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Hydroxybenzoic Acids and Their Esters: General Characterization, Synthesis, Properties and Areas of Application

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Abstract

The review of the results of scientific research in the field of obtaining and studying the properties of hydroxybenzoic acids and their esters is presented. The main representatives of this class of organic compounds, in particular, *o*- and *p*-hydroxybenzoic acids and their alkyl and cycloalkyl esters are considered. It is known that *p*-hydroxybenzoic acid is present in many organisms and acts as an intermediate in the biosynthesis of a number of other compounds. Its esters are used as preservatives in the cosmetic, pharmaceutical and food industries. It occurs in nature both in the free form and in the form of derivatives. Salicylic acid has a bactericidal effect, its salts and esters are often used in medicine and veterinary medicine as drugs. It is reported that these compounds have high antimicrobial and antifungal activity against various microorganisms and fungi. The representatives of hydroxybenzoic acid esters are widely used in medical practice as bacteriostats.

The main methods for the synthesis of hydroxybenzoic acids and their derivatives, in particular esters, salts and nitrogen-containing derivatives, are shown. It was stressed that *o*- and *p*-hydroxybenzoic acid esters are usually obtained from phenol in two stages according to the classical scheme: carboxylation of phenol with the introduction of a COOH group, and subsequent esterification with alcohols under the conditions of acid catalysis. The results of the author's own research are presented, in particular, the addition reactions of benzoic acid to polycycloolefin hydrocarbons were carried out, and the corresponding esters were obtained in a high yield. The influence of various reaction parameters on the yield of the target product was studied.

Keywords: hydroxybenzoic acids, parabens, aromatic acid esters, phenolic acids

INTRODUCTION

At present, the development of new medicinal preparations includes the synthesis of complicated organic molecules. In this respect, the synthesis of compounds possessing pharmacological properties through the formation of structures that contain the fragments of biologically active compounds is relevant. The fragments of these molecules bound with, for example, amine or ester bonds are easily cleaved in the organism under the action of enzymes. They may either cause a specific pharmacological effect after delivery to the corresponding human organs or enhance the action of each other exhibiting synergism. In addition, the manifestation of higher bioavailability is possible when they enter an organism. In this direction, the compounds deserving special attention are hydroxybenzoic acids (HBA) and their derivatives, in particular esters, amides, etc. However, these compounds demonstrate not only pharmacological effect but also other valuable properties, so the studies in the area of synthesis, investigation of the properties and areas of application of HBA and their functional derivatives undoubtedly causes theoretical and practical interest.

REPRESENTATIVES OF BENZOIC ACIDS

Hydroxybenzoic acids belong to the class of aromatic carboxylic acids and possess the properties of carboxylic acids and phenols. HBA may be also considered as the derivatives of aromatic hydrocarbons in which the hydrogen atoms of benzene rings are substituted by carboxylic and hydroxyl groups. Because of this, these compounds are characterized by the properties that are due to the presence of both kinds of functional groups and the aromatic core in the molecule.

Hydroxybenzoic acids are widespread in nature. They may be extracted from natural raw materials (blood-red hawthorn, black chokeberry, propolis), and also they are the major components of wood pitch formed as a residue during the distillation of wood resin (55–85 %) [1]. For instance, two diphenyl esters – 4-(2-carboxy-3-heptyl-5-methoxyphenoxy)-2-heptyl-6-hydroxybenzoic acid (micareic acid) and 4-(2-carboxy-3-heptyl-5-methoxyphenoxy)-2-heptyl-6-hydroxy-3-methoxybenzoic acid (methoxy-micareic acid), as well as depside (an ester of aromatic hydroxycarboxylic acids) – 4-(2-heptyl-6-hydroxy-4-methoxybenzoyloxy)-2-heptyl-6-hydroxybenzoic acid (prasinic acid) were detected in lichens of Micarea prasina Fr. Genus [2]. As a result of the investigation of Vietnamese lichen Ramalina farinacea Ach., eight new compounds were isolated, and their structures were established. There are two diphenyl esters among these compounds: 3-(2-carboxy-5-methoxy-3-propylphenoxy)-2-hydroxy-4-methoxy-6-propylbenzoic acid (ramalic acid A) and 3-(2-carboxy-5-methoxy-3-propylphenoxy)-2-hydroxy-4-methoxy-6-pentylbenzoic acid (ramalic acid B) [3].

The major representatives of mono-, di- and trihydroxybenzoic acids are characterized in Table 1.

In general, phenoloacids are solid crystalline substances with comparatively low solubility in cold water but well soluble in hot water and many organic solvents; their solubility increases with an increase in the number of phenol groups.

There are some reviews in the scientific literature that are dealing with the analysis of studies in the area of synthesis of HBA and their derivatives, and investigation of their properties. For instance, review [4] presents the results of the studies in the area of synthesis and investigation of biological activity of phenol-containing compounds including phenolic acids and the areas of their application. Results on the synthesis of *p*-HBA and its esters, investigation of their properties and the areas of their application are described in [5].

Among the major representatives of HBA and their derivatives, it is necessary to highlight the following compounds:

1) Salicylic acid, its salts and esters (salicylates). This acid possesses a bactericidal effect, its salts and esters are often used in medicine and veterinary as medicinal preparations. Salicylic acid is widely used for the production of staining paints, fungicides (salicylanilide), fragrant substances (methyl salicylate, benzyl salicylate), antiseptics in the food industry, conservation, production of medicinal substances (acetylsalicylic acid, phenyl salicylate), as reagents for the colorimetric determination of iron and copper in solutions, as an acid-base indicator for luminescence analysis, *etc*. [6].

2) Acetylsalicylic acid (aspirin) is widely used in medicine and veterinary as an antipyretic, anti-inflammatory, antirheumatic and antineuralgic agent [7]. Phenyl salicylate (salol, musolim) is used as a disinfectant in the treatment of some intestinal diseases and articular rheumatism. The methyl ester of this acid (methyl salicylate) has a strong typical odour, possesses bactericidal properties and is used to aromatize various food products, cosmetics and perfumery [8]. It is a colourless liquid and is known as synthetic checkerberry oil [9–12].

3) Gallic (3,4,5-trihydroxybenzoic) acid has a tannic taste and is a component of the molecules of tanning substances, in particular the major one - tannin. The high content of tannin is observed in oak bark and especially in galls. Gallic acid is incorporated into tannin molecule in the form of depside (digallic acid), which is an ester formed by two molecules of the initial compound. Tannin is used as a puckering agent, in the leather industry for tanning leather and fur products, and in chemical analysis as an alkaloid reagent [13].

4) *p*-Hydroxycarboxylic acid is present in many organisms and plays the part of an intermediate compound in the biosynthesis of a number of other substances [14]. It occurs in nature both in the free form (in hypericum, chaste tree, coconuts, vanilla, Antillean gooseberry, reishi mushroom, russulas, non-filtered olive oil, grape wine *etc*.) and in the form of derivatives [15]. Biosynthesis of this acid in microorganisms and fungi proceeds through enzyme-catalyzed pyruvate reaction [16]. Many symbiont bacteria form *p*-HBA from phenylalanine and tyrosine through the stage of the formation of *p*-coumarate in the organisms of plants, animals and humans. This acid serves as the raw material for obtaining

TABLE 1

Physicochemical characteristics of the major representatives of hydroxybenzoic acids

Hydroxybenzoic acid	Position of hydroxyl group	T_m, °C	n_D^{20}	Solubility in water, mass % (25 °C)
	Monohydroxybenzoic			
Salicylic (2-hydroxybenzoic)	2	159.5	1.4430	1.80
3-Hydroxybenzoic	3	203	1,4840	1.07
4-Hydroxybenzoic	4	216.3	1.4820	0.49 (20 °C)
	Dihydroxybenzoic			
Pyrocatechuic (2,3-dihydroxybenzoic)	2, 3	204	1.5420	–
β-Resorcylic (2,4-dihydroxybenzoic)	2, 4	227	–	0.57
Gentisinic (2,5-dihydroxybenzoic)	2, 5	205	–	2.10
γ-Resorcylic (2,6-dihydroxybenzoic)	2, 6	167	–	2.80
Pyrocatechuic (3,4-dihydroxybenzoic)	3, 4	200–202	1.5420	–
α-Resorcylic (3,5-dihydroxybenzoic)	3, 5	238–240	–	10.10
	Trihydroxybenzoic			
Pyrogallic (2,3,4-trihydroxybenzoic)	2, 3, 4	207–208	–	–
Oxyhydroquinonic (2,3,5-trihydrpoxybenzoic)	2, 3, 5	234–235	–	–
2,4,5-тригидроксибензойная	2, 4, 5	217–218	–	–
Phloroglucinic (2,4,6-trihydroxybenzoic))	2, 4, 6	100	–	–
Gallic (3,4,5-trihydroxybenzoic)	3, 4, 5	240	–	1.16
2,3,6-trihydroxybenzoic	2, 3, 6	189–190	–	–

Note. Dash means the absence of data

synthetic fibres (Vectran). It is used in the production of the components for colour films [17].

The esters of *p*-HBA known as parabens are widely used in the pharmaceutical and perfumery industry. Parabens do not possess specific odour, colour and taste, they are relatively non-toxic, non-mutagenic and do not get accumulated in organisms. They are used for the conservation of weakly acid food products that cannot be conserved with acids (dairy desserts, coats for meat products and cheese, fillers for confectionery and bakery) [18].

Parabens are components of plant alkaloids and pigments. This group includes seven compounds: heptyl ester of *p*-HBA (E-209), ethyl ester of *p*-HBA (E-214), the sodium salt of the ethyl ester of p-HBA (E-215), propyl ester of *p*-HBA (E-216), the sodium salt of propyl ester if *p*-HBA (E-217), methyl ester of *p*-HBA (E-218), the sodium salt of methyl ester of *p*-HBA (E-219).

All the listed compounds possess higher bactericidal action than benzoic acid and are substantially less toxic. They are not able to dissociate, so their antimicrobial action is independent of the acidity of the medium. These preparations are efficient in neutral and weakly acidic medium but are readily saponified in the alkaline medium. Their antimicrobial action involves the destruction of cell membranes of microorganisms and denaturation of intracellular proteins, and this effect increases with an increase in the size of the alkyl fragment. The most widespread compound among the indicated substances is the ethyl ester

of *p*-HBA (E-214), which is a white powder with a slight anesthetic effect.

A strong bactericidal effect and low toxicity of the esters of *p*-HJBA with the alkyl chain C_1–C_7 were reported in [19]. Due to these characteristics, these compounds are used as multipurpose preservative agents providing an increase in the storage time of the substances. The antimicrobial effect of these esters is based on deceleration of the assimilation of glucose and proline, and perturbation of the complex structure of cell membranes. In the cited work, diazotization of *p*-aminobenzoic acid with sodium nitrite was used to obtain *p*-carboxyphenyldiazonium hydrosul-phate; its subsequent hydrolysis leads to the formation of *p*-HBA. As a result of the esterification of this acid with octyl, nonyl and decyl alcohols, the corresponding esters of *p*-HBA were synthesized. Investigation of the surface tension of the aqueous solutions of octyl-, nonyl- and decyl-*p*-hydroxybenzoates demonstrated the low surface activity of these compounds. It was assumed that the esters of p-HBA undergo hydrolysis during dissolution in water, with the formation of initial compounds, that is, the acid and an alcohol, which distorts the results of measurements [19].

METHODS OF OBTAINING HYDROXYBENZOIC ACIDS AND THEIR ESTERS

It was reported in [20] that *p*-HBA and its methyl, ethyl, propyl, *n*-butyl and benzyl esters were separated by means of thin-layer chromatography using silica gel of HF254 trademark as the immobile phase. Borate buffer (pH 2) was used as the mobile phase with the addition of organic solvents when necessary. Then silica gel was subjected efficiently to extraction with methanol. It was demonstrated that the best results on the rate of separation were achieved for benzyl and *n*-butyl esters of *p*-HBA.

As a rule, the esters of *o*- and *p*-HBA are obtained from phenol in two stages according to the classical scheme: phenol carboxylation with the introduction of COOH group followed by esterification with alcohols under the conditions of acid catalysis [21]. For instance, as described in [22], salicylic acid was obtained with the yield of 64 % through carboxylation of phenol with the help of CO_2 at increased temperature (200 °C) and pressure 8 MPa for 5 h in the presence of potassium carbonate taken in excess, which is necessary for the formation of potassium phenolate. However, severe reaction conditions, the necessity to use a high-pressure reactor and a moderate yield of the target product hinder the use of this method.

Phenol carboxylation was performed in [23] through its interaction with carbon (IV) oxide in the presence of potassium, magnesium oxides and potassium hydroxide at a temperature of 200 °C and pressure 3 MPa with the formation of salicylic acid at a yield of 40 %. The reaction proceeds for 2 h. However, in this case, too, high temperature and pressure are involved, and the yield of the product is rather low, too.

Phenol carboxylation in the presence of lithium *tert*-butoxide at a temperature of 25 °C in tetrahydrofuran and pentane leads to the formation of salicylic acid with a yield of 42 % [24]. Disadvantages of this procedure also include the low yield of the target product and the necessity to use the stoichiometric amounts of highly reactive inflammable organometallic compound *tert*-butyl lithium.

The authors of [21] demonstrated that carboxylation of preliminarily synthesized sodium phenolate in the presence of triethylphosphine oxide leads to the formation of salicylic acid with a yield of 65 %. The reaction proceeds within temperature range 50–140 °C at CO_2 pressure 1 atm for 1 h with 23 % conversion. However, in this case, a 4-fold excess of the expensive and toxic triethylphosphine oxide is used, and a large amount of wastes is formed. The use of this method is hindered by the difficulty of separating salicylic acid from triethylphosphine oxide.

A known method of the synthesis of a mixture of *o*- and *p*-HBA is based on catalytic carbonylation with simultaneous phenol oxidation with a mixture of CO and O_2. The reaction proceeds at 60 °C for 15 h in the presence of acetic acid and $Pd(OAc)_2$ + $HPMo_{10}V_2$ catalyst; the ratio of reacting components is phenol/CO/O_2 = 4 : 1 : 1. Disadvantages of this method include expensive catalyst, substantial reaction time, corrosion of equipment due to the use of acetic acid as a solvent, as well as inflammability and explosiveness of the procedure due to the use of CO and O_2 [25].

The most selective method of obtaining *p*-HBA is phenol carboxylation with the help of potassium ethyl carbonate at increased temperature (200 °C) [26]. The yield of *p*-HBA is 93 %. It is reported that at 170 °C the yield is only 5 %, and the maximal yield of the target product is achieved when the reaction is carried out at 215 °C and

pressure 25 atm for 7 h. The disadvantages of this method are rigid reaction conditions, the use of expensive potassium ethyl carbonate and process conduction in a high-pressure reactor.

The authors of [27] describe the method to synthesize *p*-HBA by phenol carboxylation with CO_2 in the presence of copper powder β-CyD (β-cyclodextrin) with a yield of 98 %. The reaction proceeds at 80 °C for 15 h in 20 % aqueous solution of NaOH and CCl_4. However, in this case, a large amount of inorganic wastes and waste waters is formed, expensive dextrin is used in excess, and process duration is substantial.

Phenol carboxylation in the presence of sodium carbonate, concentrated hydrochloric acid in the solution of 1-methoxy-2-propanol at a temperature of 100–110 °C and CO_2 pressure 10 atm for 4 h was used to synthesize p-HBA with the yield of 75 % [28]. The formation of a large amount of wastes, the use of very expensive 1-methoxy-2-propanol as the solvent, the difficulties in separating the target product from the reaction mixture hinder the use of this method in preparative practice.

The synthesis of alkyl esters of hydroxyl-, methoxy-, ethoxybenzoic and hydroxytoluylic acids through the interaction of phenol, anisole and cresols with CCl_4 and alcohols in the presence of iron-containing catalysts was described in [29]. The essence of the method is in the interaction of phenol with CCl4 and alcohols (methanol, ethanol, propanol and n-butanol) in the presence of an iron-containing catalyst ($FeBr_3$, $FeCl_3 \cdot 6H_2O$, $Fe_2(CO)_9$, $FeCl_2$, $FeCl_3$, $FeCl_2 \cdot 4H_2O$), at a temperature of 130 °C for 4–8 h in the atmosphere of argon. The authors stress that the most optimal ratios between the catalyst and reagents for this reaction are $Fe_2(CO)_9$/phenol/CCl4/alcohol = 5 : 100 : 500 : 500 at 130 °C for 6 h. Under these conditions, the yields of methyl esters of o- and *p*-HBA are equal to 18 and 20 %, ethyl esters 28 and 45 %, propyl esters 34 and 66 %, *n*-butyl esters 38 and 62 %, respectively.

The synthesis of the methyl ester of 4-*n*-amyloxy-, 4-*n*-butoxy-, ethyl ester of 4-*n*-propoxy-, *n*-propyl ester of 4-ethoxy- and *n*-butyl ester of 4-methoxybenzoic acids and their hydrolysis leading to 4-*n*-alkoxybenzoic acids was described in [30].

The improved method of the synthesis of alkyl esters of *p*-HBA was proposed in the patent [31]. As a rule, the listed esters are obtained via the interaction of *p*-HBA with the corresponding alcohol in the presence of a catalyst (sulphuric acid). Thus synthesized ester contains a large amount of unreacted alcohols, free acid and other admixtures formed as side products during esterification. Washing the reaction mixture with water and alkali leads to the removal of some admixtures as a part of water-soluble lower alcohols. However, a finer purification procedure should be applied to obtain the product suitable for use as a good preservative agent. A common purification procedure is ester recrystallization from a proper solvent. The second procedure for the purification of the esters of *p*-HBA is simple vacuum distillation. The method for obtaining the indicated esters proposed by the authors is distinguished by cheapness, simplicity of implementation without the use of solvents, it proceeds almost without the formation of side products with the quantitative yield of the target product having excellent colour, odour and maximal purity. This method includes a usual esterification stage, washing followed by special treatment with steam both at the atmospheric pressure and at reduced pressure. So, the essence of the proposed method is in using the steam treatment of the product, which allows one to exclude the disadvantages typical for other procedures.

The synthesis of HBA esters conjugated with phenazine-1-carboxylic acid was carried out, and their biological activity with respect to five pathogenic fungi was investigated [32]. A high level of fungicidal activity was demonstrated, especially with respect to Rhizoctonia solani.

The authors of [33] proposed a method of HBA esterification through the interaction with halogenated carbon in the homogeneous liquid phase in the presence of a tertiary amine.

It was demonstrated in [34] that the production of shikonin by the cell cultures of *Lithospermum* is induced by cell transfer in the productive medium. The authors stress that six phenol derivatives (*p*-HBA, salicylic, caffeic, sinalic, ferulic acids and syringaldehyde) were discovered both in shikonin-producing cells and in non-producing ones. The content of these derivatives in the former cells was much higher than in the latter. Exogenous addition of *p*-HBA caused an increase in the productivity of shikonin in cells.

It was demonstrated that *Mycobacterium tuberculosis* bacteria are able to cause chronic infections and diseases affecting the congenital and adaptive immune reaction of the organism [35]. The cell walls of bacteria have a very complicated composition and contain large amounts of glycosylated compounds among which

the derivatives of *p*-HBA are the most important compounds. The authors of [35] carried out the synthesis of a significant class of biomolecules of glycan type and carried out the first *in vitro* investigation of the immunomodulating action of these compounds with respect to the indicated bacteria. It was established that the derivatives of *p*-HBA do not possess stimulating properties; quite contrary, they may inhibit the synthesis of inflammatory cytokines, in particular interferon-γ.

It was stressed in [36] that glycated methyl esters of *p*-HBA and structurally related glycolipids of phenolophthiocerol are important factors of *M. tuberculosis* virulence. Though both types of molecules are considered to be the derivatives of *p*-HBA, the origin of this assumed biosynthetic precursor in mycobacteria is to be established. The authors proposed a probable mechanism of the formation of *p*-HBA in the cells of the indicated microorganism.

The synthesis of 4-(3-(benzylydene-amino)-phenylazo)-phenyl ester of 4-*n*-alkoxybenzoic acid was carried out and its biological activity was characterized [37]. The authors report mesogenic properties if the synthesized compound.

The bacteriostatic effect of the alkyl esters of *p*-HBA with respect to Aerobacter aerogenes was studied in [38]. It was demonstrated that the high concentrations of alkyl-4-hydroxybenzoates provide efficient inhibition of the growth of this microorganism.

The authors of [39] report the synthesis of some silyl esters of acetaminophen and methylsalicylate with the general formula $ArOSiRR^1R^2$ (ArOH is p-hydroxyacetanilide or methyl ester of 2-HBA; $SiRR^1R^2$ is trimethylsilyl, triethylsilyl, dimethyl-*tert*-butylsilyl, triphenylsilyl, dimethylvinylsilyl) and their properties. It was established that these compounds may serve as synthons for obtaining a number of prodrugs.

The decomposition of several alkyl esters of vanilic acid, 3-ethoxy-4-HBA and syringic acid under the action of lignin-decomposing fungus *Polyporus dichrous* was investigated, and a possible mechanism of this process was demonstrated. A connection of the obtained results with lignin degradation was discussed [40].

A liquid crystal polymer known as Vectra was synthesized through the acidolysis of 4-HBA with 6-hydroxy-2-naphthoic acid; the mechanism of its formation was investigated [41]. It was demonstrated that the kinetics of model reactions and real polycondensation reactions are described by the kinetic equation of the second-order reaction; the corresponding rate constants are comparable.

The authors of [42] proposed an improved method to synthesize phenol-containing polyester polymer: HBA, epoxide, polyol and dicarboxylic acid are introduced into polycondensation with the formation of the indicated polymer. The reaction is carried out in two stages. The first stage includes the formation of the adduct (ester–alcohol) between HBA and the epoxy compound, so that the ratio of carboxylic groups in HBA and oxirane groups of the epoxy compound is about 1 : 1, and the second stage involves polyesterification with the indicated adduct.

The synthesis of cycloalkyl esters of HBA through the interaction of cycloalkenes with HBA in the presence of the catalyst (boron trifluoride and concentrated sulphuric acid) at a temperature of 40–125 °C was described in the patent [43]. 2,4- and 2,5-dihydroxybenzamides were obtained from the corresponding methyl esters [44]. The authors of [45] synthesized 4-O-β-*D*-glucosides of hydroxybenzoic and hydroxycinnamic acids: protocatechuic, gallic, caffeic, ferulic and *p*-coumaric acids. Their content in berries and vegetables was determined with the help of capillary and gas-liquid chromatography.

The authors of [46] studied the aerobic metabolism of 4-HBA in the *Archaea* domain through a non-standard route including intramolecular migration. The authors report a haloarcheal strain *Haloarcula* sp. D1, which was grown on 4-HBA as the only source of carbon and energy. It is rather unusual that this strain metabolized 4-HBA through gentisinic acid but not through protocatechuic acid, hydroquinone or catechol. Gentisate was detected in the cultures grown on 4-HBA, and the activity of gentisate 1,2-dioxygenase was induced on the cells grown on 4-HBA. So, the metabolism of 4-HBA in the cells of plants according to the above-indicated route was confirmed.

Hydrolysis of the esters of 4-HBA (parabens) and their aerobic transformation into phenol by the stable strain of *Enterobacter cloacae* (EM) were studied in [47]. This strain was isolated from the commercial dietary mineral additive stabilized with a mixture of methyl- and propylparaben; it is able to hydrolyze approximately 500 mg (in 1 L) of methyl-, ethyl- or propylparaben within less than 3 h in liquid culture, and the supernatant of the culture treated with ultrasound (after 30-fold dilution) was able to hydrolyze 1000 mg (in 1 L) of methylparaben for 15 min.

The authors stress that the first stage of paraben decomposition was the hydrolysis of ester bond with the formation of 4-HBA, followed by decarboxylation leading to the formation of phenol under aerobic conditions; the transformation was stoichiometric. However, in the case of higher paraben concentrations, inhibition of the growth of EM strain was observed.

The addition of benzoic acid to polycycloolefin hydrocarbons was carried out, and esters were obtained with a high yield. In particular, the thermal addition of norbornene to benzoic acid with the formation of bicyclo[2.2.1]heptyl-2-benzoate was studied. At the molar ratio of norbornene/benzoic acid = 2 : 1, temperature 100 °C and reaction time 6 h, the yield of norbornyl-2benzoate was 90 % [48]. In the investigation of the addition of benzoic acid (BA) to tricyclododecene (TD) and tetracyclododecene (TCDD), the optimal conditions for the synthesis of corresponding esters were determined: the molar ratio of TD/BA = 1 : 0.75, temperature 120 °C, duration 5 h, the yield of ester 76.8 % [49]; the molar ratio of TCDD/BA = 1 : 1, temperature 120 °C, reaction time 5 h, the yield of ester 75.8 % [50].

So, the presented review of research works provides evidence of the interest to the studies of HBA and their esters. This allows concluding that the studies aimed at the synthesis of the derivatives of HBA esters and determination of the new application areas for this class of compounds are relevant. Results of these studies form the basis for further broadening of the assortment of HBA derivatives and for the determination of new valuable properties of these compounds.

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