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RESEARCH ARTICLE

Developing and diagnoses new pharmaceutical compounds derivatives from starch and studying their inhibitory and biological activity

Safa Mohammed Jasim[1,2,*] , Sana Hitur Awad[2]

[1] *Ministry of Higher Education and Scientific Research, Baghdad, Iraq*

[2] *College of Science for Women, University of Baghdad, Iraq*

***Corresponding author:** Safa Mohammed Jasim, safa.hamad2025m@csw.uobaghdad.edu.iq

ABSTRACT

Starch, a natural polymer, is modified for drug delivery by chemical, physical, and enzymatic methods to alter its structure and properties for improved drug loading, release, and biocompatibility. Chemical modifications include esterification, etherification, and oxidation to enhance properties like gel strength, stability, and hydrophilicity. Physical methods like annealing can increase molecular mobility, aiding in controlled release. Enzymatic treatments can also alter starch structures. These modified starches are used in drug delivery systems, acting as polymers or excipients in hydrogels, nanoparticles, and films for targeted and controlled release of active pharmaceutical ingredients. Advanced pharmaceutical materials are a requirement of human health as companies seek to develop medical treatment to obtain the best results. A new types of polymer drugs were used in this study: paracetamol, amoxicillin, ampicillin, Salbutamol. sulphathiazole, and cefotaxime as new modified polymer used against microorganism. Natural starch, a polysaccharide compound, was used as a binder to form new active groups in the drug composition. The esterification mechanism was used in the reaction, resulting in the formation of starch acetate containing acetate groups after water withdrawal and pH adjustment to 7. Maleic anhydride was added to the starch acetate polymer by refluxing for 6 hours at 153C o with DMF as solvent to produce polymer the starch acetate maleate as (S3) compound. The selected standard antibiotic samples were reacted with the starch acetate maleate polymer to produce new pharmaceutical compounds such as amoxicillin starch acetate polymer and so on. The new pharmaceutical compounds were identified using FTIR, thermal gravimetric analysis (TGA) and proton nuclear magnetic resonance spectroscopy (HNMR) A study was conducted by the new pharmaceutical compounds to study their physiological and inhibiting activity on microorganism as the E.coli and the Staphylococcus with concentration of 1000 ppm. The result appears increasing in cell number for theS3- sulphametaxiol drug as 21 mm and for the S3-Cefotaxin drug as 39mm against the E.coli in addition the increasing via the S3 polymer with value of 41mm while most of the new pharmaceutical polymers showed effectiveness against Staphylococcus bacteria. In addition to study the impact of some of the new drugs on cell line. The results showed that the new drug has activity against living organisms (E. coli bacteria and Staphylococcus bacteria) in addition to its activity under normal laboratory conditions, Docking and cytotoxicity results showed a possible correlation. Sulphamethoxazole had the strongest binding (–10.8 kcal/mol), while Salbutamol was the weakest (–9.3 kcal/mol). Cefotaxime showed the highest anticancer activity, and Ampicillin the lowest. Overall, stronger docking interactions may suggest higher anticancer potential.

Keywords: Neutral starch, chemical characterization, antibiotic, fungi, bacteria

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1. Introduction

Natural starch is one of the most widely available polysaccharides and has been extensively used in both food and pharmaceutical

industries. Its popularity in pharmaceutical applications is mainly due to its low cost, non-toxicity, and good biocompatibility [1,2]. Starch can be obtained from different sources, including cereals such as corn, wheat, and rice, as well as tubers and roots like potato and cassava. Although native starches from these sources differ in properties such as viscosity, transparency, and water retention, these characteristics can be modified and improved. In fact, starch can undergo physical, chemical, enzymatic, and even genetic modifications to enhance its functional properties and expand its pharmaceutical applications [3].

At the microscopic level, starch appears as colorless, highly refractive granules, with their size and shape depending largely on the source. Each granule contains alternating amorphous and crystalline regions arranged in a lamellar structure. Chemically, starch is composed of two main components: amylose and amylopectin[4,5]. Amylose is a linear polymer with α-1,4-glycosidic linkages, while amylopectin is a branched polymer containing both α-1,4- and α-1,6-glycosidic bonds. This structural difference leads to variations in their physicochemical behavior. Typically, natural starch consists of about 20–30% amylose and 70–80% amylopectin [6].

In pharmaceutical formulations, starch is commonly used as a binder, disintegrant, diluent, and lubricant due to its ability to swell and assist in drug release [7,8]. It is considered one of the most reliable excipients because it meets key requirements such as safety, availability, and compatibility with a wide range of drug compounds.

However, despite the widespread use of conventional drugs, many of them still face important limitations, including poor water solubility, low bioavailability, limited stability, and rapid elimination from the body. These issues can reduce the overall therapeutic effectiveness and may require repeated dosing, which increases the likelihood of side effects.

For this reason, there is increasing interest in developing improved drug delivery systems. One practical approach is to use natural polymers, such as starch, as carrier systems. By chemically modifying starch, for example through esterification or grafting reactions, it is possible to introduce new functional groups that enhance its physicochemical properties. These modifications can improve drug–polymer interactions, increase solubility, and allow for more controlled or sustained drug release.

Several pharmaceutical compounds, including ampicillin, sulfamethoxazole, salbutamol, and cephalosporin antibiotics, are widely used in medical treatments [9,10]. Nevertheless, improving their delivery and biological performance remains an important challenge in pharmaceutical research.

Therefore, this study aims to prepare new pharmaceutical compounds based on chemically modified starch and to evaluate their physicochemical and biological properties. In this work, starch was modified and used as a carrier for selected drugs, including paracetamol, amoxicillin, ampicillin, salbutamol, sulfamethoxazole, and cefotaxime, to produce new polymer–drug derivatives. These compounds were characterized using FTIR, TGA, and ^{1}H-NMR techniques to confirm their structures. In addition, their biological activity was evaluated against *E. coli* bacteria and *Staphylococcus* bacteria under laboratory conditions.

2. Methodology

2.1. Materials

Standard pharmaceutical ingredients from Sigma Aldrich ,99% were used without any purification as the paracetamol, amoxicillin, ampicillin, Salbutamol. sulfamethoxazole and Cefotaxime, whereas the methanol, the absolute ethanol the Diethyl ether, Dimethyl sulfoxide (DMSO), and the Dimethyl form amide (DMF) from BDH, 99%.

2.2. Experiments

2.2.1. Synthesis of starch acetate polymer

Starch acetate is a biodegradable and biocompatible polymer synthesis through the acetylation of starch. Starch is reacted with acetic anhydride or acetic acid in the presence of a catalyst. The degree of substitution (DS) can be controlled by adjusting the reaction conditions, such as temperature, time and catalyst concentration [11].

2.2.2. Modification of Starch

Starch is modified through various physical, chemical, enzymatic, and genetic modifications, often to alter and improve the functional properties of simple starch. These modifications can be used in a variety of pharmaceutical products as excipients, either alone or in combination with its active ingredients. These modifications help improve the flow and compression properties of starch, making it more useful for drug delivery systems. Chemical modification is one such type, which involves treating starch and modifying it with one or more chemicals [12].

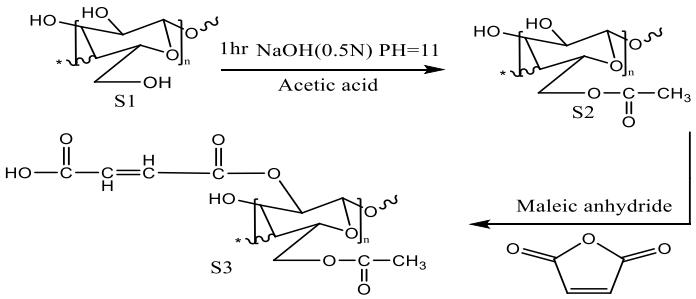
2.2.3. Chemical Modification

Chemical techniques used in starch modification include acid hydrolysis, cross-linking, esterification, oxidation, and grafting. Chemical modification involves adding new functional groups to the starch polymer structure, imparting distinctive properties. Chemical modification techniques include esterification, etherification, cationization, oxidation, and cross-linking. Thus, the introduction of various functional groups, such as acetyl groups, ultimately leads to structural reorganization due to steric hindrance and repulsion of starch molecules, enabling water to seep into amorphous regions and increasing its solubility.

Chemical modification of starch involves the introduction of ester functional groups into the starch backbone. This facilitates chemical modification of starch and increases the attachment of various functional groups. The degree of chemical modification depends primarily on the degree of substitution (DS) and the type of functional group used. The maximum permissible degree of substitution for starch is 3.0, because each glucose unit along the starch chain contains only three hydroxyl groups [13,14].

2.2.4. Synthesis of starch acetate polymer and starch acetate-malate – polymer.

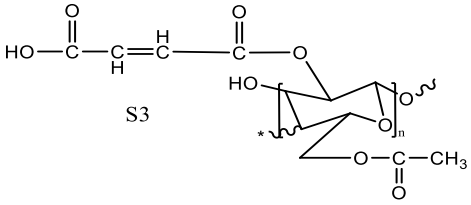
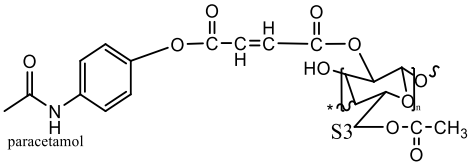
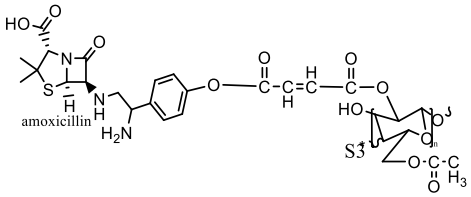
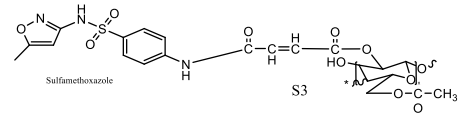
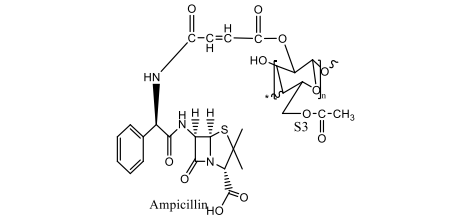
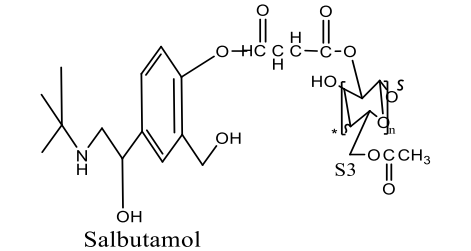
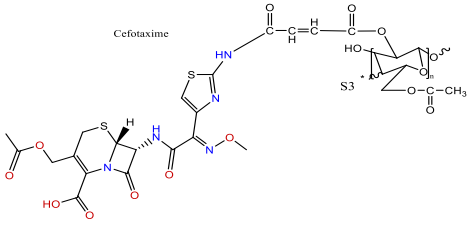
This work involved the synthesis of new pharmaceutical derivatives of starch through chemical modification. Since starch contains multiple hydroxyl groups, esterification can occur at available reactive sites within the starch structure. In this step, starch was reacted with glacial acetic acid to introduce acetyl groups, after which the reaction mixture was cooled to room temperature, forming a white precipitate that was filtered, washed, and recrystallized using diethyl ether [15]. The product was then dried in an oven at 70 °C for 1 hour. Further modification was achieved through reaction with maleic anhydride at available reactive sites by introducing an anhydrous maleic group, It should be noted that the exact position of substitution cannot be definitively confirmed under the present experimental conditions. According to the following scheme.



Scheme 1. The first step for the preparation of starch acetate- polymer as (S1, S2, S3).

In a round bottom flask provided with condenser about 1gm of S3 as placed in and dissolved 10ml of DMF, then (1.50g.,0.0041 mole) of amoxilline dissolved in 15 ml of ethanol absolute, 2ml of H2SO4 1M was add, the mixture was stirred, and heated at 80Co about 6h, the brown product was isolated and dried in a vacuum oven before weighing. Similar procedure was applied with another antibiotic compounds such as ampicillin, Salbutamol, sulfamethoxazolee and cefotaxime All physical properties of the products are listed in Table (1).

Table 1. physical properties of polymer-drug.

Pol. No	-Drug	Color	Softening point ^{0}C	Yield %
S3		White	177-185	90
S_4		Yellowish	225-235	70
S_5		white yellow	230-247	85
S_6		orange	198-215	73
S_7		Red	220-235	67
S8		White	178-190	70
S9		White yellow	220-225	68

2.2.5. The Biological Activity

The biological activity of the new pharmaceutical compounds was studied on two types of microorganism against fungi as a *Staphylococcus* and the *E-coli* bacteria in laboratory condition with concentration of 1000ppm, while preparing new drug solutions via dissolving of 5gm in 5ml from Dimethyl sulf-oxide (DMSO) from each new drug starch polymer.

2.2.6. Computational approach:

The protein data bank (PDB) provided the crystal structure of the target protein of the breast cancer cell line MCF-7, which was retrieved through the PDB ID (4XO6). Target proteins for the docking experiment were selected based on their X-ray diffraction data. Heteroatoms like ions and water molecules were removed from the PDB file through the use of the Chimera tool and Discovery Studio 2021 Client. The X-ray crystallographic structure of the protein (4XO6) was thus refined for molecular docking study so that only the desired binding chain was selected and without the other binding sites of the protein [16,17].

2.2.6.1. Setting Up Ligands

The selected ligands, namely salbutamol, ampicillin, amoxicillin, sulfamethoxazole, cefotaxime, and paracetamol, were retrieved from the PubChem database in SDF format. The chemical structures were converted into PDB format with the help of Open Babel software [18]. The ligands were optimized and prepared for molecular docking study against the breast cancer-associated protein (PDB ID: 4XO6).

2.2.6.2. Molecular Docking

Molecular docking was conducted using AutoDock Vina implemented in the PyRx software. The target protein (PDB ID: 4XO6) and ligands were prepared using AutoDock tools, and structures were converted to PDBQT format prior to the docking. Blind docking entailed the choice of grid boxes having sizes adequate to cover the entire surface of the receptor for unbiased sampling of probable binding sites. For all ligands, the grid box center was defined as follows: Salbutamol (X = 67.5898, Y = 56.4632, Z = 50.3739), Ampicillin (X = 68.2934, Y = 58.0983, Z = 61.6831), Amoxicillin (X = 57.9153, Y = 46.1948, Z = 63.5545), Sulfamethoxazole (X = 64.3429, Y = 53.4872, Z = 62.4809), Cefotaxime (X = 58.7315, Y = 55.7609, Z = 58.4854), and Paracetamol (X = 62.2732, Y = 55.6922, Z = 62.8302). The binding conformations and docking interactions were further visualized and examined by utilizing Discovery Studio Visualizer 3.0. [19]

3. Result and Discussion

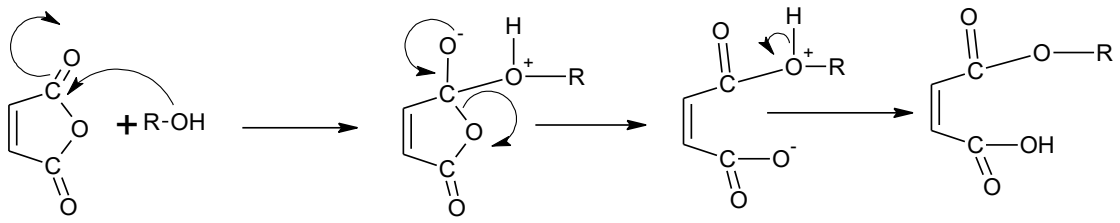
3.1. Starch modified

Modified starch finds its various pharmaceutical application as compared native starch, it mainly imparts properties like potential controlled-release polymer, swellability, excellent compressibility, higher crushing strength, better flow properties

This study involved modification of starch and substituted with different drugs

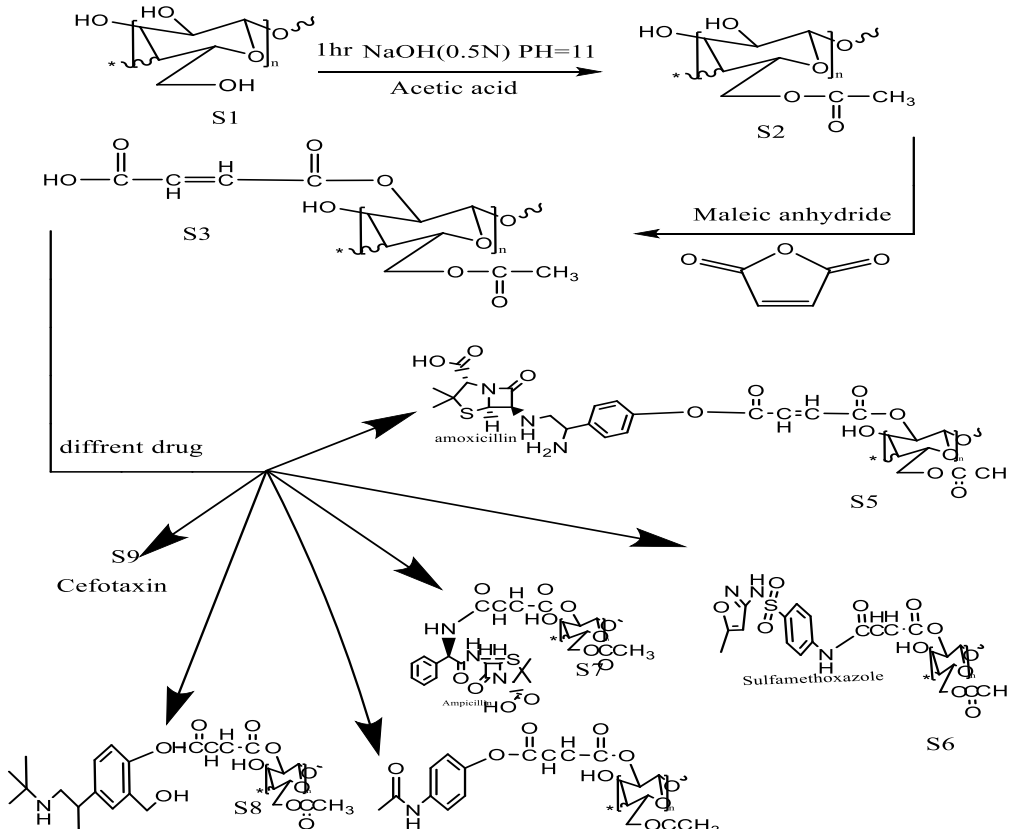
Chemical modification of starch involves the introduction of ester functional groups into the starch polymer backbone through esterification reactions.

Reaction of cyclic anhydrides with hydroxyl groups present in starch using dimethyl formamide as a Solvents, at room temperature.



Scheme 2. Ring opening reaction of acid anhydride by hydroxyl group.

The sustained release property causes entrapment of drug inside the matrix and tends to slow diffusion of drug moieties by mechanism of swellability stimuli response and along with reduced enzyme sensitivity during gastrointestinal digestion. The poly-anionic behavior of acetylated starch in hydrogels may contribute to prolonged release of drugs from systems and imparting swellability characteristics. Targeted drug delivery can also be achieved through modified starch because of high hydrogen content which enables formulation of pH responsive drug delivery system29. Acetylated starch may enhance the bioavailability of poorly water-soluble drugs and macromolecules like insulin different drugs in this study used to synthesis new drugs polymer S4-S9 as shown in scheme (3)



Scheme 3. The second step for the preparation of starch acetate- maleate –Antibiotic polymers as (S4-S9).

3.2. Fourier Transform Infrared Spectroscopy (FTIR)

The FTIR analysis was conducted in the laboratories of the Scientific Research commission. Below are the infrared spectra of the laboratory-prepared pharmaceutical polymer samples, as indicated to each sample. The solid sample can be analyzed as KBr pellets, FTIR or diffuse reflectance, the spectral range typically 4000-400 cm^{-1} [20].

A sharp band at3431 cm^{-1} and 3014 cm^{-1} assigned to ν(N-H) band or for the ν(C-H) absorption had been shown in the spectrum of the prepared starch acetate malate polymer (S3) which as ν(N=C-H) aromatic and ν (C=C-H) aromatic stretching absorption band as first competent for the preparation of new drug polymer complexes (Figure not shown). [16].

The starch acetate maleat (S2), (S3) Sample (S4) (S3+Paracetmol), Sample(S5) (S3+Amoxicillin), sample(S6) (S3+Sulfamethoxazole), sample(S7) (S3+Ampicillin). Sample (S8) (S3+Salbutamol), Sample(S9) (S3+Cefotaxime) as shown in table 2.

The same spectrum, displays a sharp band at 1730 cm^{-1} and 1660 cm^{-1} assigned to ester and amide group stretching band [17]. FIIR of compounds (S4, S5, S6, S7, S8and S9) exhibit characteristic strong absorption bands at (3500 cm^{-1}) and(3018cm^{-1}) refers to the ν(N--H) and ν(C=C-H) aromatic as previously proven [21].

A stretching vibration band at around (1730cm^{-1}) appears the carbonyl (C=O) group as the ester strong absorption band. Absorption band at (1410 cm^{-1} to 1390cm^{-1}) refers the ν (C=C) amide bond. The absorption band at around (1250cm^{-1} to 1100cm^{-1}) on the whole FTIR complexes refers to the ether lack bonds. The stretching vibrations of the nitrogen [22,23,24,25].

Table 2. FTIR Absorption of prepared compounds.

NO.	υ(O-H) cm^{-1}	υ(C-H) cm^{-1} aliphatic	υ(C=O) cm^{-1} ester	υ(C=C) cm^{-1} Alkene	υ(C=O) cm^{-1} Amid	υ(C-O) (C-O-C) cm^{-1} Stretching
S1	3417	2927	-	-	-	1159-1082
S2	3420-3410	2930-2920	1730	-	-	1150-1040
S3	3410	2930	1735-1725	1650-1640	-	1250
S4	3360-3310	2935-2867	-	1610-1590	1670-1650	1270-1240
S5	3400	2920	1730	1645	1650	1150-1000
S6	3400	2920	1730	-	1650-1660	1160-1240
S7	3300-3400	2918	1735-1725	-	1650-1660	1000-1150
S8	3400	2930	1730	-	1650-1660	1150-1250
S9	3300-3400	2920	1730		1660	1100-1150

3.3. The Proton Nuclear Magnetic Resonance Spectroscopy (HNMR)

The chemical environment of organic compounds can be determined using (HNMR) spectrometry using Tetramethy-lsilane (TMS) as a reference material for this assay as internal reference standard [26, 27].

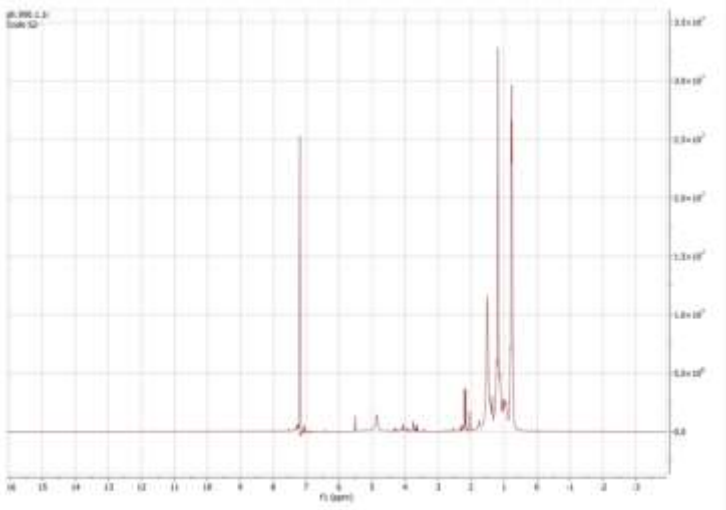


Figure 1. ^{1}H-NMR spectrum of the acetylated starch.

As show in (Fig. 1) recorded in DMSO-d_6 as solvent showed the following signals:

δ 0.9–1.8 ppm (signals possibly attributed to residual aliphatic fragments or side-chain environments, m)

δ 2.0–2.2 ppm (acetyl –$COCH_3$ protons suggesting the substitution of hydroxyl groups with acetyl groups, s),

δ 2.3–2.8 ppm (broad multiplet due to CH–CH_2 groups adjacent to carbonyls, possibly from residual acetic fragments, m),

δ 3.2–4.2 ppm (–CH–O– and –CH_2–O– protons of the glucopyranose ring forming the starch backbone, m),

δ 4.8–5.3 ppm (anomeric H-1 proton of glucose units and residual hydroxyl protons, s),

δ 6.2–6.5 ppm (weak double signals possibly due to traces of unsaturated =CH protons from minor side reactions or impurities, d).

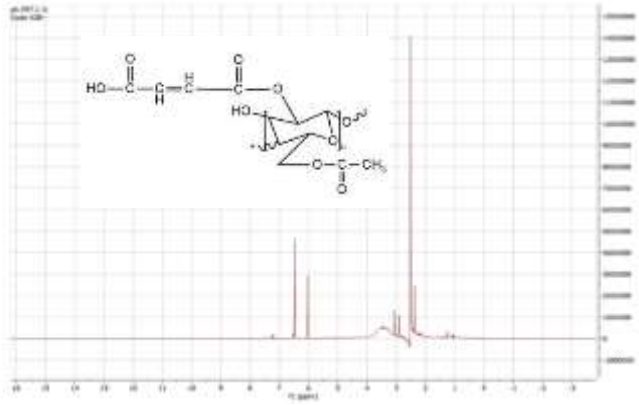


Figure 2. The HNMR analysis for the (S3.)

As shown in figure 3, δ 0.9–1.8 ppm (signals possibly attributed to residual aliphatic fragments or side-chain environments, m),

δ 2.0–2.2 ppm (acetyl –$COCH_3$ protons suggesting starch acetylation, s),

δ 2.3–2.8 ppm (CH–CH_2 protons adjacent to carbonyls from maleate or succinate fragments—opened maleic anhydride ring, broad m),

δ 3.2–4.2 ppm (–CH–O– and –CH_2–O– protons of the glucopyranose ring in the starch backbone, m),

δ 4.8–5.3 ppm (anomeric H-1 proton of the glucose unit and possible residual –OH groups, s),

δ 6.2–6.5 ppm (vinyl protons =CH–CH= from maleate units suggesting successful modification with maleic anhydride and the presence of unsaturated bonds).

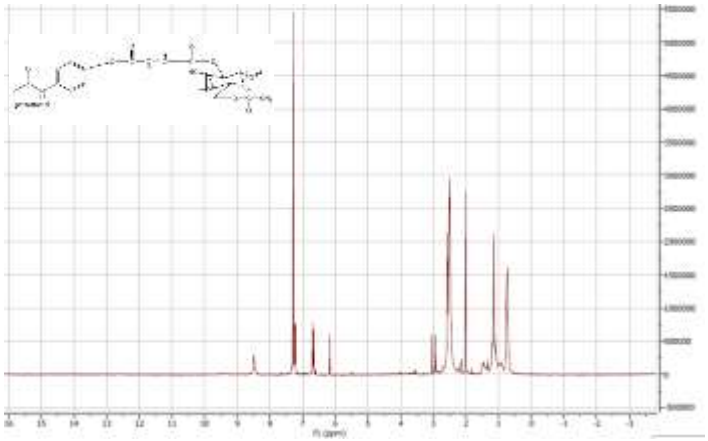


Figure 3. The HNMR analysis for the (S3+Paracetamole) of the prepared drug polymer.

The ^{1}H-NMR spectrum (figure 3) of the prepared starch–paracetamol complex recorded in DMSO-d_6 as solvent showed the following signals:

δ 0.9–1.8 ppm (CH_3, CH_2 protons of aliphatic backbone or alkyl side chains of modified starch, m),

δ 2.0–2.3 ppm (acetyl –$COCH_3$ protons of the polymer and –CH_3 attached to aromatic ring of paracetamol, broad s),

δ 3.2–4.3 ppm (–CH–O– and –CH_2–O– protons of glucopyranose units, m),

δ 4.8–5.4 ppm (anomeric H-1 of starch and –CH–O–CO– linkages formed upon complexation, s),

δ 6.5–7.5 ppm (aromatic CH protons of paracetamol –C_6H_4–OH–NH–CO–CH_3, m),

δ 8.5–9.5 ppm (amide –NH– and phenolic –OH protons of paracetamol showing hydrogen-bond interaction with the polymer matrix, broad s) [28–29].

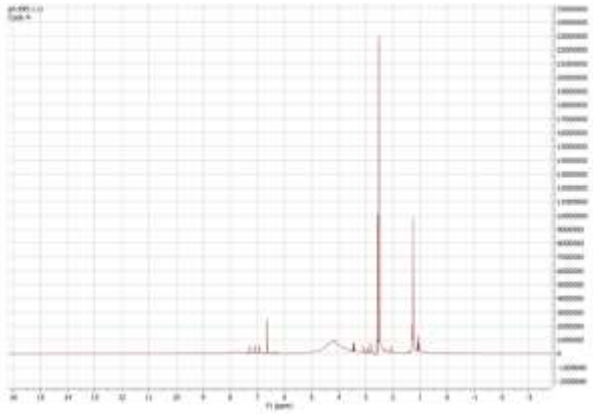


Figure 4. The ^{1}H-NMR spectrum of the starch–ampicillin complex.

As shown in Figure (4) recorded in DMSO-d_6 showed distinct shifts and broadening of specific signals, confirming intermolecular interactions between both components. The broad peaks appearing in the region δ 7.6–12.5 ppm correspond to amide (–NH–) and hydroxyl (–OH) protons, indicating the formation of hydrogen bonds between ampicillin and the starch matrix. Additionally, slight changes and overlapping observed at δ 4.8–5.7 ppm, corresponding to the anomeric proton of starch and the β-lactam proton of ampicillin, suggest possible interaction between the β-lactam carbonyl and hydroxyl groups of starch. These findings suggest that

the main binding sites in the complex are the amide and β-lactam groups of ampicillin interacting with the hydroxyl groups of starch through hydrogen bonding.

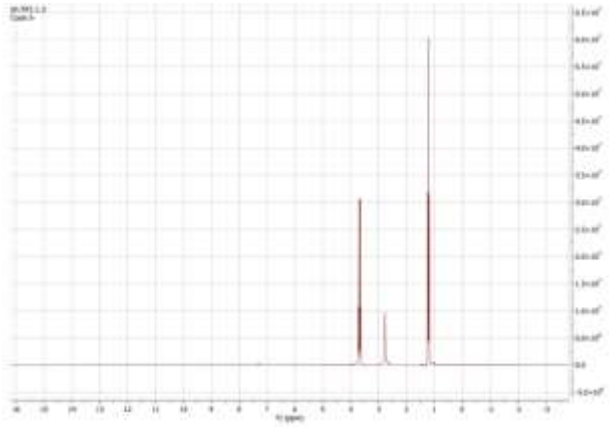


Figure 5. The ^{1}H-NMR spectrum of the starch–salbutamol complex.

As shown in Figure (5) recorded in DMSO-d_6 showed characteristic signals indicating molecular interactions between the polymer and the drug. The broad peaks observed in the region δ 8.5–9.5 ppm correspond to phenolic –OH and amine –NH groups of salbutamol, which exhibited noticeable broadening and downfield shifting, suggesting hydrogen-bond formation with the hydroxyl groups of starch. The signals of the glucopyranose ring (δ 3.2–4.3 ppm) and the anomeric proton (δ 4.8–5.3 ppm) also displayed slight shifts compared with native starch, suggesting their involvement in the interaction. These findings indicate that the main binding sites within the complex are the phenolic and amine groups of salbutamol interacting through hydrogen bonding with the hydroxyl groups of starch, forming a stable polymer–drug network.

3.4. The thermal gravimetric analysis (TGA)

Thermo gravimetric analysis (TGA), is an analysis in which the physical and chemical properties of a substance are monitored during heating in a special device, provided that the heating is at constant temperatures during the reaction time, after which the weight of the substance changes or remains constant depending on the type of substance [30].

Thermogravimetric analysis studies demonstrated the coordination of water residues (aqua or hydrate) with metal ions inside the coordination sphere. As shown if figure (6), the polymer of the (S3+Paracetamole), the decomposition reaction of the polymer started at 150C° and decomposed after around 15min in the same temperature. In figure (7), the TGA analysis of the S3+Amoxicilline shown the decomposition reaction started at 100C° and finished after 1800 min in the same temperature.

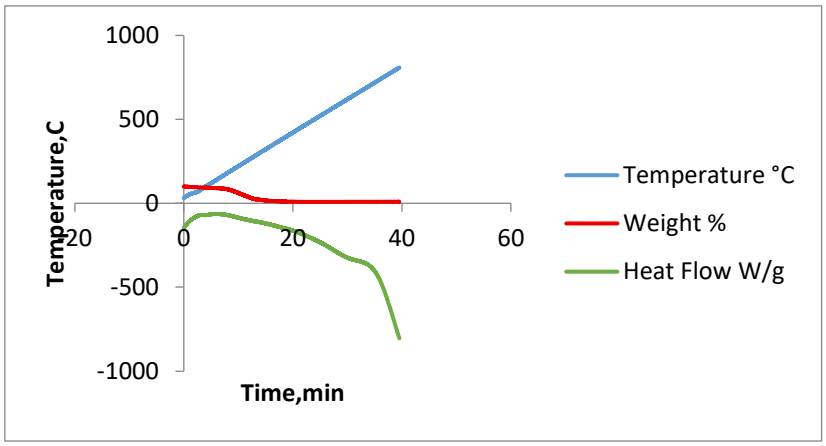


Figure 6. The thermal analysis (TGA) of the S3+Paracetamole drug polymer.

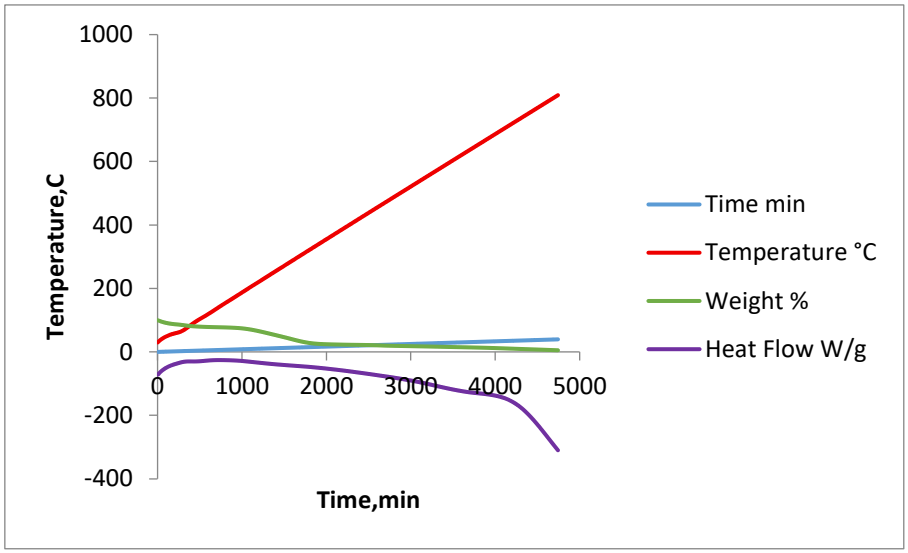


Figure 7. The thermal analysis (TGA) of the S3+Amoxicilline drug polymer.

At figure (8), which refer to the TGA analysis of the S3+Sulfamethoxazole, the decomposition started at 100C° and finished after 18 min in the same temperature.

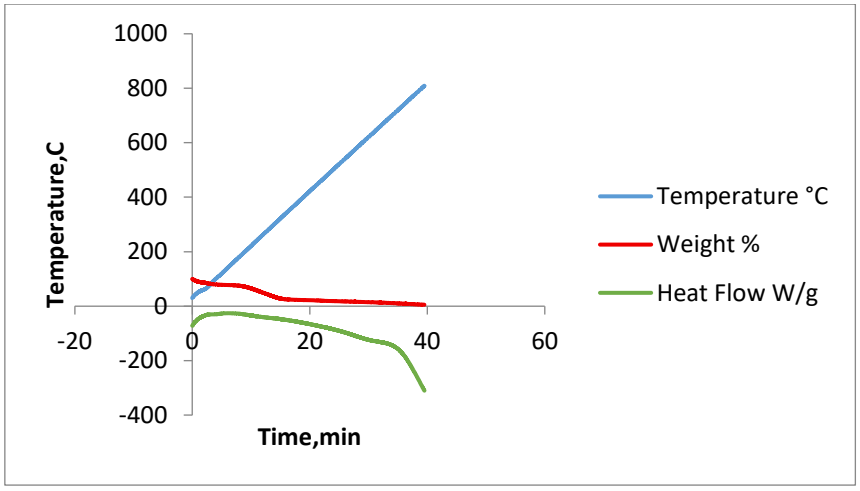


Figure 8. The thermal analysis (TGA) of the S3+Sulfamethoxazole drug polymer.

As shown if figure (9) the TGA analysis of the Starch acetate malate polymer-Ampicillin as (S3-Ampicillin), it seems that the decomposition analysis started at temperature of 100C° and finished after 1900 min in the same temperature. From the TGA flowchart this prepared drug polymer was stable till 2000 min.

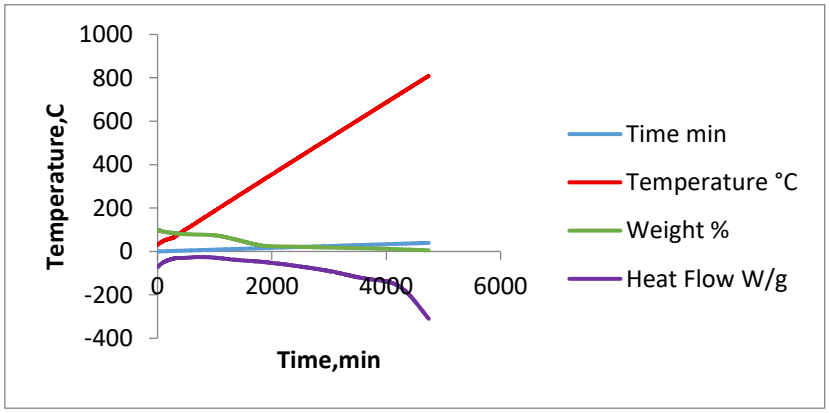


Figure 9. The thermal analysis (TGA) of the S3+Ampicillin drug polymer.

As shown if figure (10), the TGA analysis of the S3+Salbutamol, the decomposition analysis started at 100C° and finished after 40 min in the same temperature.

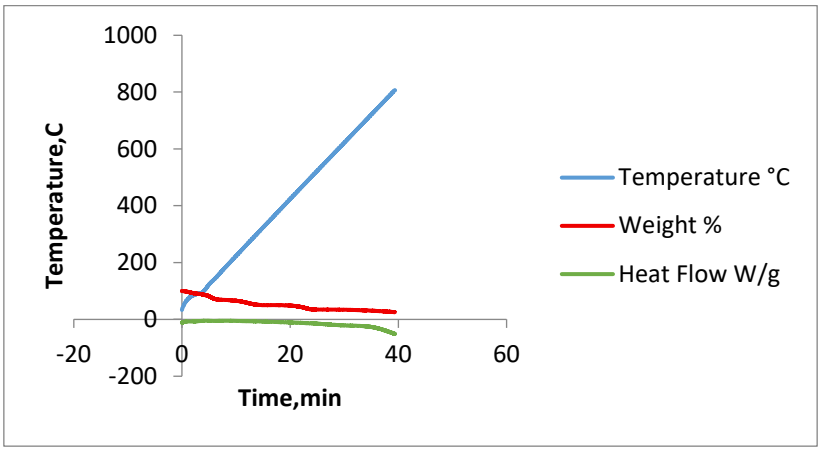


Figure 10. The thermal analysis (TGA) of the S3+Salbutamol drug polymer.

In figure (11), the TGA analysis of the starch acetate polymer as (S2). The decomposition analysis stated at temperature of 100C◦ and continue stable at the same temperature till the end of the analysis. This indicates that the polymer remained stable at this temperature.

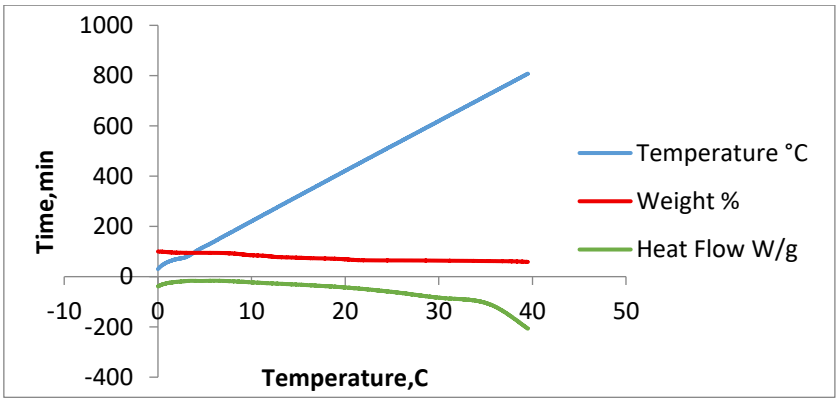


Figure 11. The thermal analysis (TGA) of the starch acetate (S2) polymer.

From the analysis above it seems that the more stable drug polymer was the Starch acetate malate polymer-Ampicillin as (S3-Ampicillin), it seems that the decomposition analysis started at temperature of 100C° and finished after 1900 min in the same temperature. Thus, this prepared drug polymer was stable till 2000 min. On the other hand, the unstable drug polymer was the S3+Paracetamole, the decomposition reaction started at 150C° and decomposed after around 15min in the same temperature.

3.5. The antibacterial activity

The results of the biological experiment (Figure 12), showed that the new pharmaceutical polymer as starch-acetate malate (S3) is a more effective substance against bacteria E-coli with inhibition ratio of 4 mm then the S3- Cefotaxime with inhibition ratio of 39% and finally the prepared drug polymer (S3-Sulfamethoxazole) with inhibition ratio of 21% as submitted in table 3.

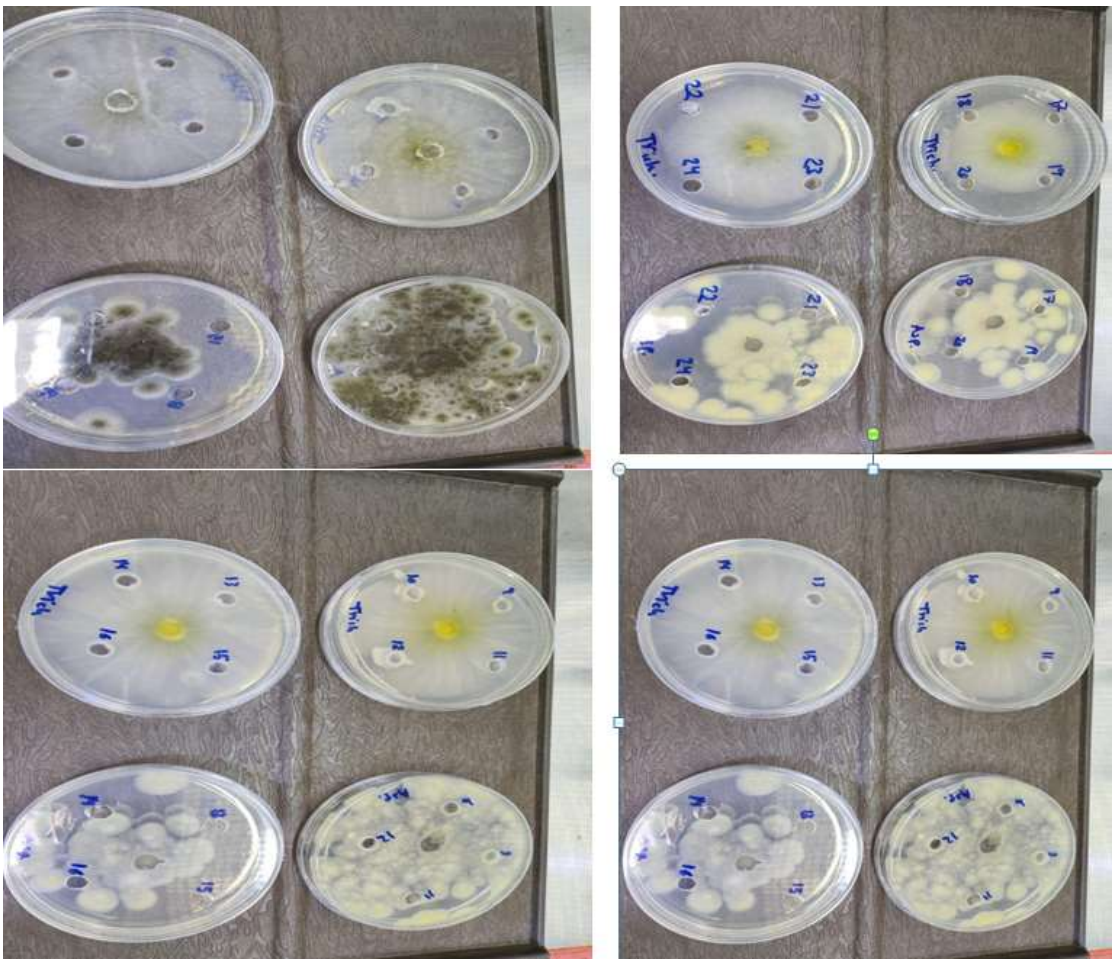


Figure 12. The biological studies for the new prepared drug polymeragainst bacteria E-Coli in laboratory conditions.

Table 3. The biological studies via the prepared drug against bacteria *E-coli*.

Values mm	Antibiotic	solvent	Type of Bacteria
21	Sulfamethoxazole	DMSO	E.coli $1.5*10^8$
39	Cefotaxin	DMSO	E.coli $1.5*10^8$
41	S3	DMSO	E.coli
0	paracetamol	DMSO	
0	Ampicillin	DMSO	
0	Amoxicillin	DMSO	
0	Salbutamol	DMSO	

As results for the biological experiment (Figure (13)), for the determination of biological studies against Staphylococcus bacteria showed that the new pharmaceutical polymer as starch-acetate malate (S3) Cefotaxin with higher inhibition ratio of 33% and the less inhibition ratio for the starch-acetate malate (S3) Salbutamol with ratio of 0% as presented in table (4).

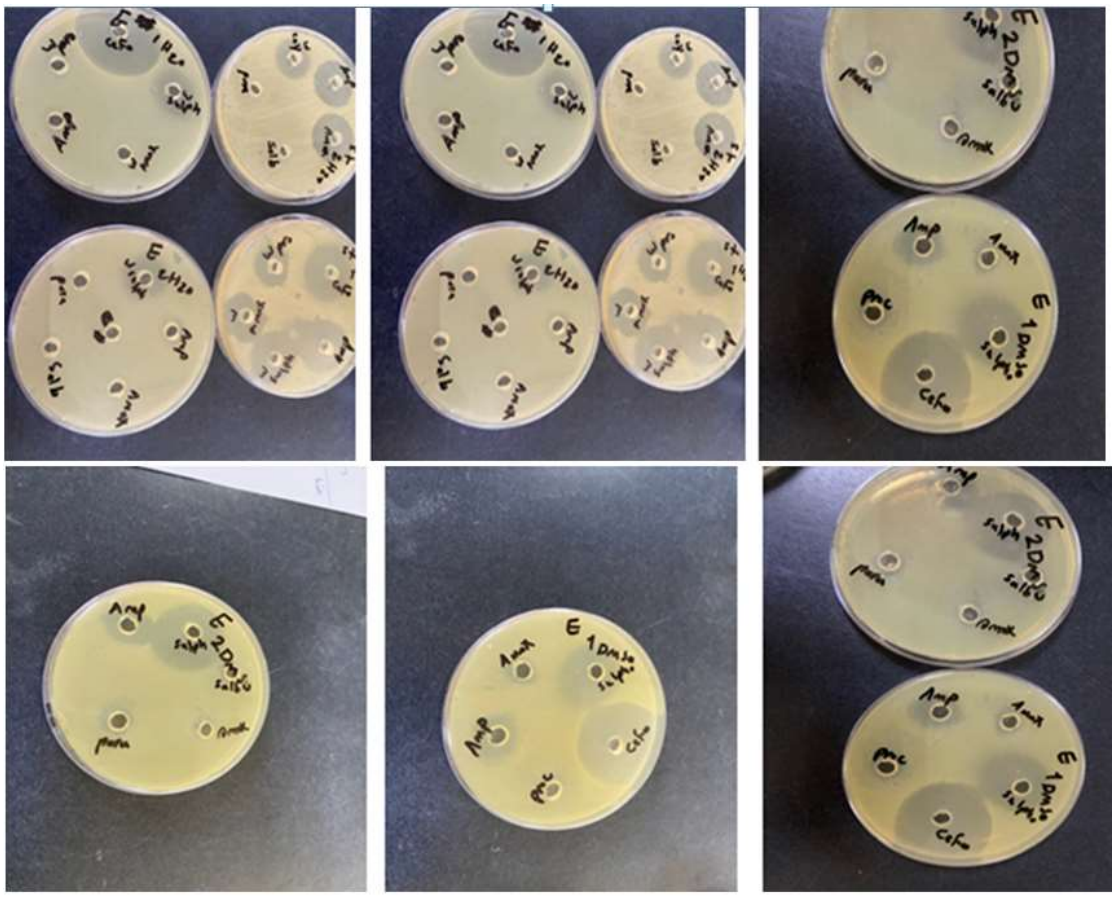


Figure 13. The biological studies for the new prepared drug polymers against Staphylococcus bacteria in laboratory condition.

Table 4. The biological studies via the prepared drug against Staphylococcus bacteria.

Values mm	Antibiotic	solvent	Type of Bacteria
22	Sulfamethoxazole	DMSO	Staphylococcus $1.5*10^8$
33	Cefotaxin	DMSO	^{8}
27	paracetamol		
24	Ampicillin	DMSO	
21	Amoxicillin		
0	Salbutamol		
27	S3		

3.6. In silico results

The breast cancer-related protein (PDB ID: 4XO6) was used to predict the binding interactions of the six selected ligands: Salbutamol, Ampicillin, Amoxicillin, Sulfamethoxazole, Cefotaxime, and Paracetamol. Auto Dock Vina using Py Rx was applied for docking experiments. Auto Dock tools were utilized for ligand and receptor structure preparation, transforming them into PDBQT format. The docking results.

Salbutamol possessed a binding affinity of –9.3 kcal/mol. Stabilization of the interaction was primarily obtained by hydrogen bonding of its phenolic hydroxyl groups with TYR24. Additional, other hydrogen bonding between hydroxyl on side chain with GLU224 as well as oxygen of carbonyl ester with SER221. Furthermore, stabilization was brought about by pi-pi stacking between its aromatic ring with HIS 222. Results shown in figures 14, 15 and 16

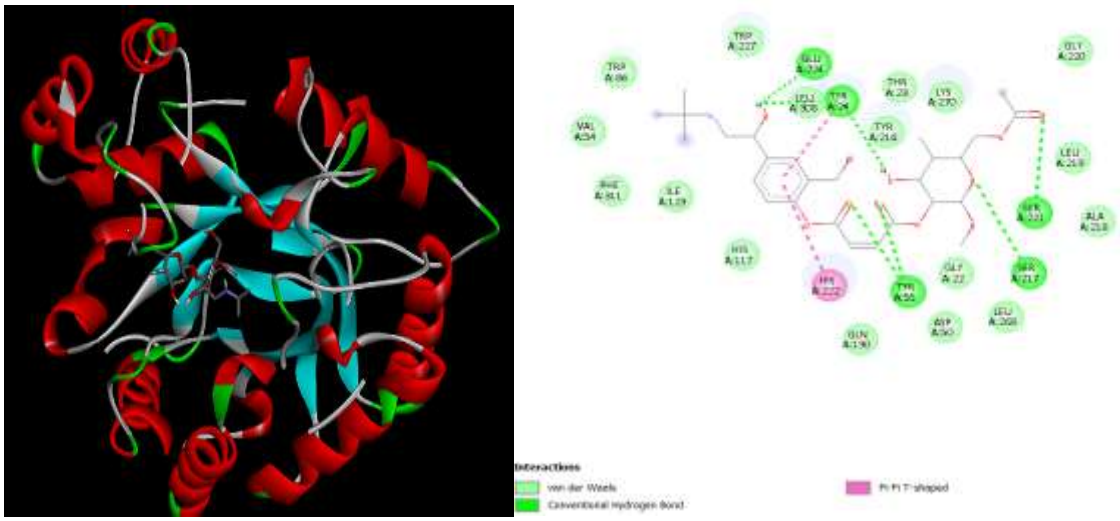


Figure 14. 2D and 3D binding interaction of Salbutamol–4XO6 complex.

Ampicillin had a docking score of –10.0 kcal/mol. Carbonyl on β-lactam ring formed key hydrogen bonds with ARG276 in the active site. In addition, hydrogen bonds between phenolic hydroxyl groups with SRE217 as well as oxygen of ester with TYR55. The hydrophobic interaction with the aromatic group and with ALA253, LEU219 were additional stabilizing forces.

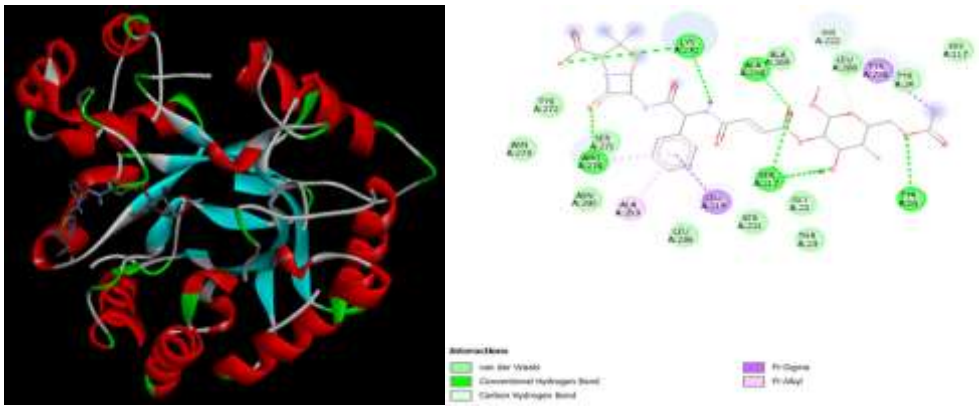


Figure 15. 2D and 3D binding interaction of Ampicillin –4XO6 complex.

The amoxicillin with the affinity –10.1 kcal/mol was bounded. First amine groups made hydrogen bonds with TRR55, while the second one with ASP50, GLN190. In addition, hydrogen bond was also taken place between three oxygen of carbonyl with different polar amino acid, while the aromatic group created π–sulfur with HIS222.

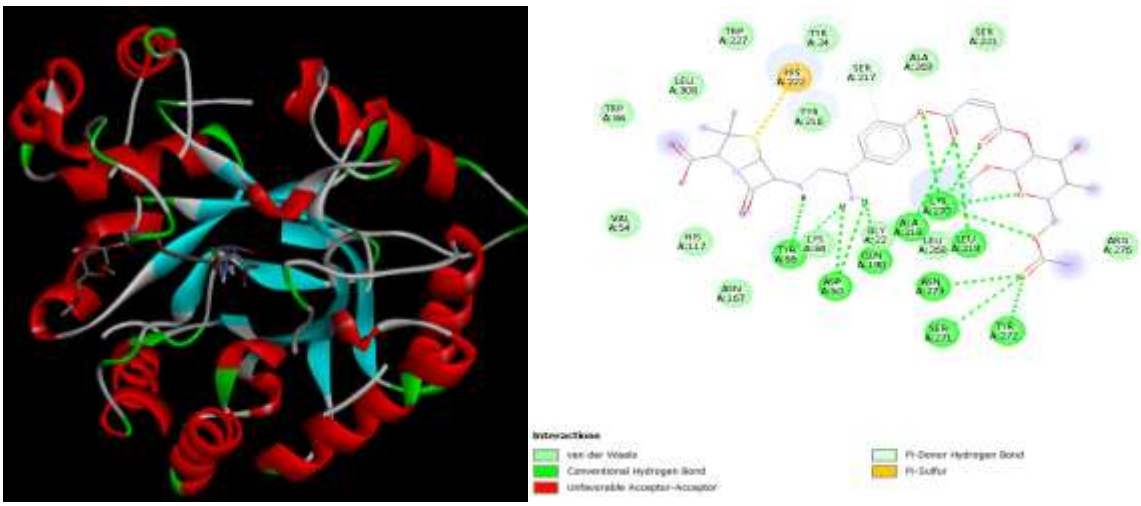


Figure 16. 2D and 3D binding interaction of amoxicillin –4XO6 complex

Docking values (–9.3 to –10.8 kcal/mol) also agreed well with cytotoxicity against MCF-7 cells. Sulphamethoxazole had the highest docking value (–10.8 kcal/mol) with clear activity (IC_{50} = 160.9 µg/mL). Both amoxicillin (–10.1) and Ampicillin (–10.0) showed strong binding, while amoxicillin was equivalent to greater cytotoxicity (IC_{50} = 139.2 µg/mL) than ampicillin (210 µg/mL). Cefotaxime (–9.5) and Paracetamol (–9.7) possessed comparatively weaker docking but highest activity (IC_{50} = 110.3 and 120.5 µg/mL). Salbutamol (–9.3) showed the lowest docking activity and moderate cytotoxicity (IC_{50} = 156.6 µg/mL). These results suggest a possible correlation between docking affinity and cytotoxic effects, indicating that molecular docking may provide preliminary insight into anticancer activity. It should be noted that the molecular docking study was performed under simplified in silico conditions without the explicit inclusion of water molecules, which may influence the calculated binding affinities. Furthermore, additional experimental and computational studies are required to compare the modified polymer–drug derivatives with the pure drug compounds and to further validate their biological activity.

4. Conclusion

The selected standard antibiotic samples were reacted with the starch acetate maleate polymer in the experimental conditions to produce new pharmaceutical compounds. The prepared drug polymer they identified using FTIR, thermal gravimetric analysis (TGA) and proton nuclear magnetic resonance spectroscopy (HNMR). The more stable drug polymer was the Starch acetate malate polymer-Ampicillin as (S3-Ampicillin), it seems that the decomposition analysis started at temperature of 100C° and finished after 1900 min in the same temperature. Thus, this prepared drug polymer was stable till 2000 min. On the other hand, the unstable drug polymer was the S3+Paracetamol, the decomposition reaction started at 150C° and decomposed after around 15min in the same temperature. A study was conducted by the new pharmaceutical compounds to study their physiological and inhibiting activity on microorganism as the *E.coli* and *the Staphylococcus* with concentration of 1000 ppm .The result appears increasing in cell number for theS3-Sulphamethazol drug with inhibition ratio of 21 % and for the S3-Cefotaxin drug as ratio of 39% against the *E.coli* in addition the increasing via the S3 polymer with ratio of 41% while most of the new pharmaceutical polymers have shown effectiveness against *Staphylococcus* bacteria .In addition to study the impact of some of the new drugs on cell line. The results showed that the new drug has activity against living organisms (E. coli bacteria and Staphylococcus bacteria) in addition to its activity under normal laboratory conditions Among the tested drugs, Sulphamethoxazole showed the strongest docking interaction (–10.8 kcal/mol), while Salbutamol had the weakest (–9.3 kcal/mol). In terms of cytotoxicity, Cefotaxime exhibited the highest anticancer activity (lowest IC_{50} = 110.3 µg/mL), whereas Ampicillin showed the lowest activity (highest IC_{50}

= 210 µg/mL). Overall, compounds with stronger docking (more negative energy) generally demonstrated higher cytotoxic effects, suggesting a possible correlation between docking affinity and anticancer activity.

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