. Phosphorus content in mushroom tissue of the first three flushes growing on horse manure was 2.7 times higher than in those from broiler chicken manure. Boron level in mushrooms in all flushes growing on broiler chicken manure was four times higher as compared with that on horse manure.

INTRODUCTION

It is possible to increase mushroom production by using other than the typical horse manure growing substrates, such as straw and broiler chicken manure. The influence of the two different growing substrates on the quality of mushrooms is important from the nutritional point of view. Carbohydrates and mineral composition are two of such quality markers. Several workers have reported the levels of soluble carbohydrates in the sporophore of *Agaricus bisporus* and speculated on their function (Hughes et al., 1958; Rast, 1965; Holtz, 1971).

Mannitol occurs in *Agaricus bisporus* in large quantities, while the disaccharide — trehalose is present at lower levels. According to investigations of Hammond and Nichols (1976), mannitol accumulated in the mushroom tissue during growth, rising from approximately 30 to 50% dry weight. The level of mannitol accumulated in the sporophores throughout development is approximately eight times greater than that in the mycelium. Since mannitol dehydrogenase activity was similar in the sporophore and mycelium (Hammond, 1977), thus a simple deficiency of this enzyme cannot be responsible for the low levels of mannitol in the mycelium. The results of radiorespirometry, enzyme assays and studies of metabolism of ^{14}C labelled sugars, suggest that mannitol synthesis is controlled through restriction NADPH supply in the mycelium as compared with that in the sporophore (Hammond, 1977; Hammond and Nichols, 1977). Parrish et al. (1976) demonstrated that a direct relationship exists between the mannitol content and yield of the mushroom strains. The results also indicated that differences in mannitol content among the flushes of a given strain were apparently a direct function of the metabolic rate as reflected by the yield.

The levels of other major soluble carbohydrates, such as trehalose fell during development from approximately 5% dry weight to 1% at later stages of development (Hammond and Nichols, 1976).

The mineral elements content of *Agaricus bisporus* is undoubtedly affected by the composition of the growth substrate. This is probably the reason why values of the mineral composition of *Agaricus bisporus* presented by various investigators are often different (Randoin and Billaud, 1956; Schall, 1962; Crisan and Sands, 1978; Gapiński and Glebionek, 1978). The published data are often presented in different units based on fresh weight or dry weight, making comparison of such data difficult. *Agaricus bisporus* has an especially high content of phosphorus, sodium and potasium. It seems that, when the data of mineral composition are used, the values should not be interpreted in an absolute sense but rather as indicative of an order of magnitude which can be expected.

MATERIALS AND METOHDS

Growing conditions

For research concerning the influence of the culture substrate on the carbohydrates and minerals content of *Agaricus bisporus* two different composts: horse and broiler chicken manure were prepared. The study was carried out using the Somycel 11 strain. Horse manure compost was prepared by adding water, urea and gypsum to the crude substrate and after fermentation it was pasteurized. The ready compost had 67% of moisture, pH 7.3 and NH_4 — 0.3% in dry matter.

Broiler chicken manure compost was prepared by mixing chicken manure with dry rye straw (1:1) and adding gypsum and water. Further steps were: fermentation and pasteurization. The ready compost obtained in this way contained 72–73% of moisture, pH 7.5 and NH_4 — 0.35% in dry matter.

For both composts the rate of spawn was 500 g/m^2. For analyses mushrooms were taken in two sizes: 25–35 mm of pileus diameter (small) and bigger than 35 mm of pileus diameter (large).

Analytical methods

Carbohydrates. Glucose, fructose, trehalose and mannitol were determined by gas-liquid chromatography quantitation of their TMS esters. Extraction of carbohydrates from mushroom tissue and derivation were done according to the method of Kline et al. (1970).

Gas chromatography conditions. A Pye Unicam series 204 gas chromatograph equipped with a DP 101 computing integrator was used for analysis. The glass column (1.5 m$\times$3 mm I.D.) was filled with 3% SE-30 on 60/80 mesh Gas Chrom Q.

Gas chromatography parameters were as follows:

injection port temperature: 250°C,

detector oven temperature: 300°C,

column oven temperature: isothermic 2 minutes at 150°C, then programmed at a rate of 8°C min to 300°C,

carrier gas: argon, at flow rate 60 $cm^3 \times min^{-1}$.

Macro- and microelements. Mineral elements of mushrooms (with the exception of phosphorus, nitrogen, sulfur and boron) were determined by atomic absorption spectrophotometry. For sample preparation the wet ashing procedure was used. One gram of dried ground material was digested with 10 ml of concentrated nitric acid by warming on a hot plate. The solution was filtered and diluted to 25 ml with deionized water.

Potassium, magnesium, copper, manganese, zinc, iron were determined with a Perkin-Elmer 300 Atomic Absorption Spectrophotometer, using an air-acetylene flame and for calcium determination the nitrous oxide-acetylene flame was used in order to avoid chemical interference. Determinations were performed according to Analytical Methods for AAS, Perkin-Elmer, 1976.

Some elements as: molybdenum, cobalt, chromium, nickel and lead were determined by flameless atomic absorption using a HGA-76 graphite furnace in conjunction with the Perkin-Elmer 300 Atomic Absorption Spectrophotometer. Suitable conditions for determination of each element (parameters for program stages) were adjusted experimentally (Czapski, unpublished data). Lead was determined by the method of additions (Analytical Methods Using HGA Graphite Furnace, Perkin-Elmer, 1977).

Phosphorus was determined colorimetrically as molybdovanadophosphoric acid (Nowosielski, 1974). Total nitrogen was determined by the micro-Kjeldahl method.

Total sulfur was determined as barium sulfate, turbidimetrically, according to the method described in The Chemical Analysis of Plant Tissue (Cornell University, Ithaca, New York, 1966). Boron was determined colorimetrically in the reaction with curcumin, according to the procedure described in The Chemical Analysis of Plant Tissue (Cornell Uniervsity, Ithaca, New York, 1966).

Statistical evaluation of the results

Confidence limit values were evaluated by Dean and Dixon's test (1968).

RESULTS AND DISCUSSION

Carbohydrates composition of mushrooms cultivated on two composts

The investigation comprised soluble carbohydrates such as mannitol, trehalose, glucose and fructose which play an important role in the physiology and metabolism of the growing sporophore.

The level of mannitol in mushrooms grown on broiler chicken manure is rather constant for both sizes of fruit-bodies in 1–4 flushes (Fig. 1). There is a tendency, of more intensive accumulation of mannitol in mushrooms in the fifth and sixth

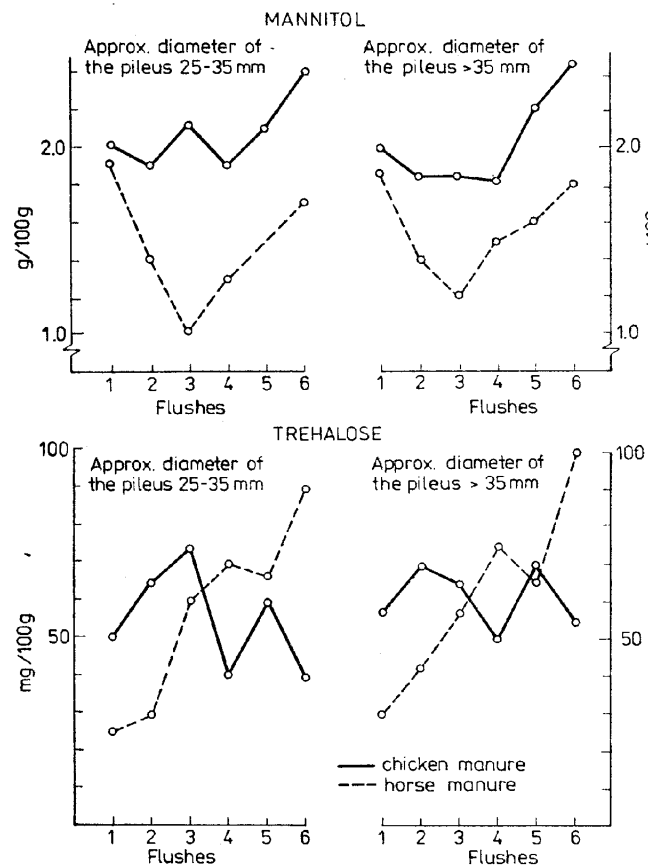

Fig. 1. Influence of flushes on carbohydrates (mannitol and trehalose) content in the mushroom *Agaricus bisporus* cultivated on horse and broiler chicken manure

flushes. For both fruit-body sizes growing on horse manure there is a pronounced trend in decreasing of mannitol content up to the third flush, and a rise in level up to the sixth flush. The average mannitol content from combined flushes 2–6 of mushrooms growing on chicken broiler manure is about 45% higher (52% for small and 39% for large fruit-bodies) than in those growing on the horse manure.

Trehalose content in mushrooms growing on broiler chicken manure changes irregularly over the flushes (Fig. 1). For both sizes of fruit-bodies grown on horse manure there is an overall tendency of rise in level of trehalose during the flushes of the crop cycle. The average content of trehalose for small and large fruit-bodies cultivated on horse manure, varies from 28.3 mg/100 g fresh weight in the first flush up to 97.6 mg/100 g fresh weight in the sixth one. Usually mushrooms cultivated on broiler chicken manure from the first two flushes contain more trehalose than those on horse manure. Opposite changes can be observed in the fourth and sixth flush.

Glucose content of mushrooms is significantly higher in all flushes for broiler chicken manure than for horse manure (Fig. 2). Glucose level in mushrooms growing on horse manure remains constant in the flushes of the crop cycle, while in mushrooms growing on broiler chicken manure there is a rise in level in the second and fifth flush.

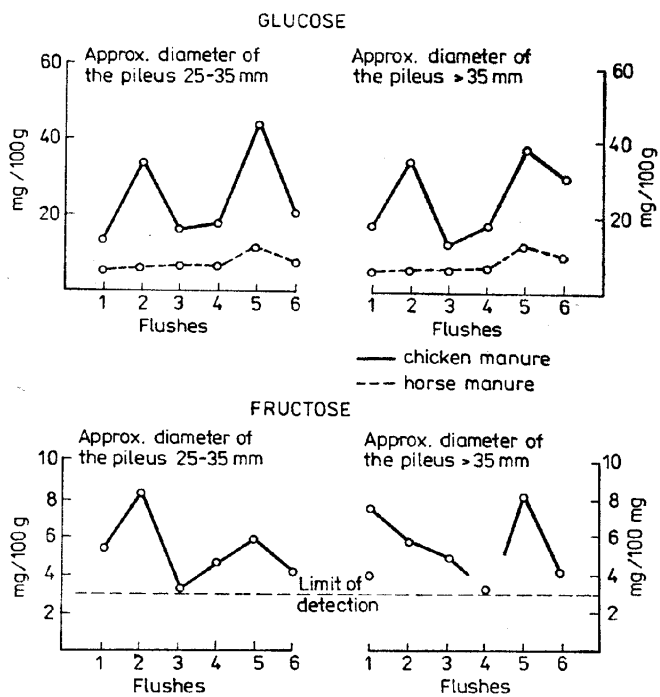

Fig. 2. Influence of flushes on carbohydrates (glucose and fructose) content in the mushroom *Agaricus bisporus* cultivated on horse and broiler chicken manure

Table

Mineral composition of cultivated mushrooms (*Agaricus bisporus*) from successive flushes,

Macro-, microelements	Flush 1		Flush 2		Flush 3	
	Approximately diameter					
	25–35	> 35	25–35	> 35	25–35	> 35
K (mg/100g)	348.4±58.3	346.2±41.4	368.1±73.8	347.6±32.6	308.9±79.2	308.9±22.6
Ca (mg/100g)	4.5±1.5	2.5±1.4	5.4±1.8	3.7±0.7	8.4±4.1	5.0±1.6
Mg (mg/100g)	11.5±1.4	11.5±0.6	11.9±1.0	11.2±0.7	10.7±0.4	10.6±1.7
S (mg/100g)	21.3±3.8	19.3±5.1	20.5±7.0	21.6±4.1	24.4±2.9	20.7±2.0
Cu (mg/100g)	0.26±0.039	0.24±0.020	0.37±0.065	0.37±0.026	0.37±0.026	0.34±0.020
Mn (µg/100g)	55.1±8.1	57.6±6.3	60.1±7.8	57.1±8.8	51.8±8.6	47.9±4.9
Co (µg/100g)	7.6±1.53	7.4±1.86	7.9±0.90	7.0±0.56	7.7±2.16	7.7±1.52
Ni (µg/100g)	2.4±1.01	2.4±0.98	2.2±0.86	2.8±0.85	3.9±1.82	3.6±1.85
Pb (µg/100g)						
Min.	3.7	9.0	3.3	3.3	9.4	8.9
Av.	10.5	14.1	10.2	9.1	15.1	22.9
Max.	18.3	24.0	23.7	14.9	20.1	38.0
Mo	Below limit of detection = 1.79 µg/100g					
Cr	Below limit of detection = 0.82 µg/100g					

* Averages from three independent replicates ± confidence limits at p = 0.95, evaluated according to Dean and

Table

Mineral composition of cultivated mushrooms (*Agaricus bisporus*), from successive flushes,

Macro-, microelements	Flush 1		Flush 2		Flush 3	
	Approximately diameter					
	25–35	> 35	25–35	> 35	25–35	> 35
K (mg/100g)	371.5±30.4	331.3±52.5	281.2±39.6	252.5±34.2	342.3±56.8	310.4±10.4
Ca (mg/100g)	9.3±0.7	6.6±1.7	7.2±2.3	5.3±0.7	8.7±1.2	3.3±1.0
Mg (mg/100g)	10.8±1.3	10.9±1.3	10.9±2.5	10.9±1.1	11.0±0.3	14.2±1.1
S (mg/100g)	14.1±2.3	13.6±7.1	16.9±4.9	18.5±3.3	19.2±4.4	18.6±6.5
Cu (mg/100g)	0.20±0.078	0.21±0.039	0.25±0.078	0.25±0.026	0.37±0.039	0.34±0.026
Mn (µg/100g)	33.3±10.3	31.9±4.3	34.1±4.1	44.0±10.0	53.0±10.5	47.6±17.2
Co (µg/100g)	5.7±0.47	5.3±0.52	6.2±1.79	6.4±1.01	6.7±1.31	6.3±1.41
Ni (µg/100g)	2.3±0.51	2.4±0.60	3.3±2.42	3.6±0.79	3.3±1.40	2.9±2.30
Pb (µg/100g)						
Min.	5.3	9.1				
Av.	9.9	20.5	11.3±4.2	5.5±2.6	9.6±3.3	11.7±4.1
Max.	14.4	28.6				
Mo	Below limit of detection = 1.79 µg/100g					
Cr	Below limit of detection = 0.82 µg/100g					

* Averages from three independent replicates ± confidence limits at p = 0.95, evaluated according to Dean and

1

growing on broiler chicken manure compost (expressed on a fresh weight basis)*

number					
4		5		6	
of the pileus (mm)					
25–35	> 35	25–35	> 35	25–35	> 35
346.6±55.9	336.3±70.4	372.2±61.9	353.4±50.0	441.8±91.8	350.6±79.2
12.0±3.4	5.2±2.1	6.2±1.8	5.4±2.2	6.8±1.1	5.1±2.0
10.6±3.0	10.8±2.1	11.3±1.3	10.9±1.7	12.7±2.3	11.2±1.7
23.1±5.3	23.2±2.7	24.6±7.6	24.8±2.4	32.5±7.6	28.2±2.8
0.34±0.065	0.36±0.013	0.35±0.104	0.33±0.052	0.46±0.117	0.41±0.091
49.5±2.9	51.7±11.3	38.5±4.1	39.6±7.3	56.8±9.6	46.5±5.2
7.2±1.39	7.2±2.64	7.9±0.44	6.3±0.92	7.5±1.55	6.8±0.44
3.2±1.41	3.5±1.45	trace	trace	2.8±1.01	2.9±0.98
4.5	4.2		9.3	9.4	
6.1	6.1	4.2±1.3	16.6	21.8	14.3±2.7
8.1	7.9		30.4	34.3	

Dixon test.

2

growing on hourse manure compost (expressed on a fresh weight basis)*

number					
4		5		6	
of pileus (mm)					
25–35	> 35	25–35	> 35	25–35	> 35
327.3±9.4	314.0±39.0	389.0±22.8	299.7±37.7	344.5±43.2	362.1±78.4
8.3±3.2	3.0±1.0	7.6±0.2	4.4±2.4	13.5±3.4	6.1±2.1
11.8±1.4	11.1±3.8	10.7±0.9	9.3±2.7	11.6±2.3	11.6±2.4
24.6±2.2	22.8±6.1	21.8±2.3	19.4±7.2	26.7±6.2	26.8±3.9
0.39±0.052	0.40±0.195	0.34±0.026	0.31±0.130	0.42±0.065	0.43±0.091
52.4±4.7	51.9±7.5	39.7±2.6	32.9±14.3	43.7±9.3	43.6±8.2
7.4±0.29	7.0±1.60	5.82±2.17	5.4±2.26	6.7±0.29	6.9±1.92
4.9±0.71	4.1±1.65	2.6±0.78	2.3±0.55	2.6±0.23	2.8±0.78
		8.5	8.1		7.6
6.8±1.1	17.6±1.7	14.7	10.0	12.7±1.9	13.8
		22.9	13.0		17.1

Dixon test.

The concentration of fructose in mushrooms grown on the horse manure remains below the limit of detection in nearly all flushes (Fig. 2). Fructose in mushrooms grown on broiler chicken manure appears in higher concentration than in mushrooms cultivated on horse manure, but changes irregularly in the flushes of the crop cycle.

Mineral composition of mushrooms cultivated on two composts

Potassium content in mushrooms does not change too much depending on flushes and compost preparation (Tables 1, 2). Only mushrooms from the second flush grown on horse manure (Table 2) show a lower content than those from some others flushes.

Interesting results were obtained for phosphorus (Fig. 3). The average phosphorus content for combined first three flushes of small and large fruit-bodies grown on horse manure was 2.7 times higher as compared with those grown on broiler

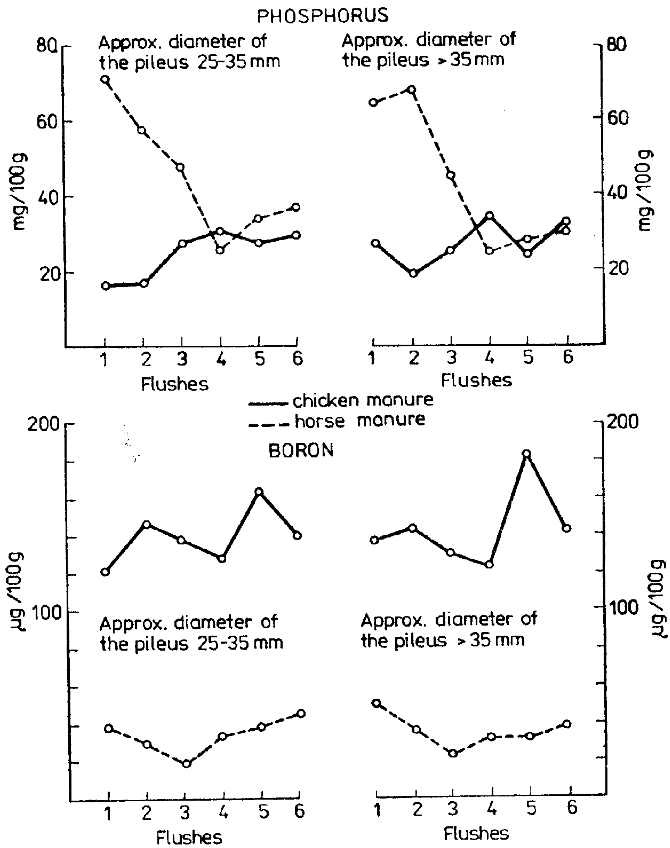

Fig. 3. Influence of flushes on minerals (phosphorus and boron) content in the mushroom *Agaricus bisporus* cultivated on horse and broiler chicken manure

chicken manure, and about two times higher than the average from the remaining flushes on horse manure. The level of phosphorus in mushrooms grown on horse manure decreases up to the fourth flush, from 60–70 mg/100 g fresh weight to about 30 mg/100 g fresh weight, remaining steady in further flushes for both composts. Phosphorus content in the initial two flushes of small fruit-bodies growing on broiler chicken manure is significantly lower than in the remaining flushes.

Calcium content does not change significantly except in the fourth flush of mushrooms growing on broiler chicken manure (Table 1). On horse manure (Table 2) small fruit-bodies usually contain more calcium than large ones. Calcium content in small fruit-bodies on horse manure from the last six flushes is higher than in others and large fruit-bodies from the third and fourth flush contain less calcium than from the other ones. Small fruit-bodies grown on the horse manure contain a higher quantity of Ca in the first and fourth flush and large ones in the initial two flushes as compared with the corresponding fruit-bodies from respective flushes on broiler chicken manure.

Magnesium levels seems to be unaffected by the flushes and compost preparation (Tables 1, 2). It was observed that for both composts there is a higher accumu-

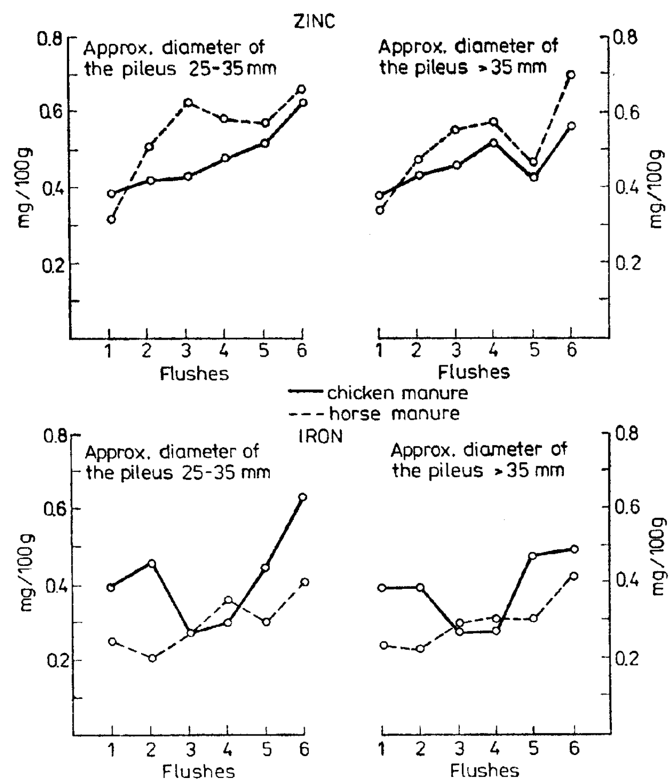

Fig. 4. Influence of flushes on minerals (zinc and iron) content in the mushroom *Agaricus bisporus* cultivated on horse and broiler chicken manure

lation of sulfur in the mushrooms of the sixth flush in comparison with the first-flush.

Values of copper and zinc contents in mushrooms during flushes have a slight ly increasing tendency for both composts (Fig. 4).

Iron content varies irregularly. Small fruit-bodies in the third flush grown on broiler chicken manure have a lower iron content than in the 1, 2, 5 and 6th flush. Besides, the sixth flush contains more iron than the first and fourth one. The sixth flush of large fruit-bodies growing on horse manure shows a higher content of iron than the first one. Comparing two composts, small fruit-bodies in the second and fifth flush grown on broiler chicken manure contain more iron than those from respective flushes growing on horse manure (Fig. 4). Lower accumulation of manganese in mushrooms growing on broiler chicken manure is observed in the fifth flush. For large fruit-bodies it is, however, significant only in comparison with the first and second flush. On the other hand, small fruit-bodies grown on horse manure show an increase of manganese content in the third and fourth flush as compared with the first, second and fifth one, while for large fruit-bodies the fourth flush differs by a higher manganese level than the first one. Usually the first flush, and for small fruit-bodies the second one on broiler chicken manure, contain significantly more manganese than the respective flushes on horse manure.

No differences are observed in the amounts of cobalt and nickel. The level of cobalt remains constant (6–7 μg/100 g fresh weight) throughout the crop cycle for both composts. Concentration of nickel is very low almost undetectable. The high differences observed in boron content, seem to be due entirely to the kind of compost (Fig. 3).

Average boron content for small and large fruit-bodies grown on broiler chicken manure for all flushes is four — fold higher than that of mushrooms on horse manure. The pattern of boron content in mushrooms on horse manure shows a tendency to decreasing up to the third flush and a rise in level up to the sixth flush.

Small amounts of lead were found in mushrooms grown on both composts, but considerable variation is noted between samples. Contents of molybdenum and chromium are below the limits of detection, although these trace elements are present in the growing substrates (Table 3). According to some investigators (Schall, 1962; Gapiński and Glebionek, 1978), the content of mineral elements in mushrooms is affected by the composition of the growth substrate. It is seen from Table 3 that in composts there exist sometimes wide differences in concentrations of some elements as P, Ca, Fe, Cu and B. Only for boron a direct relationship be found between boron concentration in mushrooms and in composts. For other elements such a relationship does not exist and for phosphorus even the opposite trend can be observed. It is known from the literature concerning the plant and soil relationship, that several factors play an important role in the uptake and accumulation of many elements in the plant. The most important are: availability for uptake, it means the chemical form which can be taken up, and interactions between some elements within the soil and plant. It seems that similar factors can affect the uptake and accumulation of mineral elements in mushrooms. Thus, the direct relationship between macro- and microelements content in compost and in the fruit-body can, but must not always exist, because of the complicated processes of uptake, transport and accumulation.

Table 3

Mineral composition (expressed on dry weight basis) and dry matter content of two different composts used for cultivation of mushrooms (*Agaricus bisporus*)

Component	Compost	
	horse	broiler chicken manure
Dry matter (2)	33.6±5.7	41.0±3.2
K (mg/g)	35.4±7.8	31.3±5.5
P (mg/g)	7.5±1.3	11.6±1.6
Ca (mg/g)	37.1±10.4	56.4±4.9
Mg (mg/g)	3.1±0.98	4.3±1.2
S (mg/g)	20.1±6.0	21.7±1.3
Fe (mg/g)	2.1±0.46	0.44±0.21
Zn (mg/g)	0.104±0.039	0.180±0.052
Mn (mg/g)	0.28±0.052	0.37±0.052
Cu (μg/g)	8.6±2.3	20.3±7.2
Co (μg/g)	0.84±0.16	1.20±0.08
Ni (μg/g)	3.8±1.9	3.4±0.8
Cr (μg/g)	24.5±9.1	12.8±0.7
Pb (μg/g)	4.1±1.2	4.7±0.8
Mo (μg/g)	0.36±0.09	0.33±0.07
B (μg/g)	6.8±0.5	14.5±0.8

CONCLUSION

1. The average mannitol content from combined flushes 2–6 of mushrooms grown on chicken broiler manure is about 45% higher than in those grown on horse manure.

2. For both fruit-bodies sizes grown on horse manure there is an overall tendency to rise in the trehalose level during the flushes of the crop cycle and it varies from 28.3 to 97.6 mg/100 g of fresh weight.

3. Glucose and fructose content of mushrooms is significantly higher in all flushes for broiler chicken manure than for horse manure.

4. The average phosphorus content for the combined first three flushes of small and large fruit-bodies grown on the horse manure is 2.7 times higher in comparison with that of those grown on broiler chicken manure and about two times higher than the average from the remaining flushes on horse manure.

5. The average boron content for small and large fruit-bodies grown on broiler chicken manure for all flushes is four-fold higher than for mushrooms on horse manure.

6. Potassium, magnesium, calcium, manganese, cobalt and nickel contents in mushrooms change irregularly during the flushes in both composts, while copper and zinc contents have a slight increasing tendency.

7. Small amounts of lead and molybdenum and chromium content below the limits of detection were found in mushrooms grown on both composts.

8. Significantly greater amounts of iron and chromium were observed in horse manure than in chicken manure compost. The situation was opposite in the case of copper and boron. There were no major differences in other element contents.

9. Relationships were not found between micro- and macroelements composition in compost and in the fruit-bodies of mushrooms cultivated on it.

Acknowledgments

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Wpływ rodzaju kompostu na zawartość węglowodanów i składników mineralnych w pieczarkach (*Agaricus bisporus*)

Streszczenie

Badano wpływ dwóch różnych kompostów: nawozu końskiego i nawozu kurzego na zawartość składników mineralnych i węglowodanów pieczarki rasy Somycel 11. Stwierdzono, że zawartość mannitolu, glukozy i fruktozy w grzybach rosnących na podłożu kurzym była istotnie większa niż w pieczarkach rosnących na podłożu końskim. Zauważalne różnice zaobserwowano również w zawartości makro- i mikroelementów w zależności od wielkości pieczarek, rzutu i rodzaju kompostu. Zawartość fosforu w pieczarkach rosnących na podłożu końskim była 2,7 raza większa podczas pierwszych trzech rzutów niż w pieczarkach rosnących na podłożu kurzym. Poziom boru w grzybach rosnących na kompoście kurzym był czterokrotnie wyższy w stosunku do pieczarek rosnących na kompoście końskim. Zawartości cynku i miedzi miały tendencje wzrostowe w miarę kolejnych rzutów dla obu kompostów, natomiast ilości potasu, magnezu, niklu i żelaza ulegały nieregularnym zmianom. Chrom i molibden występują w pieczarkach w ilościach poniżej granicy wykrywalności dla tych elementów. Natomiast nieco powyżej granicy wykrywalności znajdował się ołów. Zaobserwowano większe ilości żelaza i chromu, a niższe miedzi i boru w kompoście z nawozu końskiego w stosunku do kompostu z nawozu kurzego. Nie stwierdzono ścisłej zależności między składem mineralnym podłoża a zawartością elementów w owocnikach pieczarek na nich uprawianych.