Nat. Volatiles & Essent. Oils, 2021; 8(5): 8084-8093

NVEO Natural Volatiles & Essential Oils

OBTAINING HUMATED CARBAMIDES BASED ON CARBAMIDE AND SODIUM HUMATE, POTASSIUM AND AMMONIUM FUSION

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Abstract

The article presents the humated urea obtaining studies results by adding urea to the melt before granulation separately humate sodium, potassium and ammonium at mass ratios CO(NH2)2: humate= 100:(0,1-3). It is shown that the urea properties with the studied relations more strongly influenced by sodium humate than potassium and ammonium humate. In fertilizers obtained with the sodium, potassium and ammonium humate addition to the urea melt at CO(NH2)2 mass ratio: humate=100:3 the granules strength increases from the original 1.35 to 2.18; 2.03; 1.91 Mpa, the gyroscopic point decreases from 75.3% to 65.8; 68,8; 69,4% relatively. It was also revealed that when humates are added to the urea melt density and melt viscosity increase with an increase in the amount of introduced humates. At 142°C, an increase in the sodium humate proportion from 0.1 to 3.0 mass parts per 100 urea mass parts leads to an increase in density from 1.294 to 1.375 g/cm3 viscosity from 3.15 to 3.38 cps., potassium humate from 1.281 to 1.354 g/cm3 and from 3,12 to 3,32 cps., ammonium humate from 1,285 to 1,366 g/cm3 and from 3,14 to 3,35 cps. If industrial urea granules dissolution in water averages 112 seconds and the sodium humate introduction into its composition in an amount of 0.1 to 3 g increases dissolution time from 115 to 182 seconds, potassium humate from 114 to 168 seconds, ammonium humate from 113 to 152 seconds. The results obtained are the technological basis for the humated urea production based on urea melt and dry sodium, potassium and ammonium humate powders.

Keywords: brown coal, oxidized coal, humic acid, fulvic acids, hydrogen peroxide

Introduction

Increasing the using nutrients efficiency from mineral fertilizers by plants have great importance for agriculture and ecological safety of the environment[1,2].

Humates are the best plant growth stimulators, natural catalyst for biochemical processes which has active properties, can stimulate plant growth and microorganisms development, actively stimulate the immune system of the plant, they are able to bind toxic and radioactive elements into inactive or hard-to-dissociate compounds, as well as connections, negatively affecting the ecological situation in nature, also they can incorporate some pesticides, hydrocarbonsand phenols. They are harmless to the soil microsphere, for plants and humans. Plant feeding with sodium humate, potassium humate and ammonium humate provides an increase in productivity, activates metabolism and protein, carbohydrates and vitamins synthesis. As part of complex fertilizers significantly increases the grain and other crops yield, increases mineral fertilizers utilization rate, prevents heavy metals and pesticides accumulation, reduces nitrates accumulation. Heavy metals and pesticides due to interaction with humate become insoluble due to which the plant ceases to absorb them [3].

Currently in many countries around the world humic substances received natural confirmation in the practical solutions to environmental protection problems. Polyfunctionality of humic substances provides them with a dominant role in the accumulation and metal ions migration in the bowels, soils and terrestrial landscapes. Hydrophilicity and molecular structure predetermine the unique role of soil structure for humic substances, their air and water regime regulator, and means for the territories reclamation disturbed by human economic activity. Based on humic substances are organized production and more than ten new materials are used for environmental protection, namely sorbents of heavy metal ions; humic soil ameliorants, humic ameliorants for sandy soils, ameliorants for saline soils; humic preparations for solving environmental protection problems based on humic substances of natural caustobolites or their agglomerated compositions modified with humic substances salt forms [4-8].

Therefore the humic substances use having a growth stimulating effect and increasing soil fertility as an additive to mineral fertilizers in their production and new methods development for obtaining humic or humated mineral fertilizers as well as their use in agriculture are relevant [9-11].

Such fertilizers use is an additional method of increasing the agricultural crops yield and their products quality, high payback of mineral fertilizers by increasing the yield. Besides use of new fertilizers types, in some cases, allows reducing their application dose by 20-25% without sacrificing yield [12].

In [13] presents research results on the creation and use of briquette fertilizers with high humic acids content. In briquette fertilizers as a binder the microbiological binder "Biokhum" is used, which is an organo-mineral fertilizer, containing various components. Two options for briquette fertilizers have been developed: tableted and pivotal, necessary for the successful cultivation of plants, bushes and trees. Agrochemical tests were carried out with lawn grass, on which the briquette fertilizers effect was determined for the herbaceous plants growth and their root system development. It was found that the grass height was 1.5 times higher when using fertilizers. At the same time, the root system with the use of fertilizers increased almost 3 times.

In [14] shows the application effectiveness of the humated fertilizer Bioplant flora for pre-sowing seed treatment and foliar feeding of winter and spring wheat growing plants. In this fertilizer, the organic matter mass fraction is 55% (calculated on dry matter), the humic and fulvic acids sum is not less than 2 g/l, P_2O_5-20 g/l, N-150 g/l, K_2O-200 g/l, Co-15 mg/l Mn, Mo, Mg- not less than 100 mg/l. The yield of spring wheat with foliar feeding in the tillering and booting phases was 55.2 c/ha, and the increase in yield to the background is 9 c/ha. At the same time, the protein content, in comparison with the background calculated to obtain 5 t/ha of grain, increased by 0.8%, gluten - by 2.1%, weight of 1000 grains - by 2.68 g. The gains were even greater against the natural fertility background. In this case, the grain harvest with two additional dressings increased, in comparison with the background, by 11.4 c/ha, protein content by 1.2%, gluten by 2.9%. Humated fertilizer with microelements when used for pre-sowing seed treatment and foliar spring and winter wheat crops feeding intensifies plant growth and development, significantly increases yield (by 20-40%) and gluten content in grain (by 2-6%).

In work [18], it is shown the use effectiveness of humic concentrate "Dar" from peat extract during potato cultivation. The humic preparation had a positive effect on the growth processes and quality indicators of potato tubers. In addition, the late blight and alternaria infections manifestation was noted at a later date, compared with the control. The use of such fertilizer enriches the soil with essential nutrients, increasing the potatoes yield and quality. Contributed to obtaining the highest yield (24.5 t/ha), which exceeded the control by 11.13%. The data obtained give grounds to use the humic preparation as a growth regulator and potato plants development and as an adaptogen to various environmental conditions.

Also in the work [16] are given research results of complex fertilizers of humus nature (CFHN**)** obtained on the brown coal deposits of the South Ural brown coal basin having the following composition (wt.%) total organic matter content of 66-77; $N_{gen.}$ – 5,8; P_2O_5-0,01%; K_2O- 0,31%, pH-7-9. When introduced into typical carbonate black earth, it contributed to an increase in the amount of nitrate and ammonia nitrogen and mobile phosphorus forms, exchangeable potassium in the soil. The fertilization effect in the application year to the soil and in the aftereffect was stronger than that of manure. The CFHN effect was most clearly manifested at minimal doses; the grain mass fraction in the total spring wheat plants productivity increased by 90%. The CFHN aftereffect in the second year was the highest, as in the application year to the soil, at the lowest dose and increased the grain proportion. Bioenergetic efficiency of action in 50 and 100 kg/ha doses is 4.26 and 2.82 and aftereffect in the second year is 9.89 and 9.87 units.

In work [17], it is also shown that the humic acids interaction products with ammonium hydroxide and urea, precipitated from a solution with a mineral acid, differ somewhat from the initial humic acids not only in the chemical composition of the nitrogen-containing part, but also in some physicochemical properties. The nitrogen-containing products of this interaction have a negative charge and a slightly higher electrophoretic mobility than the initial humic acids. When interacting with Ca, Fe and Al soluble compounds, nitrogen-containing humic products are capable of forming mobile complex organomineral negatively charged compounds with these elements to a greater extent than the initial humic acids.

In the work [8], the humic preparations studies results on various agricultural crops are presented; it is shown that the maximum increases in yields can be obtained with the combined use of mineral fertilizers and preparations based on humic acids. In addition, calculations showed that on two wheat varieties, potassium-sodium humate with microelements increased the fertilizers payback by 2.6-2.8 times.

In work [19], a technology for obtaining a humic-mineral fertilizer is given, in which brown coal was used as humic substances source, mineral elements source is Kimovsky phosphorite, nitric acid and ammonia. The kinetics of coal humic acids interaction, previously oxidized with nitric acid, with $Ca(NO_3)_2$ solution, depending on the temperature and solution concentration, has been studied. To study interaction time effect of nitric acid with brown coal and phosphorite with their simultaneous introduction, three humic-mineral fertilizer samples were prepared, which were analyzed for total content, assimilable and water-soluble P_2O_5, the total yield and free humic acids. The humic acids yield with an increase in the interaction time increases due to the coal organic mass oxidation with nitric acid.

A method for obtaining a complex organic mineral fertilizer is patented, containing peat and ammonium salts, as well as sodium humate (potassium, ammonium), with the following components ratio, by mass: peat -1; phosphate fertilizer -0,01-0,09; ammonium carbonate -0,01-0,09; sodium humate (potassium, ammonium) -0,0005-0,005. Instead of peat, vermicompost may be included in the fertilizer. [20].

The work [21] presents the physicomechanical properties and agrochemical urea efficiency evaluating results with the sodium humate addition. The tests were carried out on pilot carbamide batch samples obtained at Novomoskovsk PO "Azot" by introducing 0.1% sodium humate into the melt before its granulation. It was shown that with sodium humate introduction, caking decreases, and hygroscopicity increases in comparison with the control sample. To assess the agrochemical urea efficiency with sodium humate, this fertilizer tests were carried out in the open field. Research results indicate that in arid conditions, the sodium humate addition to urea increased wheat yield. The sodium humate use led not only to an increase in wheat yield in a dry year, but also affected the grain quality. So, with pre-sowing drug application in an amount of 13 kg/ha mixed with urea, the gluten mass in the grain increased by 0.5%, with post-sowing - by 1.9%.

In [22], to obtain organomineral fertilizers, it is proposed to mix equal brown coal amounts from the Alexandria deposit with a humic acid content of 32% and urea at 75°C temperature for 2-3 hours in order to increase the fertilizer efficiency. The resulting product is a free-flowing powder containing 23% nitrogen. The experiments results on the dissolution rate show that nitrogen dissolves from this organomineral fertilizer 8 times slower than from urea. Agrochemical tests in field experiments with barley show that nitrogen-humus fertilizer provides not only dosed nitrogen nutrition for plants, but also has a stimulating effect on plant growth and development due to the preserved physiological humic acids activity in brown coal. The resulting fertilizers were also tested on vegetable crops. This fertilizer use led not only to an increase in the tomato fruits yield by 18.2 t/ha, carrots by 10.0 t/ha, but also to a decrease in nitrates in them.

From the given literature data, it is clear that humatized or organomineral fertilizers use is more effective and environmentally acceptable than the use of some mineral fertilizers[23-24]. Despite this, at present, in many countries of the world, including Uzbekistan, mineral fertilizers are mainly used to increase the agricultural crops productivity. Therefore, the study and development of new organomineral and humatized fertilizers obtaining methods and their implementation in production are relevant.

This work purpose is to study the processes of obtaining a humatized granular carbamide based on carbamide and sodium humate fusion, potassium and ammonium. Sodium humate, potassium and ammonium were introduced into the urea melt in the powder form before granulation. Humates are obtained from oxidized brown coal of Angren deposit with hydrogen peroxide in an alkaline medium by extraction followed by drying. It is known that the main starting materials for the humates production are oxidized coal in natural conditions with a humic acid content above 45%. And coals with a humic acid content up to 20% must be oxidized. In the brown coal of Angren deposit, the humic acids content is very low. Therefore, in order to convert the organic coal part into humic acids, we studied the oxidation process [25].

Research methods

The experiments used brown coal from the Angren deposit, having, after drying to an air dry state and grinding in a ball mill to 0.25 mm size, the composition (wt%): moisture 15,66; ash 12,11; organic 72,23; humic acids 4,24 on organic matter. The oxidation process was carried out at hydrogen peroxide concentration from 10 to 30%, sodium hydroxide solution from 20 to 40% and the coal weight ratio (organic part):H_2O_2 :NaOH from 1 : 0,1 : 0,05 to 1 : 1 : 0,05. First, the coal was processed in a mechanical mortar with a NaOH solution at the coal ratio: NaOH = 1:0,05 within 30 minutes. Then, the resulting mass was added to the tubular reactor, where hydrogen peroxide solution was poured in advance, with stirring, and processed for 2 hours. Under optimal conditions, i.e. when using 30% hydrogen peroxide, 40% sodium hydroxide and a coal mass ratio (organic part of coal):H_2O_2 :NaOH = 1:0,6:0,05 the coal oxidation state was 65.5%. In the resulting product, the humic acids content was 52.96% per organic oxidized coal mass.

In this work, to obtain oxidized coal, the original coal was oxidized under the above optimal conditions. In the case of obtaining potassium humate by coal oxidation as an alkaline reagent used 40% KOH and in the case of obtaining ammonium humate, the alkaline solution was not used and humic acids yield was 41.2%. To obtain ammonium, sodium and potassium humates by treating oxidation products with aqueous solutions of NH_4OH, NaOH and KOH based on previous studies, the following mode of humic acids extraction was selected: concentration of ammonium hydroxide solutions 2%, sodium hydroxide 0.1%, potassium hydroxide 0.1%, temperature 80oC, the interaction time is 30 min and the mass ratio of the alkaline reagent solution: coal (S : L = 8 : 1). As a result of the extraction, humates solutions 1-2% concentration were obtained. The extract separation from unreacted coal particles was carried out by centrifugation at a rotational speed of 3000 rpm for 10 min. By the evaporation method and these solutions evaporation at 80°C, humate crystals were obtained, which composition is shown in Table 1. Then it was crushed to a particle size of no more than 0.1 mm in a ball mill.

Table 1. The chemical composition of solid humates

Product name	Moisture, %	Ash, %	Humic acids, %	Mass fraction of alkali, %	pH (10% solution)	Hygroscopic point
Sodium humate	5,88	9,88	84,24	5,67	9,07	50,8
Potassium humate	5,32	8,56	86,12	4,96	9,28	51,6
Ammonium humate	5,01	3,77	91,22	-	7,56	50,3

To obtain humated urea as the main component served factory product (JSC «Maxam-Chirchiq») - carbamide $(NH_2)_2CO$ of A grade with a content of 46.3% N and humate.

Results

The experiments were carried out as follows: urea was melted in a metal cup on an electric stove, humate powder was introduced into the melt at 137-140°C at a mass ratio of $(NH_2)_2CO$: humate=100 :(0,1-3), the temperature was kept constant by heating, the melt was kept after dosing for 1-2 minutes with constant stirring until a homogeneous state, after which it was poured into a granulator, which is a metal glass with a perforated bottom, the holes diameter in which was 1.0 mm. The pump created pressure in the upper part of the glass and the melt was sprayed from 35 meters height. In this case, humated urea granules were obtained. Then the chemical composition and fertilizer granules strength were determined. The fertilizer granules strength with 2-3 mm granule size was determined in accordance with SS 21560.2-82 using an IPG-1M electronic device. The nitrogen content in the products was determined using a catalyst for the nitrogen conversion in urea to ammonia by heating in a sulfuric acid solution, followed by distillation and ammonia absorption in an excess of a standard sulfuric acid solution and back titration with sodium hydroxide solution in the SS 2081-2010 indicator presence. The humic acids and the alkali yield content were determined according to SS 54221-2010. The hygroscopic points of the feedstock and finished fertilizers were determined at 25°C by the desiccator method [26].

pH of 10% aqueous solutions value measurement of starting materials and finished fertilizers were carried out in a laboratory and onomer I-130M with an electrode system of electrodes LGE 63-07, TLE-1M3.1 and TKA-7 with 0.05 pH units accuracy. Also, in order to determine the rheological melts properties, their density and viscosity were studied at the above $(NH_2)_2CO$ ratios: humates in the temperature 142-145°C range. The density was determined by the pycnometric method with a measurement accuracy of 0.05% ratio, the kinematic viscosity - using a glass capillary viscometer, the transparent liquids viscosity - 1 with 0.2% ratio error in the temperature range 137-140°C.

For this, the mixture of the resulting product was milled. The resulting powder was introduced into a pycnometer and a viscometer, which were then placed in a thermostat filled with glycerin. The temperature in the thermostat rose to a predetermined value. In this case, the powder melted. The melt was kept for 1-2 minutes, and then measurements were taken. The dissolution rate of sample granules in water was determined as follows. The fertilizer granule was dipped into a glass with 100 ml of distilled water, in which its complete dissolution was visually observed and recorded. Room temperature, tests five times. All results obtained are shown in Tables 2-4.

Table 2. Chemical composition of fertilizers obtained by introducing solid sodium, potassium and ammonium humate into the carbamide melt

Mass ratio of $(NH_2)_2CO$: humate	N, %	Humic acids %	Mass fraction of alkali, %	pH (10% solution)	Humidity, %	Strength of granules, MPa	Hygroscopic point, %
With sodium humate additive							
100:0	46,20	-	-	9,31	0,181	1,35	75,3
100:0,1	46,11	0,081	0,0055	9,43	0,184	1,38	75,1
100:0,25	45,97	0,201	0,0218	9,56	0,187	1,46	74,1
100:0,5	45,88	0,407	0,0331	9,88	0,192	1,54	73,6
100:1	45,64	0,807	0,0559	10,37	0,206	1,78	71,7
100:2	45,22	1,592	0,1104	10,71	0,227	1,96	70,9
100:3	44,81	2,372	0,1644	11,03	0,249	2,18	65,8
With potassium humate additive							
100:0,1	46,13	0,083	0,0042	8,78	0,183	1,37	75,2
100:0,25	46,01	0,205	0,0144	8,83	0,186	1,41	74,4
100:0,5	45,92	0,412	0,0224	9,28	0,189	1,48	73,9
100:1	45,67	0,813	0,0438	9,86	0,203	1,65	72,4
100:2	45,24	1,614	0,0914	10,24	0,218	1,82	71,3
100:3	44,83	2,392	0,1364	10,32	0,235	2,03	68,8
With ammonium humate additive							
100:0,1	46,15	0,085	-	7,78	0,182	1,36	74,9
100:0,25	46,08	0,211	-	7,92	0,184	1,4	73,8
100:0,5	46,01	0,421	-	8,05	0,186	1,46	73,1
100:1	45,80	0,842	-	8,32	0,194	1,59	71,1
100:2	45,42	1,671	-	8,17	0,211	1,71	70,2
100:3	45,04	2,487	-	8,01	0,225	1,91	69,4

Table 3. The melt density and viscosity obtained by introducing sodium, potassium and ammonium humate into the carbamide melt

Mass ratio of $(NH_2)_2CO$: humate	Density (g/cm^3), at a temperature, °C				Viscosity (cps), at a temperature, °C			
	142	143	144	145	142	143	144	145
$(NH_2)_2CO$	1,278	1,244	1,226	1,195	3,11	2,96	2,84	2,70
With sodium humate additive								
100:0,1	1,294	1,267	1,248	1,227	3,15	3,09	3,04	2,99
100:0,25	1,314	1,285	1,266	1,243	3,17	3,11	3,06	3,00
100:0,5	1,328	1,305	1,276	1,255	3,22	3,16	3,10	3,05
100:1	1,349	1,325	1,297	1,274	3,28	3,22	3,16	3,11
100:2	1,362	1,338	1,312	1,299	3,33	3,26	3,21	3,16

100:3	1,375	1,345	1,326	1,306	3,38	3,31	3,26	3,20
With potassium humate additive								
100:0,1	1,281	1,256	1,234	1,214	3,12	3,06	3,01	2,96
100:0,25	1,300	1,276	1,252	1,235	3,13	3,07	3,02	2,97
100:0,5	1,316	1,293	1,267	1,243	3,17	3,11	3,06	3,00
100:1	1,334	1,305	1,285	1,268	3,23	3,17	3,11	3,06
100:2	1,343	1,315	1,295	1,275	3,27	3,21	3,15	3,10
100:3	1,354	1,325	1,312	1,288	3,32	3,25	3,20	3,15
With ammonium humate additive								
100:0,1	1,285	1,260	1,238	1,218	3,14	3,08	3,03	2,98
100:0,25	1,308	1,282	1,260	1,240	3,16	3,10	3,05	3,00
100:0,5	1,321	1,295	1,272	1,252	3,21	3,15	3,09	3,04
100:1	1,342	1,316	1,292	1,272	3,26	3,20	3,14	3,09
100:2	1,354	1,327	1,304	1,283	3,31	3,25	3,19	3,14
100:3	1,366	1,339	1,316	1,295	3,35	3,28	3,23	3,18

Table 4. The dissolution rate of fertilizer granules in water obtained by introducing solid sodium potassium and ammonium humate into the carbamide melt

Mass ratio of $(NH_2)_2CO$:humate	complete dissolution time of granules, sec.					**Average value**
	1	**2**	**3**	**4**	**5**	
With sodium humate additive						
100:0	113	112	111	110	112	112
100:0,1	115	115	114	116	116	115
100:0,25	125	129	129	130	129	128
100:0,5	139	141	138	141	137	139
100:1	152	150	154	152	151	152
100:2	174	170	172	171	169	171
100:3	183	185	181	182	179	182
With potassium humate additive						
100:0,1	114	115	114	114	112	114
100:0,25	118	125	122	123	123	122
100:0,5	132	135	132	129	129	131
100:1	144	142	139	141	143	142
100:2	156	158	157	155	158	157
100:3	170	168	167	169	165	168
With ammonium humate additive						
100:0,1	113	112	111	115	113	113
100:0,25	117	116	115	118	117	117
100:0,5	124	126	123	125	126	125
100:1	132	135	130	129	132	132
100:2	142	140	143	139	142	141
100:3	154	152	152	149	152	152

The data in table 2 show that with an increase in the humates addition, the nitrogen content in the product decreases, and the humic acids content increases. The humates use as an additive, on the one hand, reduces the nitrogen content, on the other hand, enriches it with physiological active substances, which contribute to a significant increase in the fertilizers and crop yields efficiency. By mixing humates with urea melt, granular humate fertilizers it was obtained with N content from 44.81 to 46.11% and humic acids from 0.081 to 2.487%. It can also be seen from the table that with an increase in the amount of humates, the product granules strength increases. When the mass ratio of carbamide melt to humates changes, the granules strength changes as follows: for sodium humate at $(NH_2)_2CO$ ratio: humate sodium 100 : 0,1 – 1,38 MPa; 100 : 1 – 1,78 MPa; 100 : 2 – 1,96 MPa; for potassium humate:100 : 0,1 – 1,37 MPa; 100 : 3 – 2,03 MPa; 100 : 1 – 1,65 MPa; 100 : 2 – 1,82 MPa; MPa; for ammonium humate:100 : 0,1 – 1,36 MPa; 100 : 3 – 1,91 MPa; 100 : 1 – 1,59 MPa; 100 : 2 – 1,71 MPa. The above data show that an increase in the amount of added humates from 0.1 to 3 g per 100 g of urea melt leads to an increase in the granules strength from 1.38 to 2.18; 1.37 to 2.03; from 1.36 to 1.91 MPa, respectively, for sodium, potassium and ammonium humate. The highest urea strength is obtained when sodium humate is used, i.e. 2.18 MPa. The hygroscopic points of fertilizer granules were determined by f N.E. Pestov's method. The hygroscopic fertilizers point values obtained at various urea mass ratios: humate according to N.E. Pestov's hygroscopicity scale refers to hygroscopic substances, and they are more hygroscopic than the original carbamide (75.3%). In fertilizers obtained at $(NH_2)_2CO$ mass ratio: humate = 100: 3 gyroscopic point is reduced to 65.8; 68.8; 69.4%, respectively, for sodium, potassium and ammonium humate. When processing humate-containing kabamide melts into granular fertilizers, their rheological properties play an important role. In this regard, the melts density and viscosity were studied at the above carbamide weight ratios: humate in the temperature range 142-145°C. The results are shown in table 3. Experimental data show that the density and viscosity value mainly depends on the humate temperature and mass fraction introduced into the urea melt. Both the density and the viscosity decrease with increasing temperature, and vice versa, increase in the amount of humate in the urea melt. An increase in the amount of humate addition from 0.1 to 3 g per 100 g of carbamide melt at 142°C temperature leads to an increase in the melts density and viscosity from 1.294 to 1,1375 g/cm^3; from 3,15 to 3,38 cpz; from 1,281 to 1,354 g/cm^3; from 3,12 to 3,32 cpz; from 1,285 to 1,366 g/cm^3; from 3,14 to 3,35 cpz for sodium potassium and ammonium humate, respectively. A similar pattern is observed at other temperatures. The highest density and viscosity of urea melts with sodium humate addition. So, if, when using sodium humate as an additive to urea, the melt density and viscosity with urea: humate sodium = 100 : 3 and 142°C temperature are equal to 1,294 g/cm^3 and 3,15 cpz, then, in the ammonium humate, these indicators are respectively 1.285 g/cm^3 and 3.08 cps. However, in any case, with the studied carbamide ratios: humate in the temperature range 142-147 °C, all urea-humate melts samples have sufficient fluidity, which creates favorable conditions for their granulation in the existing granulation tower without any special technological difficulties. It is known that the lower the water solubility of urea granules, the slower nitrogen is released from the fertilizer in the soil, which exhibits a prolonged effect on the plant. So, if the complete dissolution of industrial $(NH_2)_2CO$ granules is on average 112 seconds, then the humates introduction into its composition in the powder form in an amount from 0.1 to 3 g per 100 g of carbamide reduces the dissolution rate of the product granules from 113 to 182 seconds, respectively (table 4).

It should be noted that the average humate consumption when applied together with mineral fertilizers is 4-7 kg per 1 hectare of sown area and the urea application rate, depending on the plant type, is from 100 to 200 kg per 1 ha in nitrogen. Considering the above, we consider the optimal mass of carbamide to humates ratio to be 100: 1. In this case, urea contains 45,64; 45,67; 45,80% N and 0,807; 0,813; 0,842% humates, and its granules strength is 1,78; 1,65; 1,59 Mpa, respectively for sodium humate, potassium and ammonium.

Conclusions

Thus, conducted research on the granular urea production based on sodium humate, potassium and ammonium and urea melt showed the fundamental possibility of obtaining humated carbmides with sufficient granules strength. Humatized urea granules have weaker solubility compared to pure urea, i.e. they will gradually release nutrients, as a result of which nitrogen losses in the soil are reduced, humates in the urea composition increases the application efficiency, enhance biological activity in the soil, which contribute to significantly improve the agrochemical and agrophysical properties of the soil and increase its fertility.

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