PROSPECTS OF CURCUMIN USE IN NANOBIOTECHNOLOGY

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The aim of the work was a generalization of literature data on the prospects for curcumin usage in biotechnology as a component for biologically active nanocomplexes with anti-inflammatory and antioxidant activity creation. It is emphasized that their effectiveness depends on the solubility in aqueous medium and on the metabolism rate decreasing in the body. Current trend is the development of creation methods of hydrophilic curcumin-based nanostructures to increase the time of its biological action. Its nanostructures with silicium, polylysine, copolymers of lactic and glycolic acids and metal ions are the most promising in this respect. For multicomponent hybrid nanoparticles effective usage the substantiation of their component combined use features is necessary. The practical task is to create and to study the functional properties of such combined nanocomplexes. Curcumin complex with metal ions creation contributes to its water solubility and to increase the efficiency of biological action. These complexes have specific characteristics depending on the nature of metal ion. The creation of curcumin-based biocompatible nanocomposites with amplifiers of its action that are known pharmaceuticals is perspective. Such multifunctional nanocomplexes will facilitate the targeted medicines delivery to the places of pathological processes localization and the reduction of their side effects.

Key words: curcumin, multicomponent nanocomplexes.

Nanomaterials (NM) due to their unique properties, especially fluorescent, attract growing attention for application in biomedicine [1–10] through visualization by fluorescent [1, 11–14] and electron microscopy [1, 15]. Rapidly developing direction of nanomedicine is the creation of biologically active complex biocompatible nanomaterials. For instance, these NM facilitate delivery of drugs into the places of pathological processes localization and cause synergistic effect of medicines [1, 10, 16].

Current problems of nanomedicine have been considered in the works of Ukrainian scientists [2–4, 7, 8]. Fullerenes and carbon nanotubes were used in the synthesis of new complex biologically active NM [3–8]. Such materials characterized by high biocompatibility, low toxicity and high specificity. The practical tasks are to create NM-based combined medicines and to investigate their functional properties [7, 8]. A series of natural and synthetic nanoscale carriers for fluorescent images of biological objects creation and for the usage as medicine transporters has been developed [7].

C_{60}-fullerenes [3, 4, 7–9], nanodiamonds, carbon nanotubes [1, 3, 5, 6, 11], nano silicium dioxide [9, 15, 17–25] occupy an important place for address transport of medicines to target organs. Used nanoparticles should be non-toxic, easily synthesizing or self-assembling and decaying and easily excreting from the body. Today, the most promising structures are nanodiamonds, nano silicium dioxide [9, 17–25], nanostructures which decompose eventually: poly (L-lysine) [22], poly (lactic-co-glycolic acid) (PLGA) [26, 27] and curcumin-based nanoparticles [17–25, 28] (Fig. 1). These nanostructures are not new objects of study, but now they are quite widely used [1, 9–12, 15, 17–26, 27–30].

The investigations, which were conducted during the last half-century, show however, that most of chronic diseases can be cured only through multi-therapy [10, 16, 31]. Curcumin is one of the agents that can be

used to achieve this due to the potential for various diseases treating [16, 23, 31, 32, 33, 34], including cancer [16, 19, 23−25, 33, 34, 35−39].

Multicomponent nanoparticles are those containing two or more components with different biological activity, leading to an increase in the therapeutic effect [40]. That is, in this case, several components are added to the nanoparticle-carrier. Multicomponent hybrid nanocarriers will eventually become the basis for targeted and controlled low-toxic medicines release in target cells [1].

New NM application in biomedicine requires a comprehensive study of their properties. Taking into account curcumin biocompatibility, fluorescent response and light availability it is hoped that the structures based on it will match similar tasks [17−25, 28]. Curcumin is a hydrophobic substance that prevents its use in aqueous media (solutions), but the methods of different types of hydrophilic surface nanoparticles creating have been already developed [28], which provides the possibility of surface functionalization by necessary organic compounds [15, 26].

Among the methods for nanoparticles creating, there are the necessary components inclusions (capture) during the synthesis or aggregation, or the use of porous structures with large surface. For example, mesoporous nanoparticles of silicium dioxide is such nanosystem for improvement the bioavailability of poorly water-soluble medicines and biologically active substances (BAS) [9, 15], including curcumin [17−25]. Also short-chain polymers [10, 22, 26, 27], which are capable of self-assembling, and curcumin molecular complexes with multicharged metal ions [28] are used for this purpose. The complexes (conjugates) of medicines created in such a way are promising to overcome tumor resistance to the action of medicines [10, 16] and to their address transportation [10]. The combination of nanoparticles with fluorescent labels makes it possible to use them for visualization of organelles and biological processes on the surface and inside cells [1, 15, 17−25, 41−43].

For effective usage of hybrid multi-component nanoparticles, it is necessary to study the synergistic action of these substances.

Turmeric (curcumin) medicinal properties

In India, turmeric plant that contains curcumin is added to curry for cooking, in Japan and Korea it is added to drinks, in the United States it is used as a dye and preserving agent of foods, such as mustard sauce, cheese, butter and chips. Curcuma medicinal properties are known for thousands of years in India and China, where it is used as antiseptic and anti-inflammatory agent, for the relief of gastrointestinal discomfort, and in cosmetics [44].

Many nutraceuticals with addition of curcumin are used in the treatment of
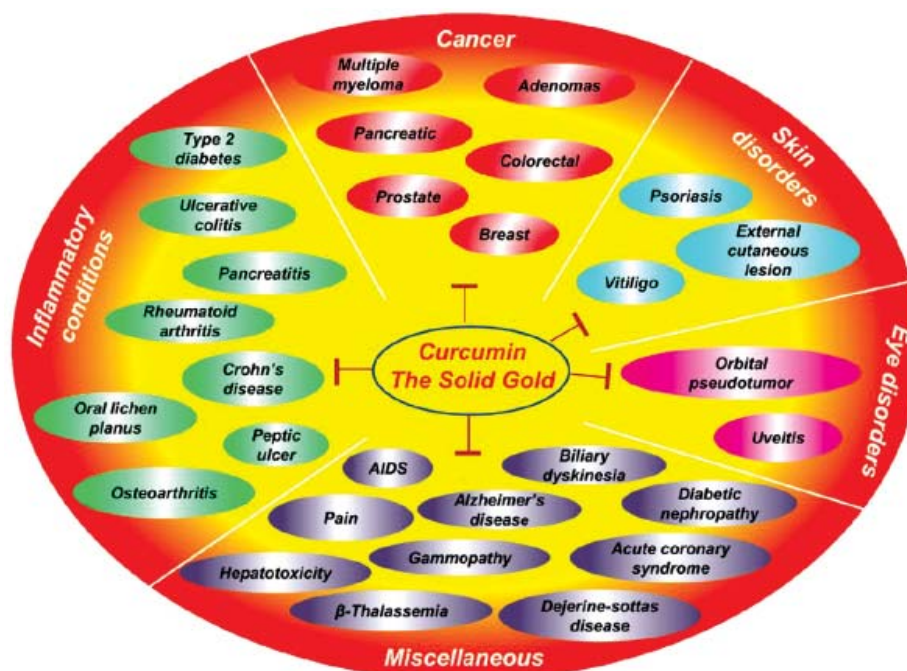

Fig. 1. **Curcumin effectiveness in the treatment of a number of human diseases according to the results of clinical trials [33]**

inflammatory diseases [10, 16]. As far back as 1995, it has been shown that curcumin exhibits anti-inflammatory activity [33]. However, the interest in curcumin research has increased dramatically only in the last years. As of October 2015, there were over 8.000 articles related to curcumin in the PubMed database. In clinical trials of curcumin, it is recommended as a component of medicines in a safe oral dose of 8 g or less per day [33] as well as in a daily dose of 12 g per 3 months [31].

Curcumin is now considered as promising agents for the treatment of a number of diseases [32, 33]. However, the most prominent results of curcumin action were obtained only in experiments *in vitro*. The results of curcumin action evaluation *in vivo* on rodents do not coincide with those obtained in model experiments on cell lines [32, 33].

In addition to the above considered activity, curcumin has shown a positive impact on a number of other diseases, including those of eyes, lungs, liver, kidneys and gastrointestinal and cardiovascular, nervous systems, as well as muscle atrophy, obesity, diabetes; it is used as early wound healing medicine in the treatment of burns and as analgesic [33] (Fig. 1).

Curcumin is more effective against blood clotting than aspirin and does not cause stomach irritation [33]. Curcumin, taking part in several signaling pathways, has various positive effects at cellular and organism level that provides the basis for its application in case of many human diseases [34] (Fig. 2).

Curcumin inhibits lipid peroxidation in microsomes of rat liver and exhibits antioxidant activity in blood plasma, platelets and numerous cell lines. It has been shown that *in vitro* curcumin completely inhibits the production of superoxide anion, incapacitates hydrogen peroxide and nitrite radicals [33]. Over the past few years in many experimental models, it has been shown that curcumin can decrease the inflammatory response [46, 58]. Curcumin in cell lines shows antioxidant and pro-apoptotic [33, 34], antimicrobial activities [33, 45, 46]. Its antifungal properties have been proved on 14 tested strains of *Candida* [33, 46]. In some samples of cell cultures, curcumin showed antivirus [33, 45–47], antiparasitic activity against African trypanosomes, adult worm *Schistosoma mansoni*, antimalarial and nematodocidal activity [33].

Curcumin reduces beta-amyloid accumulation in the mouse model for Alzheimer's disease [33, 48], while keeping anti-inflammatory effect [49]. It can cross the hematoencephalic barrier and reduce the concentration of amyloid plaques. In animals, it has been shown that curcumin is a preventive
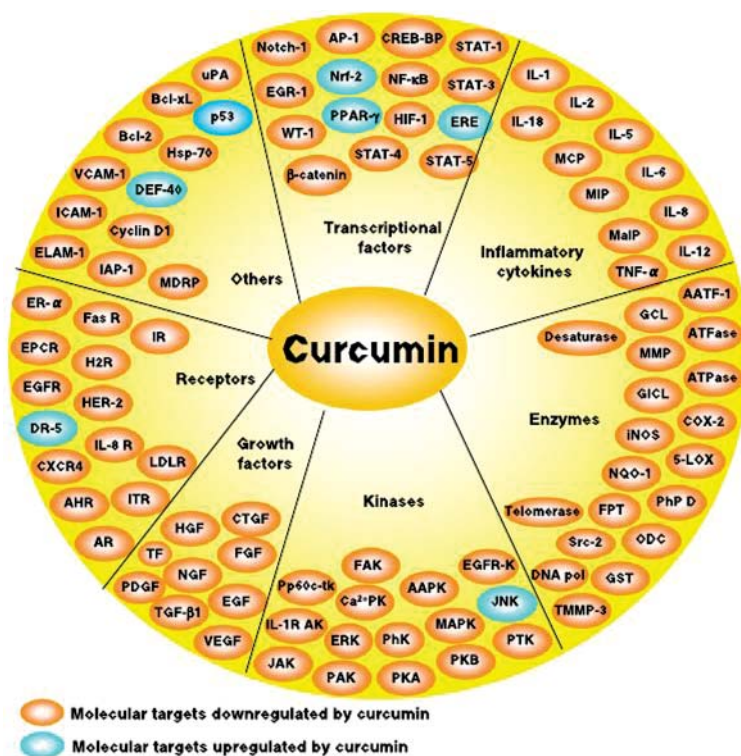

Fig. 2. **Curcumin molecular targets [34]**

agent against Parkinson's disease and epilepsy [33, 50, 51]. It exhibits antidepressant activity in model of depression in mice [33, 35–39].

Curcumin as anticancer agent

For the last decades in a number of experimental models *in vitro* and *in vivo* it has been shown that curcumin has preventive and therapeutic potential against cancer and radiation damage [33, 34, 35–39]. Fig. 3 schematically shows preventive and therapeutic potential of curcumin against certain types of cancer [34].

Curcumin inhibits the growth of many cancer cells, causing cytotoxic effect. The main mechanism is the induction of apoptosis. Curcumin also inhibits the proliferation of malignant cells [33, 52] (Fig. 4).

It also helps eliminate chemo resistance of tumor cells. For example, curcumin along with 5-fluorouracil enhances apoptosis [33, 41].

Altogether, the potential of curcumin as a therapeutic agent against many human diseases is generally understood. At this time, dozens of clinical trials are conducted for the further assessment of curcumin therapeutic potential [32, 33].

Curcumin chemical properties

Researches of curcumin are under way more than four decades. Its antioxidant activity is shown, which can be used in the treatment of a number of chronic diseases [33, 34, 35–39].

The studies of chemical structure include the methods of its extraction from turmeric, laboratory synthesis, chemical and
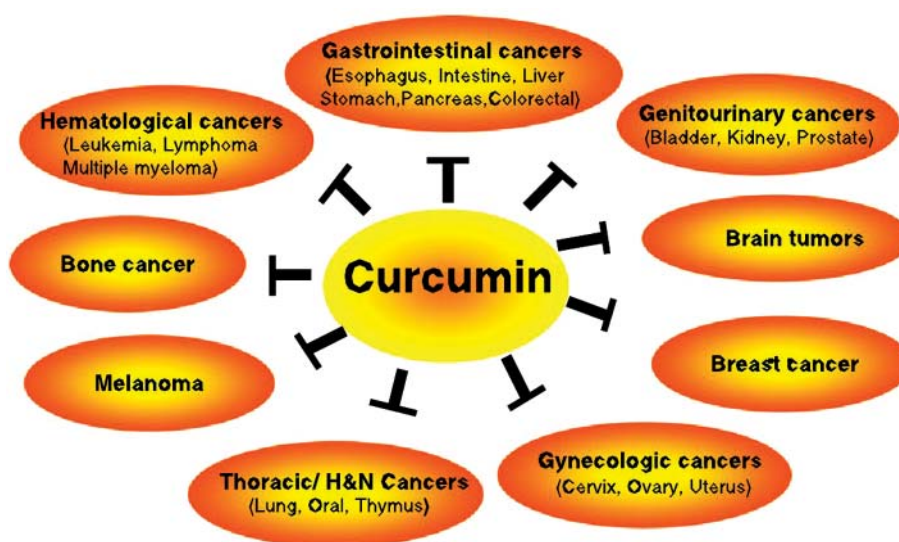

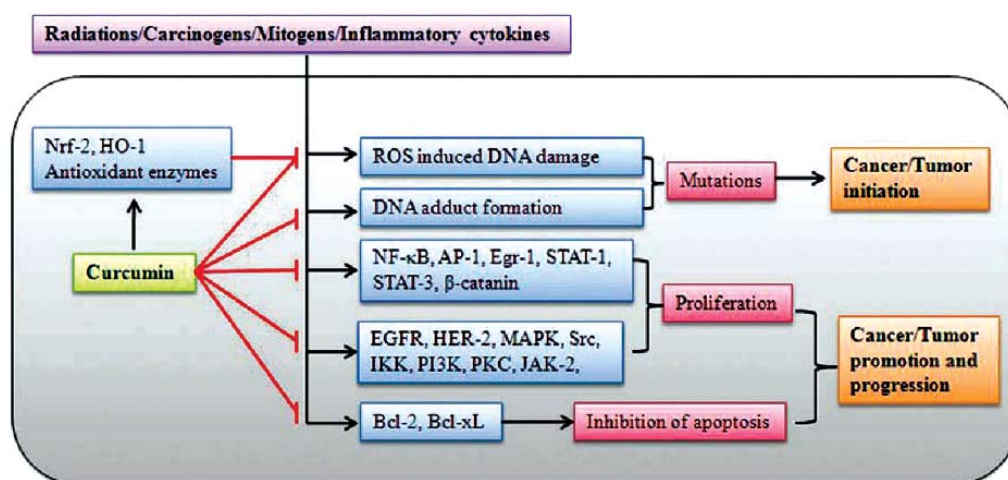*Fig. 3*. **Types of cancer against which curcumin has preventive and therapeutic effects [34]**

Fig. 4. **Curcumin anticancer effects [52]**

photochemical processes of degradation and metabolism.

In analytical chemistry, the unique spectroscopic properties of curcumin absorption are used for the detection and quantification of trace elements, such as boron, which complexes with curcumin have red color (Fig. 5) [53, 54].

In curcumin organic chemistry, one of the main subjects of the research is the synthesis of curcumin and its new synthetic derivatives [53].

Curcumin (diferuloylmethane) is a substance with the chemical formula $C_{21}H_{20}O_6$ and the molecular weight of 368.38. It has three functional groups in its structure: two aromatic rings containing chain linked o-methoxy-phenol groups composed of seven carbon atoms with alpha-, beta-unsaturated diketone group. Di-keto-ether groups possess keto-enol tautomerism (Fig. 6) [54, 55].

Curcumin has three reactionary active functional groups: one diketone fragment and two phenol groups. Often the loss of hydrogen during the reaction leads to curcumin oxidation. Thanks to conjugation, ϖ·-electrons "cloud" is united throughout the molecule. Curcumin in a solution exists as cis-trans isomers. Calculated curcumin dipole moment in the ground state is equal to 10.77 D. This is hydrophobic molecule with a value of log P about 3.0. Curcumin is practically insoluble in water and highly soluble in polar solvents such as DMSO, methanol, ethanol, acetonitrile, chloroform, ethyl acetate, etc., sparingly soluble in hydrocarbon solvents such as cyclohexane and hexane [12].

Curcumin is produced from turmeric long (*Curcuma longa*), which is cultivated in tropical and subtropical regions. The world's largest turmeric producer is India where it is used for centuries in the treatment of many diseases [32, 44].

Depending on its origin and soil growth conditions, turmeric contains 2% — 5% — 9% of curcuminoids. The term "curcuminoid" refers to a group of compounds: curcumin, demethoxycurcumin and bis-demethoxycurcumin (Fig. 7) [32]. Turmeric extract obtained chromatographically has the composition: curcumin — 77% demethoxycurcumin — 18%, bis- demethoxy-curcumin — 5% [31, 32, 44].

The method of solvent extraction followed by column chromatography is mostly used for curcumin separation from turmeric. For this purpose, polar and non-polar organic solvents including hexane, ethyl acetate, methanol, acetone, and so on are used. The best solvent
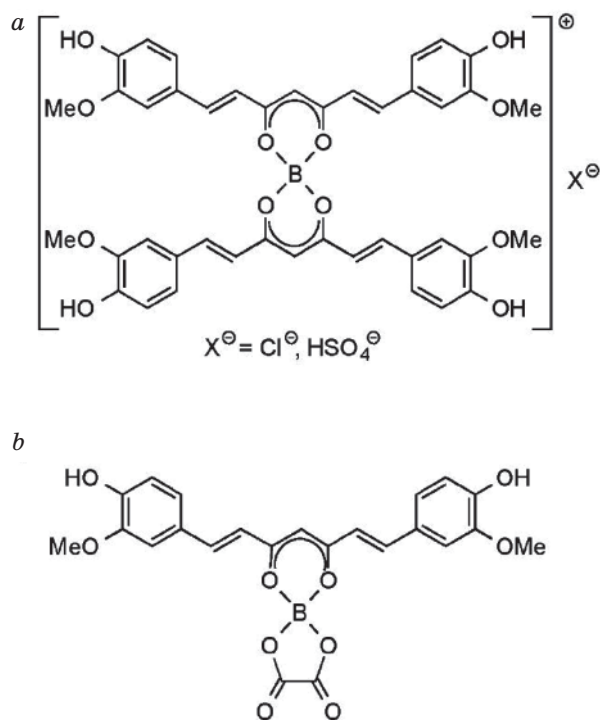

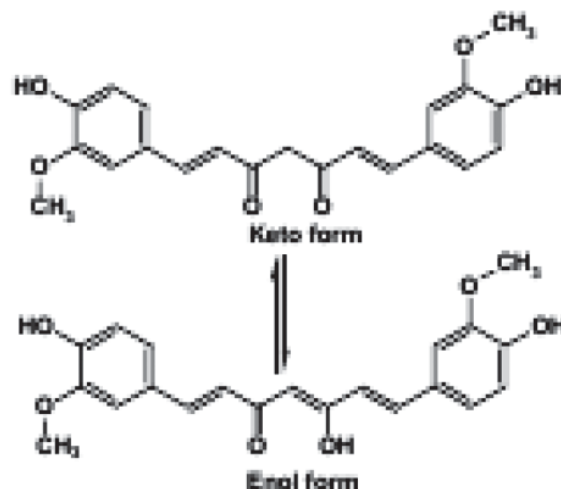*Fig. 5.* **Schematic representation of rosocyanin (*a*) and rubrocurcumin (*b*) [54]**

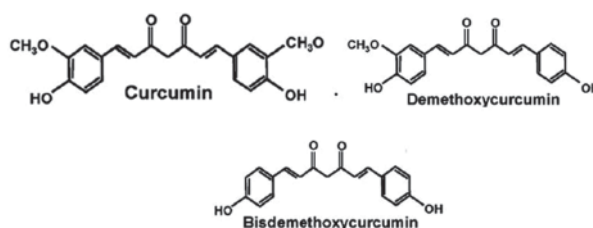*Fig. 6.* **Curcumin keto-enol tautomerism in solution [55]**

Fig. 7. **"Curcuminoids": curcumin, demethoxycur-cumin, and bis-demethoxycurcumin [32]**

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for curcumin extraction is ethanol. Despite the fact that chlorinated solvents extract curcumin from turmeric very effective, they are not used in food industry because of their toxicity [56]. The most frequently the ultrasonic and microwave extraction is used. Temperature rising in the range of 60 to 80 °C increases its yield [56, 57, 58]. For appropriate food additives obtaining the methods of curcumin concentration using, for example, triacylglycerols are used [59].

For curcumin finding, the absorption detectors operating in the wavelength range of 350 to 450 nm or in UV range with the wavelength of 250 to 270 nm are used [12, 44]. The absorption spectrum of curcumin has two intense absorption bands, one in the visible area with a maximum in the range of 410 to 430 nm and the other in the UV region with a maximum of 265 nm. The molar absorption coefficient of curcumin in methanol is equal to $55,000 \, dm^3 * mol^{-1} * cm^{-1}$ at 425 nm. Curcumin is a weak acid with three labile protons. In the pH range of 7.5–8.5 curcumin has color from yellow to red, in alkaline pH (pH > 10) it is fully deprotonated [12].

Curcumin chemical destruction and metabolism

Notwithstanding the fact that curcumin is effective in treating of a number of human diseases, the main problem is its low bioavailability, which is primarily due to the poor solubility in water, low absorption in the digestive system and rapid metabolism,

that leads to its destruction and numerous side effects caused by the metabolites [33]. Curcumin is subjected to chemical degradation in water-organic solvents at elevated pH, which is a serious problem of its application. In dilute (i.e. in micromolar) solutions, the 90% of curcumin becomes degraded for 30 min. However, the percentage of degradation will decrease at low pH values [12, 44]. As a result of curcumin degradation the ferulic aldehyde, ferulic acid, vanillin and feruloyl methane, etc. are formed (Fig. 8) [12].

By photophysical studies, it has been calculated the lifetime of excited curcumin triplet states in µs, suggesting that degradation can occur very quickly and compete with the formation of singlet oxygen. During curcumin metabolism in rats and humans, various products of its decay are produced [60, 61].

When interacting with reactive oxygen species (ROS), curcumin actively absorb them; this property is the basis of its antioxidant activity in normal cells [60, 62–64]. Curcumin [63] and especially its complexes with Cu^{2+} and Mn^{2+} [44] act as imitators of superoxide dismutase. Detailed studies have confirmed that during the reaction with the formation of free radicals, free hydrogen reacts with phenolic -OH group of curcumin, resulting in the formation of phenoxy radicals, which are less reactive than peroxide radicals are, thereby curcumin protects cell from ROS-induced oxidative stress [44].

The degradation is significantly reduced because of the application of the methods
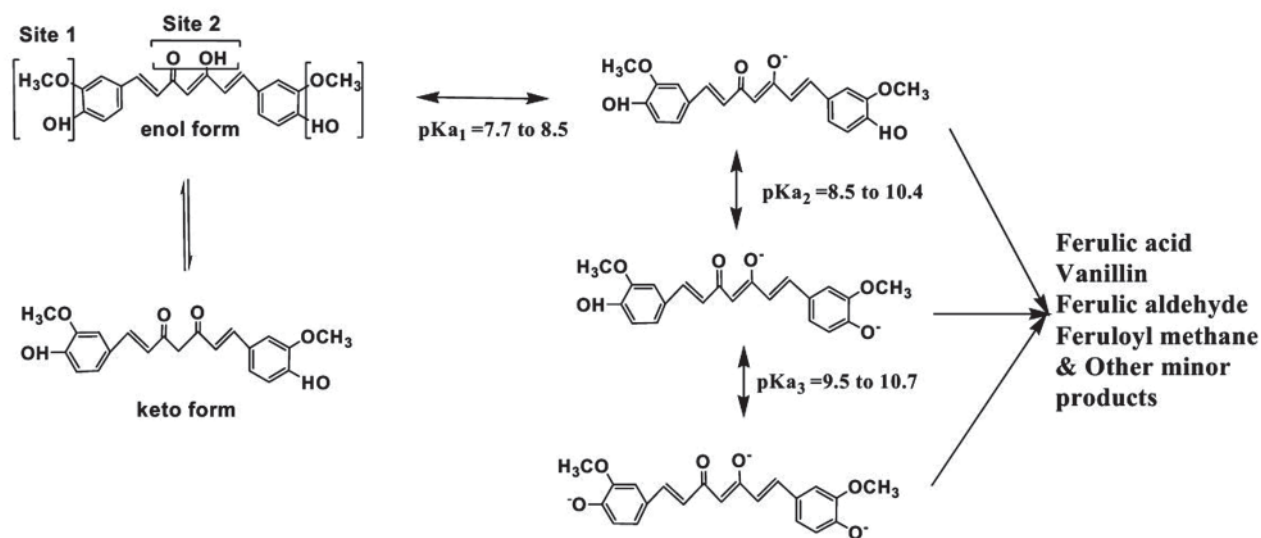

Fig. 8. **Curcumin degradation to: ferulic aldehyde, ferulic acid, vanillin, feruloyl methane and others [12]**

that improve curcumin solubility and reduce its destruction in water, increasing bioavailability. This is achieved by it binding with lipids [29, 30] with the formation of phospholipid complexes of curcumin [33, 65–67], albumin, surface-active polymers and other molecules [33, 60]. There are known curcumin supramolecular complexes with cyclodextrins and cucurbyturyl. Curcumin dissolves in them mainly due to hydrophobic interactions. Curcumin aqueous solutions can be obtained by surfactants, albumin, cyclodextrins and so on adding. To create curcumin high concentrations in water the micellar solutions with surfactants are the most acceptable [60].

The new structures based on hydrogels and biocompatible organic substances such as poly (L-lysine) [22], poly (lactic-co-glycolic acid — PLGA) [26, 27], polyethylene glycol, biopolymers, cellulose, etc. are also developed [33, 65–67].

Other promising approaches for curcumin bioavailability increase include the use of nanoparticles and structural chemical analogues of curcumin [33, 52, 65–67]. Measures for curcumin bioavailability improving using substances called bioenhancers that can block the curcumin metabolism were applied. In pharmaceutical preparations to increase bioavailability, piperine-based enhancers are used [10]. Synergism also occurs when adding quercetine [10, 34], resveratrol [43], silibinin [10], vitamins D, C, E and unsaturated fatty acids that improve it solubility, preservation and transfer in the bloodstream (Fig. 9) [32, 33].

For example, when 2 g of curcumin was administered, its concentration in human blood serum was very low, but the accompanying piperine introduction led to 20 times curcumin bioavailability increase [33, 68].

Curcumin complexes with metal ions
There are known complex formation reactions with virtually all metal ions and S, Se and B [12, 28, 44, 53–55, 69]. Complexes with divalent metal ions [28, 44, 54, 69] and B (Fig. 5), S, Se ions are synthesized and used (Fig. 10) [53, 54, 69].

The stable structures of stoichiometry of 2:1 (ligand: divalent metal ion) and 3:1 (ligand: trivalent metal ion) are known. Curcumin forms three different types of complexes with Al^{3+}, depending on the reaction stoichiometry. Curcumin coordinate bond with metal ions is formed due to enol group where enol proton is replaced by metal ion, and O-methoxy-phenol fragment in complexes remains unchanged (Fig. 11) [55].

Spectroscopically the "metal-oxygen" bond is characterized by infrared signal in the region of 455 cm^{-1}, and carbonyl groups coordinated with metals in the complexes are characterized by a slight peak shift by —10 cm^{-1}. NMR reveals the shift in the curcumin interaction with metal ions [12, 70–72]. Curcumin complexes with transition metals (Ni^{2+}, Zn^{2+}, Pd^{2+}, Fe^{3+} and Mn^{2+}, Cu^{2+}, Co^{2+}, Cr^{3+}) are known [55]. There have been also synthesized the complexes with intransitive and rare earth metals ions (Al^{3+}[72], Ga^{3+} In^{3+} , Sm^{3+} Eu^{3+}, Dy^{3+} [F2], Y^{3+}, Se^{2+}) [12] and metal oxides such as VO^{2+} (Fig. 13) [12, 54].

Complexes penetration into target cell enables their visualization or impact on cell metabolism [25, 28, 44]. Curcumin complexes with Zn^{2+}, Cu^{2+}, Co^{2+} and Ni^{2+} are the most important [55]. The intensity of their fluorescence is enough to obtain a good image in confocal microscopy [28, 44].
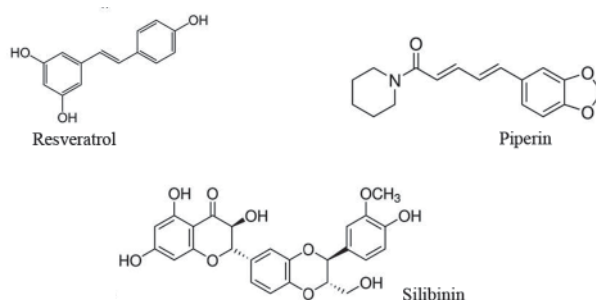
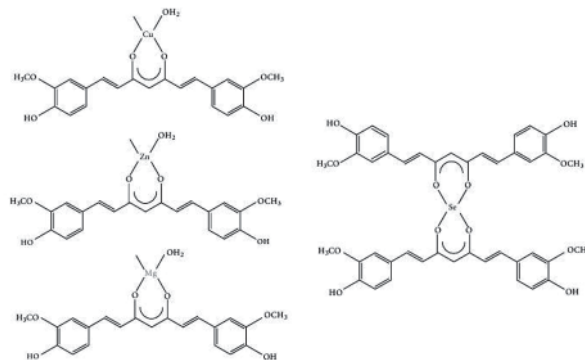*Fig. 9.* **Curcumin amplifiers (synergists): resveratrol, piperine and silibinin [10, 32, 33]**

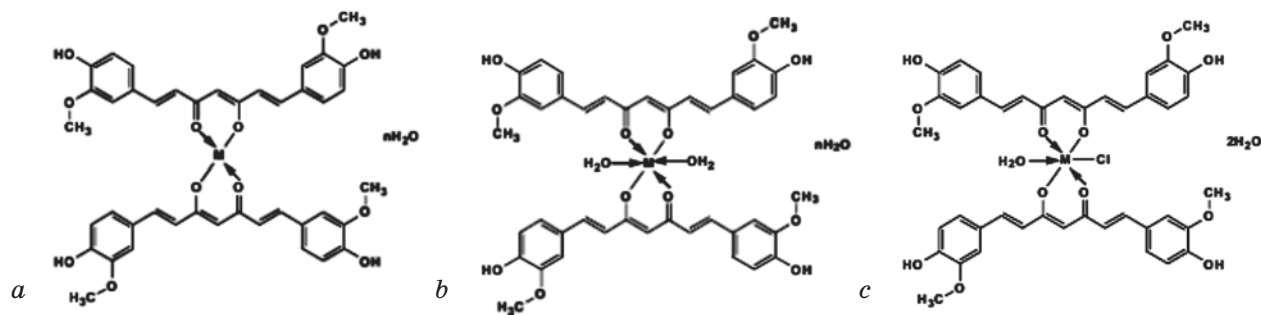*Fig. 10.* **Curcumin complexes structure proposed on the bases of theoretical calculations [54, 69]**

Fig. 11. **Structure of curcumin complexes:**
a — [M(cur)$_2$]*nH$_2$O (where M = Cu II, or Zn II; n = 0, or 2);
b — [M(cur)$_2$(H$_2$O)$_2$]*nH$_2$O (where M = Mn II, Co II or Ni II; n = 0, 2 or 6); c — [M (cur)$_2$(Cl)(H$_2$O)]*2H$_2$O
(where M = Cr III or Fe III) [55]

The structure and physical properties of these systems depend on the nature of the metal ion and stoichiometry in the reaction, which in turn affects their stability and reactivity. Stable (2:1) complexes of some transition metals can be prepared by stoichiometric amounts of curcumin and metal salts mixing in appropriate organic solvents [28, 44]. The complex can be separated as sediment and purified by column chromatography and re-crystallization. Curcumin-metal complexes not only change curcumin physical and chemical properties, but also affect the biological activity of metal ions. In natural conditions, curcumin with metal ions complexes formation plays an important role in reducing metal-induced toxicity. Through coordination with the metal, curcumin reduces the toxicity of heavy metals such as Hg^{2+}, Cd^{2+}, Pb^{2+} [12, 31, 73, 74] and also Cu^{2+} and Mn^{2+} [44]. Weak toxicity of curcumin complexes with Cr^{3+}, Fe^{3+}, Mn^{2+}, Co^{2+}, Ni^{2+}, Cu^{2+} and Zn^{2+} ions on the following microorganisms was found: Gram-positive *Bacillus subtilis* and *Staphylococcus aureus*; Gram-negative *Escherichia coli* and *Pseudomonas aeruginosa,* and two strains of fungi: *Aspergillus flavus* and *Candida albicans* [55]. Metal ion complexes with curcumin can be used in the treatment of Alzheimer's disease; due to it lipophilic nature, curcumin can cross the blood-brain barrier and chelate toxic to neurons metal ions forming stable complexes [12, 44, 71].

Ga^{3+}-curcumin complexes are under development in innovative bioceramics. In rats Zn^{2+}-curcumin complexes cause anticancer, gastroprotective and antidepressant effects. Au^{3+}-curcumin complexes show anti-arthritic effect [55], vanadyl-curcumin (VO * (Curc)$_2$)$^{2+}$ complexes show antioxidant and anti-rheumatic action [54].

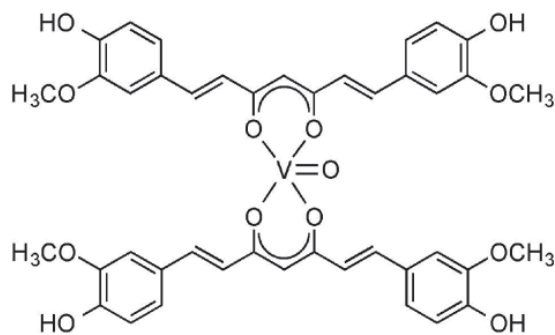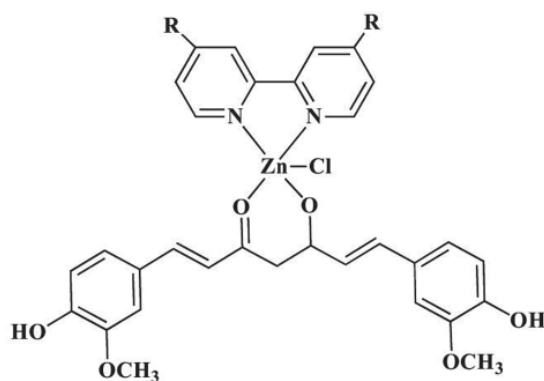*Fig. 12.* **Schematic representation of vanadyl curcumin complex — VO*(Curc)$_2$ [54]**

Fig. 13. **Schematic representation of "curcumin — 4.4'bipirydyn" with Zn^{2+} complex [52, 54]**

Complexes of metal ions with curcumin are also studied as anticancer agents; their activity is more than curcumin activity. Some complexes with metal ions act as antioxidants and some may be pro-oxidants. This antioxidant/pro-oxidant activity of complexes depends on several factors such as the nature of metal ion, coordination number, structure, stability and electrochemical potential of complex [44, 71].

Mixed complexes "metal ion — ligand-curcumin"

Mixed complexes "metal ion-ligand-curcumin" with curcumin to metal ion ratio of 1 : 1 are synthesized, which combine the properties of metal ion, curcumin and ligand. Depending on the purpose of research, their properties may be combined, creating fluorescent probes or specific biologically active substances. Thus, the mixed complexes "ligand-porphyrin-curcumin Cu^{2+}, Ni^{2+} and Zn^{2+}" are created with higher photodynamic activity in models with plasmid DNA [73–76]. If neuroblastoma cells are removed, the complexes "curcumin — 4.4′bipirydyn with Zn^{2+}" are more effective than curcumin alone [52, 54]/

Complexes "curcumin-terpirydyl-lanthanum (La^{3+})" have high photo-cytotoxicity to HeLa cells [74], and mixed ligand-curcumin complexes with rare earth metals such as Sm^{3+}, Eu^{3+} and Dy^{3+} have antibacterial activity [74–76]. In mixed complexes with ligands, curcumin fluorescence remains almost unchanged. Rare-earth complexes of curcumin and pyridine have two-photon absorption in the range of 700–800 nm and such complexes have been used to visualize cells MCF-7 [75]. Complexes "Re $(CO)_3$ * Curcumin * H_2O" [13] luminesce and have affinity for beta-amyloid fibrils that can be used in microscopy to visualize tissue of patients with Alzheimer's disease. Detailed studies of different curcumin-metal complexes are promising for the usage as visualizing agents [12–14].

Multicomponent hybrid nanocarriers

To load with curcumin, different types of nanoparticles are used. It is easy to obtain with high reproducibility the nanoparticles based on curcumin complexes with bivalent ions Cu^{2+} and Zn^{2+} [28, 55]:

Such nanoparticles improve the solubility of hydrophobic curcumin in water and increase its bioavailability [28, 44].

Fig. 15 shows curcumin-Zn^{2+} nanoparticles microphotographs made using scanning electron microscopy and transmission electron microscopy. The sample consists of a large number of spherical nanoparticles with a diameter of about 80–500 nm; each nanosphere has a rough surface [28, 55].

Complex multicomponent nanocarriers [1] are created with a view to provide target delivery of multicomponent compositions into the cells and for their controlled release into cytosol [10, 17–26]. Minimal non-specific binding is achieved through the creation on their basis of composites, or hybrid nanoparticles, coated with polyethylene glycol and receptor compounds. In this manner, negligible toxicity to normal cells is achieved. These nanoparticles can be used for visualization or target transport of medicines into the cells [10, 25, 28, 44]. Curcumin based dual combinations
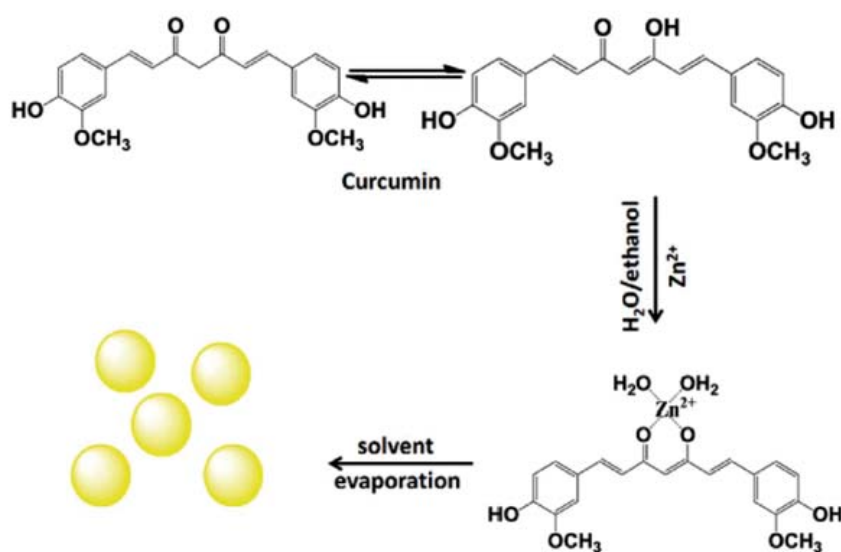

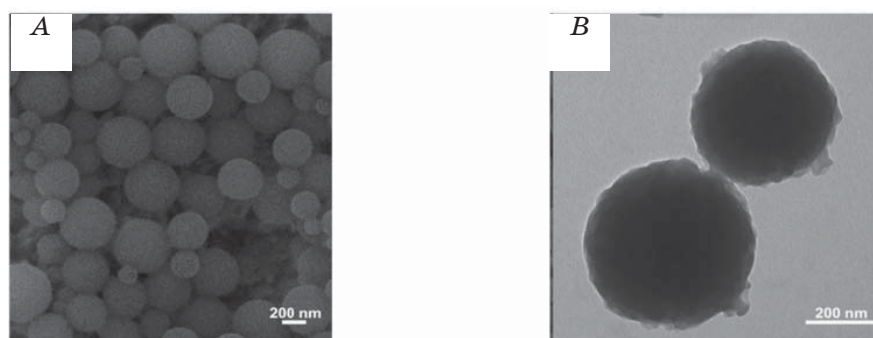*Fig. 14.* **The chart of Zn^{2+}-curcumin nanoparticles formation [28]**

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Fig. 15. **Image of "curcumin-Zn^{2+}" nanoparticles using: scanning (*A*)
and transmission electron microscopy (*B*) [28]**

with a synergistic effect: "curcumin-quercetin", "curcumin-piperin", "curcumin-silibinin" have been developed [10]. Target nanoparticles loaded with multicomponent medicines usage is a new approach to treating cancer multiple drug resistance [10]. The creation of such multicomponent nanoparticles becomes widely used in medicine [1, 10, 15, 26].

Therefore, the practical curcumin usage is motivated by that it causes significant anti-inflammatory and antioxidant effects on the processes in the body and can be used to create complex preparation of antitumor activity. It is hoped that new medicines involving curcumin will be developed, because of its significant biocompatibility. The study of different curcumin complexes with metal ions specific biological activity in order to create new medicines on their basis is actively carried out.

With its inhibitory effect on the malignant cells proliferation, curcumin is used as a supplement to existing medicines. It inhibits the growth of various cancer cells, causing cytotoxic effects associated with apoptosis induction. At action on cancer cells, it also shows radiation-sensitizing activity. Luminescent "curcumin-metal" complexes and mixed complexes "metal ion-ligand-curcumin" are promising for the usage as visualizing agents in microscopy. It is also shown that the efficiency of curcumin action depends on the solubility in aqueous media and on the reduction of its metabolism rate in the body. Hydrophilic structures created with the participation of curcumin complexes with metal ions and nanomaterials with curcumin in their composition, which are nano silicium dioxide, polylysine, poly (lactic-co-glycolic acid) are the most important. The usage of multicomponent hybrid nanoparticles on their basis, supplied with curcumin and amplifiers, for example, with silibinin, quercetine, piperine and medicines, is perspective. These multifunctional nanoparticles will significantly strengthen the effect of medicines at the location of pathological processes and are promising for prevention and treatment of a number of human diseases.

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ПЕРСПЕКТИВИ ВИКОРИСТАННЯ КУРКУМІНУ В НАНОБІОТЕХНОЛОГІЇ

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Метою роботи було узагальнення даних літератури стосовно перспективи використання куркуміну в біотехнології як компонента для створення біологічно активних нанокомплексів із протизапальною та антиоксидантною активністю. Наголошується, що їхня ефективність залежить від розчинності у водному середовищі та зменшення швидкості метаболізму в організмі. Сучасним напрямом є розроблення методів створення гідрофільних наноструктур у складі з куркуміном для збільшення часу його біологічної дії. Найбільш перспективними у цьому сенсі є наноструктури з діоксидом кремнію, полілізином, сополімерами молочної та гліколієвої кислоти та з іонами металів. Для ефективного використання мультикомпонентних гібридних наночастинок необхідним є обґрунтування особливостей сумісного застосування компонентів, що входять до їхнього складу. Практичне завдання полягає у створенні та вивченні функціональних властивостей таких комбінованих нанокомплексів. Використання комплексів куркуміну з іонами металів сприяє розчинності його у воді та збільшенні ефективності біологічної дії. Ці комплекси мають специфічні характеристики залежно від природи іона металу. Перспективним є створення комплексних біосумісних нанокомплексів на основі куркуміну та підсилювачів його дії – відомих лікарських препаратів. Такі багатофункціональні нанокомплекси сприятимуть цілеспрямованому доставленню лікарських засобів у місця локалізації патологічних процесів та зменшенню побічної дії ліків.

Ключові слова: куркумін, мультикомпонентні нанокомплекси.

ПЕРСПЕКТИВЫ ИСПОЛЬЗОВАНИЯ КУРКУМИНА В НАНОБИОТЕХНОЛОГИИ

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Целью работы было обобщение данных литературы о перспективах использования куркумина в биотехнологии в качестве компонента для создания биологически активных нанокомплексов с противовоспалительной и антиоксидантной активностью. Подчеркивается, что их эффективность зависит от растворимости в водной среде и уменьшения скорости метаболизма в организме. Современным направлением является разработка методов создания гидрофильных наноструктур на основе куркумина для увеличения времени его биологического действия. Наиболее перспективны в этом плане его наноструктуры с диоксидом кремния, полилизином, сополимерами молочной и гликолевой кислоты и с ионами металлов. Для эффективного использования мультикомпонентных гибридных наночастиц необходимо обоснование особенностей совместного применения компонентов, входящих в их состав. Практическое задание заключается в создании и изучении функциональных свойств таких комбинированных нанокомплексов. Использование комплексов куркумина с ионами металлов способствует его растворимости в воде и увеличению эффективности биологического действия. Эти комплексы имеют специфические характеристики в зависимости от природы иона металла. Перспективным является создание биосовместимых нанокомплексов на основе куркумина и усилителей его действия — известных лекарственных препаратов. Такие многофункциональные нанокомплексы будут способствовать целенаправленной доставке лекарственных средств в места локализации патологических процессов и уменьшению побочного действия лекарств.

Ключевые слова: куркумин, мультикомпонентные нанокомплексы.