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ESTIMATION OF THE USABILITY OF THE EXCESSIVE ACTIVATED SLUDGE AS FODDER

Criteria, according to which the usability of the excessive activated sludge for feeding purposes can be estimated, have been characterized. A tentative estimation of the usability of the excessive activated sludge from dairies and by-products processing plants has been presented. It has been stated that the composition of the meat-and-bone feed is similar to that of tested ones and that the latter can be utilized as fodder after their bacteriological stabilization.

1. INTRODUCTION

The ever increasing protein deficiency all over the world is the main reason for the search of new protein raw materials which — after a suitable processing — could be utilized in form of food products or fodder for farm animals. That is why attempts are made to utilize the wastes from slaughterhouses (cattle, pultry, ect), fish and other wastes as well as to microbiologically synthetize proteins from wastewater, liquid manure, and even from some fraction of crude oil.

Wastewater treatment by activated sludge method results in the excessive production of biomass which must be carried off the system. The superfluous activated sludge, containing bacteria, numerous protozoa, moulds and fungi, may be a potential source of proteins.

The commonly applied utilization methods of the excessive activated sludge consist in its oxygen stabilization (self-oxidation) or in its mineralization in anaerobis processes, dehydration, drying and storage on dumping grounds. Such solutions, though ecologically effective, lead however to irrevocable losses of the activated sludge biomass.

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Dry weight of activated sludge comprises total nitrogen (6–15 %), phosphorus (2–5 %), potassium (0.35 %), the total organics ranging within 75 %. Total protein (calculated from nitrogen according to Kiejdahl) ranges from about 20 % to 50 % of dry weight. The amount of fats varies from several to over 30 % of dry weight (maximal value is found in the activated sludge from slaughterhouses) [2], [5]–[7], [10], [14].

The utilization of dry activated sludge as fodder depends on:

a) chemical composition of feed obtained, chiefly on the contents of total protein, available protein, fats, fibers and ashes,

b) composition of amino acids in the protein of activated sludge and its nutritive value,

c) hygienic and sanitary factors,

d) toxicological assessment (contents of heavy metals, pesticides and toxines),

e) carcinogenic factors,

f) economic efficiency of dehydration technology, including thickening, dehydration, drying and sterilization.

Chemical composition of feed produced from the activated sludge should be evaluated by comparing it with the standards for fodders. The following components should be determined: raw total protein, chlorides, fats, inorganic compounds insoluble in 10 % hydrochloric acid, calcium compounds, water content, depending on the kind of the feed produced [13].

Evaluation of the composition of amino acids in activated sludge protein. Nutritive value of protein is defined by the composition of amino acids, and mainly by exogenic amino acids. It may be evaluated as: Chemical Score (CS) calculated by MITCHELL'S and BLOCK'S method [11] or an assessment of exogene amino acids (EAA) according to OSER [12].

The value of CS is determined from the ratio of the separate exogene amino acids content (a) in examined protein and their content (a_j) in standard protein

$$CS = a/a_j \cdot 100\,\%. \tag{1}$$

The lowest value of CS represents the so-called limiting amino acid.

The exogene amino acid assessment (EAA) is calculated from the ratio of the separate amino acid contained in the examined a_i and standard a_{ij} protein, according to the equation

$$EAA = \sqrt[8]{100 \prod_{i=1-8} \frac{a_i}{a_{ij}}}. \tag{2}$$

According to the recommendations of the Expert's Committee FAO/WHO the following amino acids are considered in the above calculations: isoleucine,

leucine, lysine, methionine + cystine, phenylalanine + tyrosine, valine, treonine and tryptophane. From many studies, in which the biological methods for determining the nutritive value of protein (e.g. PER or BV methods) were compared with the CS method, it follows that the CS indices are, in general, lower than the PER or BV ones, whereas the EAA index gives higher values. Evaluation of hygienic and sanitary conditions is based on microbiological analyses consisting in determining the numbers of fungi (mould, yeast) and bacteria (*Salmonella*, streptococci, pathogenic staphylococci, antrax bacillae) and in test made for the presence of the resting spores of bacillae under anaerobic conditions [13].

Assessment of toxical and carcinogenic factors consists in determining the contents of heavy metals, pesticides, toxines, washing agents and desinfectants as well as in determining the subacute and chronic toxicities, carcinogenicity, mutagenic and teratogenic (during nutritional tests) abilities. Estimation of economic efficiency includes: the value of feed obtained from activated sludge – assumed as profit and consumption of energy in dewatering, drying and sterilization of activated sludge – as cost.

2. THE AUTHOR'S INVESTIGATIONS

The purpose of the investigations was to determine the possible utilization of the superfluous activated sludge produced in treatment of wastewater from: 1) the factories processing by-products (slaughterhouse offal, gurry, etc), 2) dairy and 3) municipal and industrial wastes.

Methods. Activated sludge was taken from secondary settling tanks. The activated sludge was thickened gravitationally for 6 h and then dried in a natural way in plots, equipped with filter cloth, by pouring over these plots with a 0.15 m layer of the thickened sludge (drying time about 48 h). Next the sludge was dried thermally and sterilized under laboratory conditions (at 405 K under the pressure of 1519. 8 hPa for 0.5 h). The dried sludge was ground and in the obtained feed the amino acids, heavy metals, bacteria and fungi were determined [13].

Results of investigations. The results of chemical analyses of feed obtained from the activated sludge are presented in tab. 1. For comparative reasons the analogical results obtained for a meat–and–bone feed produced from the common by-products and the standards determining the admissible composition of such a feed are also given.

The composition of amino acids in the investigated feed is given in tab. 2, microbiological analysis and contents of heavy metals in this feed being presented in tabs. 3 and 4, respectively.

Table 1

Chemical composition of feed from activated sludges
Skład chemiczny mączek paszowych

Type of feed	Nitrogen acc. to Kjeldahl		Digestible nitrogen compounds			Content of		
	Content of							
	% of nitrogen in reference to dry weight	% of proteins N × 6.25	% of nitrogen in reference to dry weight	% of proteins N × 6.25	% of digestible proteins	chlorides, % of dry weight	raw fat, % of dry weight	water %
From the dairy activated sludge	6.1	38.1	4.5	27.9	10.2	2.12	2.7	5.7
From activated sluge of by-products processing plant	7.8	48.6	1.9	11.6	37.0	1.47	2.0	2.9
From activated sludge of the municipal sewage treatment plant	5.8	36.5	0.3	2.0	34.5	1.48	13.3	2.0
Meat-and-bone	11.0	68.6	0.8	5.1	63.5	1.04	11.4	10.6
Standard composition of meals BN-73/818/-01	—	40.0	—	—	—	15	15	11

Table 2

Composition of amino acids in feed produced from activated sludges, g/100 g of protein

Skład aminokwasowy mączek z osadów czynnych, g/100 g białka

Amino acid	Feed no.			
	1(1)	2(2)	3(3)	4(4)
Isoleucine	3.13	3.61	0.58	6.3
Leucine	3.97	3.13	0.99	8.0
Lysine	4.8	3.94	1.19	7.0
Phenylalanine	3.33	2.66	0.78	4.5
Tyrosine	1.51	1.40	0.38	3.6
Cystine	—	—	—	—
Methonine	3.07	2.98	0.62	2.0
Treonine	3.33	3.16	0.03	4.0
Tryptophane	—	—	—	—
Valine	4.96	4.60	1.23	5.8
Glutamic acid	5.20	5.10	4.13	—
Aspartic acid	4.61	4.43	3,27	—
Alanine	3.80	3.98	1.38	—
Arginine	3.43	3.74	0.72	7.0
Glycin	3.77	2.86	1.61	—
Serine	3.21	2.52	0.50	—
Proline	—	—	—	3.57
Histidine	1.12	0.98	—	2.0

(1) – feed from the dairy activated sludge.
(2) – feed from the activated sludge of by-products processing plant.
(3) – feed from the activated sludge of municipal and industrial wastewater treatment plant.
(4) – meat-and-bone feed.

3. DISCUSSION

In feed investigated the content of total nitrogen did not differ from that given in the literature. The content of digestible protein ranged within 10–37 % of dry weight. Total protein, determined according to Kiejdahl, varied from 36.5 to 48.6 % of dry weight, thus was similar to that in meat-and-bone feed. The contents of chlorides and fats in the feed investigated were much lower than the standard ones.

The nutritive value of protein in the feed obtained from activated sludge was estimated from the composition of amino acids. Graphical interpretation of the composition of amino acids of proteins contained in the feed investigated

Table 3

Microbiological analysis of feed from activated sludges
Ocena mikrobiologiczna mączek paszowych wyprodukowanych z osadów czynnych

Feed coming from	The number of microorganisms in 1 g of feed			
	Proteolytic bacteria	Ammoni – ficators	Fungi	
			saprophytic	producing toxins
Dairy activated sludge	30,000	48,000	none	none
Activated sludge of by-products processing plant	3,500	10,000	none	none
Activated sludge of municipal and industrial wastewater treatment plant	not numerous	10,000	none	none
Meat-and-bone feed	3,000	38,000	890	none
Standard composition of feed – Polish Standard PN-76/R-64791	3,000	25,000	500	10 feed for poultry, 50 feed for other animals

Table 4

Content of metals in feed produced from activated sludges
Zawartość metali w mączkach paszowych z osadów czynnych

	Feed made of activated sludge coming from	Content of metals, g/g of dry weight $\times 10^{-3}$						
		Zn	Fe	Cr	Mg	Pb	Cu	Ni
Feed tested	Dairy	1.13	17.12	0.27	16.25	0.97	0.14	1.01
	By-products processing plant	1.01	13.01	0.75	16.2	1.41	0.12	1.19
	Municipal and industrial wastewater treatment plant	142.8	188.0	16.17	59.41	5.79	169.2	6.84
Conventional feed	Meat-and-bone feed	1.85	30.0	0.82	37.5	1.31	0.177	1.48
	Fish feed	1.38	12.9	0.46	56.7	1.29	0.14	1.29

is given in the figure. The concentration ranges found for the individual amino acids from 52 tests of proteins were divided into classes (ca 0.2 g of amino acid in 100 g of protein) and the given class frequency was determined. The mid-

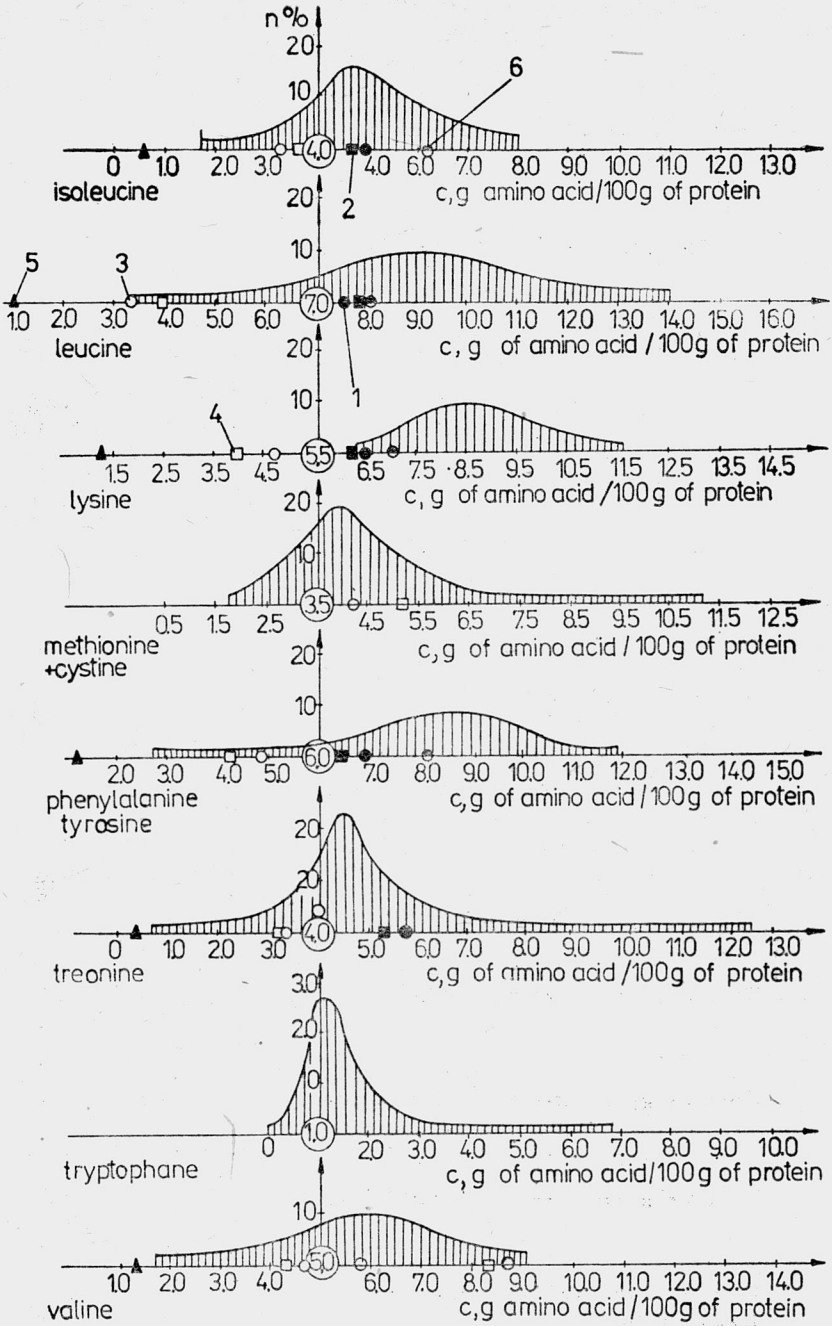

Figure. Diagram of the composition of amino acids in feed

1 — feed from slaughterhouse activated sludge, *2* — feed from the slaughterhouse wastewater, *3* — feed from the dairy activated sludge, *4* — feed from activated sludge from by-products processing plant, *5* — feed from the treatment plant for municipal and industrial wastewaters, *6* — meet-and-bone feed, 1 cm — 1.5 g of amino acid /100 g of protein, *c* — amino acid concentration (g of amino acid/100 g of protein), *n* — class frequency (%), 5.0 — amino acid concentration in standard protein according to FAO (g of amino acid/100 g of protein)

Rysunek. Diagram składu aminokwasowego mączek paszowych

1 — mączka z osadu czynnego z rzeźni, *2* — mączka z osadów ściekowych z rzeźni, *3* — mączka z osadu czynnego z mleczarni, *4* — mączka z osadu czynnego z zakładu utylizacyjnego, *5* — mączka z osadu czynnego z oczyszczalni komunalno-przemysłowej, *6* — mączka mięsno-kostna, 1 cm — 1,5 g aminokwasu/100 g białka, *c* — stężenie aminokwasu (g aminokwasu/100 g białka), *n* — liczebność klasowa (%), 5,0 — zawartość aminokwasu w białku wzorcowym według FAO (g aminokwasu/100 g białka)

Comparison of the composition of amino acids in feed
Obliczenie wskaźnika aminokwasu ograniczającego i zintegrowanego wskaźnika

Feed produced from activated sludge		Content of amino acid, Valine	Tre-onine	Lysine
FAO/WHO 1973 Recommendation		7.26	5.07	6.45
Feed from dairy		5.96	3.33	4.8
	x	68.3	65.5	74.4
Feed from by-products processing plant		4.60	3.10	3.94
	x	63.3	62.3	61.1
Feed from municipal sewage treatment plant		1.23	0.83	1.19
	x	10.9	16.4	18.4
Meat–and–bonefeed		5.8	4.0	7.0
	x	79.9	78.9	108.5
Acc. to LAWRENCE [1]		3.93	3.82	3.06
	x	54.1	75.0	47.5
From slaughterhouse, REDDE [4]		3.3	3.5	4.6
	x	45.4	69.03	71.3
From post-sulfite wastewater, KIN [11]		5.68	3.60	4.9
	x	78.2	71.0	75.9
From pulp-mill wastewater, LO [9]		4.3	3.72	—
	x	59.2	73.3	—
From slaughterhouse, acc. to KAVANAGH [7]		3.8	4.2	3.9
	x	52.3	82.8	60.4
From slaughterhouse, acc. to KAVANAGH [7]		3.9	4.8	4.3
	x	53.7	94.6	66.6
From slaughterhouse, acc. to FRITZ [18]		8.77	5.36	5.93
	x	120.7	105.7	91.9
From meat processing plant, acc. to HERBERT [5]		5.3	6.4	7.3
	x	73.0	126.2	113.0
From meat processing plant, acc. to HERBERT [5]		5.3	5.3	7.4
	x	73.0	104.0	114.0

x – CS value calculated acc. to eq. (1) for each amino acid.

Table 5

produced from various kinds of activated sludges
aminokwasów egzogennych w białkach mączek z różnych osadów

g/100 g of protein

Leucine	Isoleucine	Phenylalanine + tyrosine	Methionine + cystine	Tryptophane	CS	EAA
8.85	6.64	10.03	5.54	1.6	100	—
3.97	3.13	4.84	3.07	—	41.1	55.5
44.8	41.1	48.2	55.4	—		
3.13	3.61	4.06	2.98	—		
35.3	54.4	40.1	53.7	—	35.3	51.7
0.99	0.58	1.16	0.62	—		
11.2	8.8	11.6	11.2	—	11.2	13.0
8.0	6.3	8.1	2.0	—		
90.4	94.8	80.7	36.1	—	36.1	76.6
5.21	6.36	6.33	2.09	0.73		
58.8	95.8	63.1	37.7	45.6	37.7	67.3
5.6	3.7	6.2	1.8	1.0		
63.2	55.7	61.8	32.4	62.5	32.4	56.12
5.53	4.68	7.74	5.2	—		
62.4	70.4	75.1	93.8	—	62.4	74.6
8.73	4.24	—	3.06	—		
98.6	63.8	—	55.23	—	55.23	68.5
5.8	2.5	5.5	not determined	not determined	37.6	57.1
65.5	37.6	54.8	—	—		
6.1	2.5	6.2	not determined	not determined	37.6	61.5
68.9	37.6	61.8	—	—		
7.55	4.83	7.0	3.86	not determined	69.6	83.89
85.3	72.7	69.7	69.6	—		
6.6	3.3	8.5	3.0	not determined	49.7	76.04
74.5	49.7	84.7	54.1	—		
6.3	3.2	7.8	2.6	not determined	46.9	70.92
71.1	48.2	77.7	46.9	—		

points of given class intervals are determined by the abscissae of the curve of frequency distribution, the class frequency being given by the ordinate of this curve. The shape of the above curves indicates that for each amino acid there exists a certain concentration range. Points of intersection of the abscissa with the successive ordinates denote the composition of exogene amino acids of the standard protein, established by FAO (1973). The points of the appropriate abscissae give the information about the composition of amino acids of feed obtained from the activated sludge. It appears that this composition is similar to that of standard protein and other animal proteins. The calculated limiting amino acid, CS and EAA indices are presented in tab. 5. The value obtained for CS, ranging from 11.2 to 59.5 (minimal value for the activated sludge from municipal wastewater), compared with the value of CS in proteins of caseine and milk, prove that in the feed proteins the value of CS is sufficiently high. The values of CS for the proteins in meat and its products are much higher (45.7–68.9) [15], while in feed produced from the by-products the values of CS for fish meal, meat meal, blood meal [17], meal from fish pulp and for a full valued fish meal amount to 48, 48, 57, 50 and 44, respectively.

The integrated index of exogeneous amino acid in the feed obtained from activated sludge ranged from 13 to 76 (minimal value for the activated sludge from municipal wastewater treatment plant). For comparison, in feed from classical by-products, this index amounts to 81.2, 71.3, 71.4 [17], 79.3 [18] and 72.9 for the feed from meat, blood, fish pulp and full valued fish, respectively.

The literature data for the CS and EAA indices for proteins of activated sludge [1], [3]–[5], [7], –[9] are given in tab. 5. According to the above data the values of CS range from 32.4 to 69.6 (the average value is 47), and those of EAA vary within 56–83 (the average value is 67). From these data it follows that the meals from activated sludge may be used as fodder.

Microbiological analysis of the examined feed from activated sludge has shown the absence of saprophytic and toxinogenic fungi. Elevated numbers of proteolytic bacteria and ammonifiers have been found in the feed from activated sludge coming from dairy, whereas in feed obtained from activated sludge from slaughterhouse and municipal wastewaters the contents of the above bacteria were below the standards for fee.

From the analyses of heavy metals it follows that their contents in feed obtained from the activated sludge from municipal and industrial wastewaters were 100 times higher than in conventional feed. Therefore they cannot be used for feeding purposes.

The investigations performed have shown that the feed may be produced from the excessive activated sludge. This possibility has been also proved by the balance-digestion investigations performed on broilers [3] fed with feed produced from the slaughterhouse wastewater. It has been stated that at 3–9 %

content of this feed in protein food mixtures the development of chicken is correct. This makes it possible to reduce or eliminate entirely the fish feed.

Feed from activated sludges may be produced in technological lines of Hartman's plants. Such a solution does not require any investment costs. Thus, these plants which, because of the construction of big industrial complexes for the processing of side products based on the Stork–Duke licence, were to be partially liquidated may be further used in this country.

4. CONCLUSIONS

1. Microbiological analyses of feed obtained from activated sludge have shown that their compositions are similar to that of conventional meat-and-bone feed. The values of CS and EAA of the examined feed produced from activated sludge are similar to those in the meat–and–bone feed. The contents of digestive protein and fats are lower than in the meat–and–bone feed.

2. Feed produced from the activated sludge coming from by-product processing plants and from dairy may be used as fodder after their bacteriological stabilization.

3. Feed from the activated sludge from the treatment plant of municipal and metal industry wastewaters cannot be used as fodder because of the elevated contents of heavy metals.

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OCENA MOŻLIWOŚCI WYKORZYSTANIA NADMIERNEGO OSADU CZYNNEGO NA PASZE

Scharakteryzowano kryteria oceny wykorzystania nadmiernego osadu czynnego na pasze. Przedstawiono wstępną ocenę możliwości wykorzystania osadów nadmiernych z mleczarni i zakładów utylizacyjnych i stwierdzono zbieżność składu badanych mączek ze składem konwencjonalnych mączek mięsno-kostnych oraz możność ich wykorzystania po stabilizacji bakteriologicznej.

DIE MÖGLICHKEITEN DER VERWENDUNG VON ÜBERSCHUßBELEBTSCHLAMM ALS VIEHFUTTER

Die Kriterien zur Abschätzung der Verwendbarkeit von Überschußbelebtschlamm als Viehfutter werden bestimmt. Es handelt sich um den Belebtschlamm aus Molkereien und Fleischereien. Es wird festgestellt, daß sich das untersuchte Mehlfutter von traditionellen Fleisch- und Knochenmehl kaum unterscheidet und daß es nach einer bakteriologischen Stabilisierung angewendet werden darf.

ОЦЕНКА ВОЗМОЖНОСТИ ИСПОЛЬЗОВАНИЯ ИЗБЫТОЧНОГО АКТИВНОГО ИЛА ДЛЯ КОРМА

Представлена предварительная оценка возможности использования избыточных илов из молочного завода и утилизационных заводов и выявлено сходство состава исследуемых порошков с составом традиционных мясно—костных порошков, а также отмечена возможность их использования после бактериологической стабилизации.