BAB V
KESIMPULAN DAN SARAN

5.1 Kesimpulan

Berdasarkan hasil penelitian yang telah dilakukan, dapat disimpulkan bahwa:

1. Besi Fe_3O_4–AT memiliki kinerja yang lebih baik untuk proses adsorpsi dibandingkan besi Fe_3O_4 karena adanya gugus hidroksil ($-OH^-$) sebagai penyambung tambahan antara besi Fe_3O_4 dan *BSA* sehingga *BSA* dapat berikatan lebih banyak pada permukaan besi Fe_3O_4.
2. Kapasitas adsorpsi pada besi Fe_3O_4 dan besi Fe_3O_4–AT bergantung pada pH. Kapasitas maksimum adsorpsi diperoleh pada pH 4,8; mendekati titik isoelekrik *BSA* karena pada pH ini, struktur *BSA* menjadi lebih *compact* dan memudahkan terjadinya adsorpsi. Mekanisme adsorpsi pada besi Fe_3O_4 diakibatkan oleh ikatan elektrostatik antara Fe_3O_4–BSA; pada besi Fe_3O_4-AT diakibatkan oleh ikatan hidrogen dan interaksi hidrofobik antara asam tannin–BSA.
3. Model isotherm Langmuir merupakan model adsorpsi yang paling cocok untuk menggambarkan proses adsorpsi pada besi Fe_3O_4 maupun besi Fe_3O_4–AT; menunjukkan proses adsorpsi terjadi secara homogen karena adanya keseragaman energi selama proses adsorpsi.
4. Hasil termodinamika adsorpsi menunjukkan bahwa pada besi Fe_3O_4 maupun besi Fe_3O_4–AT terjadi proses adsorpsi secara spontan yang ditunjukkan dengan nilai positif pada energi bebas Gibbs (ΔG°), endoterm yang ditunjukkan dengan entalpi (ΔH°) yang bernilai negatif, serta adanya ketidakberaturan molekul *BSA* yang menempel pada permukaan besi ditandai dengan nilai entropi yang bernilai positif.(ΔS°).

5.2 Saran

Beberapa saran yang dapat berikan untuk penelitian lebih lanjut, adalah:

1. Perlu dilakukan analisis titik isoelektrik pada besi Fe_3O_4 dan Fe3O4-AT untuk menentukan secara akurat jumlah muatan yang terkandung pada keduanya.
2. Rentang pH yang digunakan perlu diperkecil agar mendapatkan kapasitas adsorpsi maksimum pada pH yang lebih akurat.

DAFTAR PUSTAKA

Abdel-Shafy, H., & Mansour, M. S. M. 2017. Polyphenols: properties, occurrence, content in food and potential effects. *Toxicology*. 6, 232-261.

Ahadi, M. 2003. Kandungan Tanin Terkondensasi dan Laju Dekomposisi pada Serasah Daun Rhizospora Mucronata Lamk pada Ekosistem Tambak Tumpangsari, Purwakarta, Jawa Barat. [Skripsi].Bogor(ID): Institut Pertanian Bogor.

Ahmed, M. F., Molla, M. R., Saha, M., Shahriar, I., Rahman, M. S., Halim, M. A.,& Asiri, A. M. 2019. Aggregation behavior of cetyldimethylethylammonium bromide under the influence of bovine serum albumin in aqueous/electrolyte solutions at various temperatures and compositions: conductivity and molecular dynamics study. *RSC advances*. 9(12), 6556-6567.

Allison, S. P., Lobo, D. N., & Stanga, Z. 2001. The treatment of hypoalbuminaemia. *Clinical Nutrition*. 20(3), 275–279.

Al-Mahmoud, S. M. 2019. Adsorption of Some Alephatic Dicarboxylic Acids on Zinc Oxide: A kinetic and Thermodynamic Study. *Baghdad Science Journal*. 16(4), 892-897.

Altun, S., Çakiroğlu, B., & Özacar, M. 2015. A facile and effective immobilization of glucose oxidase on tannic acid modified $CoFe_2O_4$ magnetic nanoparticles. *Colloids and Surfaces B: Biointerfaces*. 136, 963–970.

Anderson, J., & Mattiasson, B. 2006. Simulated moving bed technology with a simplified approach for protein purification: separation of lactoperoxidase and lactoferrin from. *Journal of Chromatography A*. 1107(1–2), 88–95.

Andrade, F.H., Uhart, S.A., Arguissain, G.G., & Ruiz, R.A. 1992. Radiation use efficiency of maize grown in a cool area. *Field Crops Res.* 28, 345-354.

Atacan, K., & Özacar, M. 2015. Characterization and immobilization of trypsin on tannic acid modified Fe3O4 nanoparticles. *Colloids and Surfaces B: Biointerfaces*. 128, 227–236.

Atacan, K., Çakiroğlu, B., & Özacar, M. 2017. Efficient protein digestion using immobilized trypsin onto tannin modified Fe_3O_4 magnetic nanoparticles. *Colloids and Surfaces B: Biointerfaces.* 156, 9–18.

Atkins, P., & Paula, J. D. 2006. *Physical Chemistry*. New York: W.H. Freeman & Company.

Ayawei, N., Angaye, S. S., Wankasi, D., & Dikio, E. D. 2015. Synthesis, characterization and application of Mg/Al layered double hydroxide for the degradation of congo red in aqueous solution. *Open Journal of Physical Chemistry*. 5(3), 56.

Ayawei, N., Ebelegi, A. N., & Wankasi, D. 2017. Modelling and interpretation of adsorption isotherms. *Journal of Chemistry*. 1, 1-11

Baishya, P., Mandal, M., Gogoi, P., & Maji, T.K. 2017. Natural polymer-based nanocomposites: a greener approach for the future. *Handbook of Composites from Renewable Materials*.1(8),433–439.

Bajpai, A. K. 2000. Adsorption of bovine serum albumin onto glass powder surfaces coated with polyvinyl alcohol. *Journal of Applied Polymer Science.* 78(5), 933–940.

Bayrakci, M., Gezici, O., Zeki, S., Ozmen, M., & Maltas, E. 2014. Novel humic acid-bonded magnetite nanoparticles for protein immobilization. *Materials Science & Engineering* C. 42, 546–552.

Berg, J., Tymoczko, J., & Stryer, L. 2002. *Biochemistry* (3rd ed.). New York: Freeman WH & Company.

Bigley, D. 1970. Carboxylic acid chemistry. *Nature*. 227(7), 531–541.

Bond, A. D., Edwards, M. R., & Jones, W. 2001. Sebacic acid. *Acta Crystallographica Section E: Structure Reports Online*. 57(2), 141-142.

Bradford, M.M. 1976. A rapid and sensitive method for the quantitation of microgram quantities of protein utilizing the principle of protein-dye binding. *Anal Biochem*. 72, 248–254.

Burr, R. 2001. Protein purification from milk. *Protein purification application – a practical approach.* New York: Oxford University Press.

Cairns D. 2009. *Essentials of Pharmaceutical Chemistry* (2nd ed.). Jakarta: Penerbit Buku Kedokteran EGC.

Chang, R. 2005. *Kimia Dasar Konsep-Konsep Inti* (3rd ed). Jakarta: Erlangga.

Chen, S. 2010. *Polymer-coated iron oxide nanoparticles for medical imaging* (Doctoral dissertation, Massachusetts Institute of Technology).

Chiou, C. T. 2002. Bioconcentration of organic contaminants. *Partition and Adsorption of Organic Contaminants in Environmental Systems*. Hoboken: John Wiley & Sons, Inc, 257.

Comuzzo, P., & Battistutta, F. 2019. Acidification and pH Control in Red Wines. *In Red Wine Technology*. 2, 17-34

Cornell, R. M., & Schwertmann, U. 2003. *The Iron Oxides: Structure, Properties, Reactions, Occurences and Uses* (2nd ed.). Weinheim: Wiley-VCH.

Cornils, B., Lappe, P., & by Staff, U. 2000. Dicarboxylic acids, aliphatic. *Ullmann's Encyclopedia of Industrial Chemistry*. 10, 18-22.

Deaville, E. R., Givens, D. I., & Mueller-Harvey, I. 2010. Chestnut and mimosa tannin silages: Effects in sheep differ for apparent digestibility, nitrogen utilisation and losses. *Animal Feed Science and Technology*. 157(3-4), 129-138.

Dias, A., Hussain, A, Marcos, A.S., Roque, A. 2011. A biotechnological perspective on the application of iron oxide magnetic colloids modified with polysaccharides. *Biotechnol.* 29, 142–155.

Eddy, S., & Sulistiyati, T. D. 2017. *Metabolisme protein*. Malang: Universitas Brawijaya Press.

Elmorsi, T.M. 2011. Equilibrium isotherms and kinetic studies of removal of methylene blue dye by adsorption onto miswak leaves as a natural adsorbent. *Journal of Environmental Protection*. 2(6), 817–827.

Felgueiras, H. P., Antunes, J. C., Martins, M. C. L., & Barbosa, M. A. 2018. Fundamentals of protein and cell interactions in biomaterials. *Peptides and Proteins as Biomaterials for Tissue Regeneration and Repair*. 2, 1-27.

Foo, K.Y., & Hameed, B.H. 2010. Insights into the modeling of adsorption isotherm systems. *Chemical Engineering Journal*. 156(1), 2–10.

Franch, A.G. 2001. The meaning of hypoalbuminaemia in clinical practice. *Clinical Nutrition*. 20(3), 265–269.

Fukuzaki, S., Urano, H., & Nagata, K. 1996. Adsorption of bovine serum albumin onto metal oxide surfaces. *Journal of Fermentation and Bioengineering.* 81(2), 163–167.

Gatta, A., Verardo, A., & Bolognesi, M. 2012. Hypoalbuminemia. *Internal and emergency medicine*. 7(3), 193-199.

Goldberg, S. 2005. Equations and models describing adsorption processes in soils. *Chemical processes in soils*. 8, 489-517.

Guadalupe, R., Reynel, A.H., Bonilla, P.A, Cano, R.I, Velasco, S.C, Martinez, H. 2008. Recycling poultry feathers for Pb removal from wastewater: kinetic and equilibrium studies. *Proc World Acad Sci Eng Technol* 2(11):338–346

Günay, A., Arslankaya, E., & Tosun, I. 2007. Lead removal from aqueous solution by natural and pretreated clinoptilolite: adsorption equilibrium and kinetics. *Journal of Hazardous Materials*. 146(1-2), 362-371.

Guo, M., Jan, L. Y., & Jan, Y. N. 1996. Control of daughter cell fates during asymmetric division: interaction of Numb and Notch. *Neuron*. 17(1), 27-41.

Haslam, E. 1998. *Practical polyphenolics: from structure to molecular recognition and physiological action*. Cambridge: University Press.

Herrmann, F.R., Saqfran, C., Levkoff, S.E., Minaker, K.L. 1992. Serum albumin level on admission as a predictor of death, length of stay and readmission. *Arch Intern Med* 152, 125–130

Hirayama, K., Akashi, S., Furuya, M., & Fukuhara K. I. 1990. Rapid confirmation and revision of the primary structure of bovine serum albumin by ESIMS and Frit-FAB LC/MBiochemical, S., and biophysical research communications. *Biochem. Biophys. Res. Commun.* 173, 639–646.

Hlady,V., & Buijs, J. 1996. Protein adsorption on solid surfaces. *Curr Opin Biotechnol.* 7, 72-77.

Horbett, T. 1996. *Proteins: structure, properties, and adsorption to surfaces*. In: Biomaterials Science. London: Academic Press; p. 133–41.

Huang, X.L., Yang, Y.,& Ding, J. 2013. Epitaxial growth of gamma-Fe_2O_3 thin films on MgO substrates by pulsed laser deposition and their properties. *Acta Mater*. 61, 548-557.

Hutson ND and Yang RT (2000) Theoretical basis for the Dubinin-Radushkevitch (D-R) adsorption isotherm equation. *Adsorption*. 3, 189–195

Inglezakis, V. J., & Zorpas, A. A. 2012. Heat of adsorption, adsorption energy and activation energy in adsorption and ion exchange systems. *Desalination and water treatment*. 39(1-3), 149-157.

Jao, D., Xue, Y., Medina, J., & Hu, X. 2017. Protein-based drug-delivery materials. *Materials*. 10(5), 517.

Jeyachandran, Y.L., Mielczarski, E., Rai,B., & Mielczarski, J.A. 2009. Quantitative and qualitative evaluation of adsorption / desorption of bovine serum albumin on hydrophilic and hydrophobic surfaces. *Langmuir*. 25(7), 11–20.

Kajjumba, G. W., Emik, S., Öngen, A., Özcan, H. K., & Aydın, S. 2018. Modelling of adsorption kinetic processes—errors, theory and application. *Advanced sorption process applications*. 3, 14-28.

Keshavarz, M., & Ghasemi, Z. 2011. Coating of iron oxide nanoparticles with human and bovine serum albumins: A thermodynamic approach. *Journal of Physical & Theoretical Chemistry*. 8(2), 7-17.

Khan, A. A., & Singh, R. P. 1987. Adsorption thermodynamics of carbofuran on Sn (IV) arsenosilicate in H^+, Na^+ and Ca^{2+} forms. *Colloids and Surfaces*. 24(1), 33–42.

Kim, M., Lim, B., Jeong, Y., Cho, Y. W., & Choa, Y. 2007. Surface modification of magnetite nanoparticles for immobilization with lysozyme. *Journal of Ceramic Processing Research*. 8(4), 293-295.

Kipling, J. J. 1965. *Adsorption from Solutions of Non-Electrolytes*. London: Academic Press.

Kopac, T., Bozgeyik, K., & Yener, J. 2008. Effect of pH and temperature on the adsorption of bovine serum albumin onto titanium dioxide. *Colloids and Surfaces A: Physicochemical and Engineering Aspects*. 322(1-3), 19–28.

Kruger, N. J. 2009. The Bradford method for protein quantitation. *The protein protocols handbook*. Totowa: Humana Press, 17-24.

Kuchma, E., Kubrin, S., & Soldatov, A. 2018. The Local Atomic Structure of Colloidal Superparamagnetic Iron Oxide Nanoparticles for Theranostics in Oncology. *Biomedicines*. 6(3), 78-84.

Lai, B. H., Yeh, C. C., & Chen, D. H. 2012. Surface modification of iron oxide nanoparticles with polyarginine as a highly positively charged magnetic nano-adsorbent for fast and effective recovery of acid proteins. *Process Biochemistry*. 47(5), 799–805.

Lam, U.T., Raffaella, M, Kiyonori, S., & Foster, N.R. 2008. Processing of iron oxide nanoparticles by supercritical fluids. *Industrial and Engineering Chemistry Research.* 47(3), 599–614.

Laurent, S.; Forge, D.; Port, M.; Roch, A.; Robic, C.; Elst, L.V., & Muller, R.N. 2008. Magnetic iron oxide nanoparticles: Synthesis, stabilization, vectorization, physicochemical characterizations, and biological applications. *Chem. Rev*. 108, 2064–2110

Lee, S. H., & Ruckenstein, E. 1988. Adsorption of proteins onto polymeric surfaces of different hydrophilicities—a case study with bovine serum albumin. *Journal of colloid and interface science*, *125*(2), 365-379.

Lehninger, A. L. 1982. *Dasar-dasar Biokimia* (1st ed). Jakarta: Erlangga.

Li, G., Du, Y., Tao, Y., Deng, H., Luo, X., & Yang, J. 2010. Iron(II) cross-linked chitin-based gel beads: Preparation, magnetic property and adsorption of methyl orange. *Carbohydrate Polymers*. 82(3), 706–713.

Liang, H. F., & Wang, Z. C. 2010. Adsorption of bovine serum albumin on functionalized silica-coated magnetic MnFe2O4 nanoparticles. *Materials Chemistry and Physics*. 124(2-3), 964-969.

Liang, Y. Y., Zhang, L. M., Li, W., & Chen, R. F. 2007. Polysaccharide-modified iron oxide nanoparticles as an effective magnetic affinity adsorbent for bovine serum albumin. *Colloid and Polymer Science*. 285(11), 1193-1199.

Liao, M.H., & Chen, D.H. 2002. Preparation and characterization of a novel magnetic nanoadsorbent. *Mater*. 12, 654–659.

Lide, D.R. 2005. *CRC Handbook of Chemistry and Physics* (5th ed). Boca: CRC Press.

Liu, L., Gao, Z. Y., Su, X. P., Chen, X., Jiang, L., & Yao, J. M. 2015. Adsorption removal of dyes from single and binary solutions using a cellulose-based bioadsorbent. *ACS Sustainable Chemistry & Engineering*, *3*(3), 432-442.

Long, F., Gong, J.L., Zeng, G.M., Chen, L., Wang, X.Y., & Deng, J.H. 2011. Removal of phosphate from aqueous solution by magnetic Fe–Zr binary oxide. *Chem Eng Journal*. 171,448–55.

Luo, H., Zhang, S., Li, X., Liu, X., Xu, Q., Liu, J., & Wang, Z. 2017. Tannic acid modified Fe_3O_4 core–shell nanoparticles for adsorption of Pb^{2+} and Hg^{2+}. *Journal of the Taiwan Institute of Chemical Engineers*. 72, 163-170.

Lyubchik, S., Lyubchik, A., Lygina, O., & Fonseca, I. 2011. Comparison of the thermodynamic parameters estimation for the adsorption process of the metals from liquid phase on activated carbons. *Thermodynamics-Interaction Studies-Solids, Liquids and Gases*. 3, 607-678.

Machala, L., Tucek, J., & Zboril, R. (2011). Polymorphous transformations of nanometric iron (III) oxide: a review. *Chemistry of Materials*. 23(14), 3255-3272.

Maciel, J., Oliveira, M.I., Gonçalves, R.M ., & Barbosa, M.A. 2012. Acta biomaterialia The effect of adsorbed fibronectin and osteopontin on macrophage adhesion and morphology on hydrophilic and hydrophobic model surfaces. *Acta Biomaterialia.* 8(10), 669–677.

Madureira, A. R., Pereira, C. I., Gomes, A. M. P., Pintado, M. E., & Malcata, F. X. 2007. Bovine whey proteins – overview on their main biological properties. *Food Research International*. 40, 1197–1211.

Mahdavi, M., Ahmad, M. B., Haron, M. J., Namvar, F., Nadi, B., Rahman, M. Z. A., & Amin, J. 2013. Synthesis, surface modification and characterisation of biocompatible magnetic iron oxide nanoparticles for biomedical applications. *Molecules*. 18(7), 7533-7548.

Mahmoodi, N.M., Hayati, B., Arami, M., & Mazaheri, F. 2010. Single and binary system dye removal from colored textile wastewater by a dendrimer as a polymeric nanoarchitecture: equilibrium and kinetics. *Chemmical Engineering Journal*. 55, 660-668.

Makkar, H. P., Blümmel, M., Borowy, N. K., & Becker, K. 1993. Gravimetric determination of tannins and their correlations with chemical and protein precipitation methods. *Journal of the Science of Food and Agriculture*. 61(2), 161-165.

Maldonado, R. A. P. 1994. *The Chemical Nature and Biologycal Activity of Tannins in Forages Legumes Fed to Sheep and Goat* (Doctoral dissertation, Thesis, Departement of Agriculture Australia, University of Quensland Australia, Australia).

Maleki, M. S., Moradi, O., & Tahmasebi, S. 2017. Adsorption of albumin by gold nanoparticles: Equilibrium and thermodynamics studies. *Arabian Journal of Chemistry*.

10, 491–502.

Marques, S. et al. 2016. Enzyme tunnels and gates as relevant targets in drug design. *Medicinal Research Reviews*. 37(5), 1095-1139.

Mashuri. 2011. Synthesis of Fe_3O_4 Nanoparticles from Iron Sands and Effects of Ni and Zn Substitution on Structures and Magnetic Properties. *Journal of Materials Science and Engineering*. 1, 182-189.

Matsudomi, N., Rector, D., & Kinsella, J. E. 1991. Gelation of bovine serum albumin and β-lactoglobulin; effects of pH, salts and thiol reagents. *Food Chemistry*. 40(1), 55-69.

Menon, P. K., Sharma, A., Lafuente, J. V., Muresanu, D. F., Aguilar, Z. P., Wang, Y. A., & Sharma, H. S. 2017. Intravenous administration of functionalized magnetic iron oxide nanoparticles does not induce CNS injury in the rat: influence of spinal cord trauma and cerebrolysin treatment. *Nanomedicine in Central Nervous System Injury and Repair*. 5, 47–63.

Mohamed, M. A., Jaafar, J., Ismail, A. F., Othman, M. H. D., & Rahman, M. A. (2017). Fourier transform infrared (FTIR) spectroscopy. *Membrane Characterization*. Elsevier, 3-29.

Mohan, S. V., & Karthikeyan, J. 1997. Removal of lignin and tannin colour from aqueous solution by adsorption onto activated charcoal. *Environmental Pollution*. 97(1-2), 183–187.

Mohapatra, M., & Anand, S. 2010. Synthesis and applications of nano-structured iron oxides/hydroxides a review. *Int. J. Eng. Sci. Technol.* 2, 127-146

Nasiruddin, K.M., & Sarwar, A. 2007. Determination of points of zero charge of natural and treated adsorbents. *Surface Review and Letters.*14(3), 461–469.

Nharingo, T., Shoniwa, V., Hunga, O., & Shumba, M. 2013. Exploring the biosorption of Methylene Blue dye onto acid treated sugarcane bagasse. *International Jornal of Current Research*. 8(5), 2169-2175.

Norde, W. 1986. *Adsorption of proteins from solution at the solid-liquid interface*. Advances in Colloid and Interface Science, 25, 267–340.

Norde, W., & Lyklema, J. 1978. The adsorption of HPA and bovine pancreas ribonuclease at negatively charged polystyrene latices. *Journal of Colloid and Interface Science*. 66, 295-302.

Oscik, J., & Cooper, I. L. 1994. *Adsorption*. Chichester: Ellis Horwood Publisher, Ltd.

Papers & Milan, K.R. 2015. Adsorption, chemisorption, and catalysis. *Chemical Papers*. 68(12), 1625-1638.

Peng, Z. G., Hidajat, K., & Uddin, M. S. 2004. Adsorption of bovine serum albumin on nanosized magnetic particles. *Journal of Colloid and Interface Science*, 271(2), 277–283.

Peters, T. 1995. Metabolism: albumin in the body. *All About Albumin: Biochemistry, Genetics, and Medical Applications*. San Diego: Academic Press.

Phan, H., Shannon, B.H, Keith, B.R., Mathias, S., & Jason, C.B. 2015. Investigation of bovine serum albumin (*BSA*) attachment onto self-assembled monolayers (SAMs) using combinatorial quartz crystal microbalance with dissipation (QCM-D) and spectroscopic ellipsometry (SE). *Plos One Journal.* 10(10), 141-282.

Rabe, M., Verdes, D., & Seeger, S. 2009. Surface-induced spreading phenomenon of protein clusters. *Soft Matter*. 5(5), 1039-1047.

Rabe, M., Verdes, D., & Seeger, S. 2011. Understanding protein adsorption phenomena at solid surfaces. *Advances in Colloid and Interface Science.* 162(1-2), 87–106.

Rahdar, S., Rahdar, A., Ahmadi, S., & Trant, J. F. 2019. Adsorption of bovine serum albumin (*BSA*) by bare magnetite nanoparticles with surface oxidative impurities that prevent aggregation. *Canadian Journal of Chemistry*. 97(8), 577-583.

Raoufinia, R., Mota, A., Keyhanvar, N., Safari, F., Shamekhi, S., & Abdolalizadeh, J. 2016. Overview of albumin and its purification methods. *University of Medical Sciences* 6(4), 495–507.

Rebodos, R. L., & Vikesland, P. J. 2010. Effects of oxidation on the magnetization of nanoparticulate magnetite. *Langmuir*. 26(22), 16745-16753.

Rezwan, K., Meier, L. P., Rezwan, M., Vörös, J., Textor, M., & Gauckler, L. J. 2004. Bovine serum albumin adsorption onto colloidal Al_2O_3 particles: A new model based on zeta potential and UV−Vis measurements. *Langmuir*. 20(23), 10055–10061.

Ridwan, S. H. D. 2012. Magnetik untuk adsorpsi kromium eksavalen penentuan pH point zero charge. *Jurnal Sains Materi Indonesia.*13(2), 136–140.

Rieger, M.M. 1985. *Surfactant in Cosmetics. Surfactant Science Series*. New York: Marcel Dekker, Inc.

Ringot, D., Lerzy, B., Chaplain, K., Bonhoure, J.P., Auclair, E., & Larondelle, Y. 2007. In vitro biosorption of ochratoxin A on the yeast industry by-products: Comparison of isotherm models. *Bioresour Technol*. 98, 1812–1821.

Rosen, M.J. & Kunjappu, J.T. 2012. *Surfactants and Interfacial Phenomena* (4th ed). New York: John Wiley & Sons Ltd.

Ruthven, D. M. 1984. *Principle of adsorption and Adsorption Process*. John Wiley dan Sons: New York, 124-141

Seader, J.D., Henley, E.J., & Roper, D.K. 2006. Drying of Solids. *Separation Process Principles*. Wiley & Sons, 695-742.

Sharifi, M., Dolatabadi, J. E. N., Fathi, F., Rashidi, M., Jafari, B., Tajalli, H., & Rashidi, M.R. 2017. Kinetic and thermodynamic study of bovine serum albumin interaction with rifampicin using surface plasmon resonance and molecular docking methods. *Journal of Biomedical Optics.* 22(3), 37-42.

Stan, M., Lung, I., Soran, M. L., Opris, O., Leostean, C., Popa, A., & Porav, A. S. 2019. Data on the removal of optilan blue dye from aqueous media using starch-coated green synthesized magnetite nanoparticles. *Data in brief*. 25, 104-165..

Subramanian, A., & Rodriguez, S.L. 2009. Fourier Transform Infrared (FTIR) Spectroscopy. *Infrared Spectroscopy for Food Quality Analysis and Control.* 2, 145–178.

Suhardi. 1991. *Kimia dan Teknologi Protein*. Yogyakarta: PAU Pangan dan Gizi UGM.

Sui Y., Cui Y., Nie Y., Xia G.M., Sun G.X., Han J.T. 2012. Surface modification of magnetite nanoparticles using gluconic acid and their application in immobilized lipase, *Coll. Surf. B Biointerf* .93, 24-8.

Sun, Y. K., Ma, M., Zhang, Y., & Gu, N. 2004. Synthesis of nanometer-size maghemite particles from magnetite. *Colloids and Surfaces A: Physicochemical and Engineering Aspects*. 245(1-3), 15-19.

Supattarasakda., Kitibodee., Karat, P., & Tharaporn, P. 2013. Control of hematite nanoparticle size and shape by the chemical precipitation method. *Powder Technology.* 249, 353–359.

Tan, K. L. AND Hameed, H.B. 2017. Insight into the adsorption kinetics models for the removal of contaminants from aqueous solutions. *Journal of the Taiwan Institute of Chemical Engineers.* 74, 25–48.

Teja, A. S., & Koh, P. Y. 2009. Synthesis, properties, and applications of magnetic iron oxide nanoparticles. *Progress in crystal growth and characterization of materials*. 55(1-2), 22-45.

Temkin, M. AND Pyzhev, V. 1940. *Kinetics of Ammonia Synthesis on Promoted Iron Catalysts*. Acta Physicochimica URSS. 12, 217-222

Todaka., Takashi., Tomoyasu, K, & Masato, E. 2008. Low curie temperature material for induction heating self-temperature controlling system. *Journal of Magnetism and Magnetic Materials.* 320(20),702–710.

Topală., Tamara., Andreea, B., Luminiţa, O., & Radu, O. 2014. Bovine serum albumin interactions with metal complexes. *Clujul Medical*.87(4):5.

Trimble, W. S., & Grinstein, S. 2015. Barriers to the free diffusion of proteins and lipids in the plasma membrane. *The Journal of Cell Biology,* 208(3), 259–271.

Tscharnuter, W. 2000. *Photon correlation spectroscopy in particle sizing*. Encyclopedia of Analytical Chemistry. New York: John Wiley & Sons.

Üçer, A., Uyanik, A., & Aygün, Ş. F. 2006. Adsorption of Cu(II), Cd(II), Zn(II), Mn(II) and Fe(III) ions by tannic acid immobilised activated carbon. *Separation and Purification Technology*. 47(3), 113–118.

Ur Rahman, Z., Dong, Y. L., Ren, C., Zhang, Z. Y., & Chen, X. 2012. Protein adsorption on citrate modified magnetic nanoparticles. *Journal of Nanoscience and Nanotechnology.* 12(3), 2598–2606.

Veisi, H., Moradi, S. B., Saljooqi, A., & Safarimehr, P. 2019. Silver nanoparticle-decorated on tannic acid-modified magnetite nanoparticles (Fe3O4@ TA/Ag) for highly active catalytic reduction of 4-nitrophenol, Rhodamine B and Methylene blue. *Materials Science and Engineering: C*. 100, 445-452.

Veisi, H., Pirhayati, M., Mohammadi, P., Abdi, M. R., & Gholami, J. 2017. Magnetite nanoparticles coated with tannic acid as a green reductant and stabilizer sorbent for palladium ions: Synthetic application of Fe_3O_4 @TA-Pd NPs as magnetically

separable and reusable nanocatalyst for reduction of 4-nitrophenol and Suzuki reactions. *Catalysis Today*. 2(1), 102-108.

Verma, D., Gulati, N., Kaul, S., Mukherjee, S., & Nagaich, U. 2018. Protein based nanostructures for drug delivery. *Journal of Pharmaceutics.* 1, 10-18.

Vijayaraghavan, K., Palanivelu, K., & Velan, M. 2006. Biosorption of copper(II) and cobalt(II) from aqueous solutions by crab shell particles. *Bioresource Technology*. 97(12), 1411–1419.

Weber, T. W., & Chakravorti, R. K. 1974. Pore and solid diffusion models for fixed-bed adsorbers. *AIChE Journal,* 20(2), 228–238.

Wu, W., He, Q., & Jiang, C. 2008. Magnetic iron oxide nanoparticles: synthesis and surface functionalization strategies. *Nanoscale Research Letters*. 3(11), 397–415.

Wu, W., Wu, Z., Yu, T., Jiang, C., & Kim, W. S. 2015. Recent progress on magnetic iron oxide nanoparticles: synthesis, surface functional strategies and biomedical applications. *Science and technology of advanced materials*. 16(2), 23-51.

Xiao, Q., Liu, C., Ni, H., Zhu, Y., Jiang, Z., & Xiao, A. 2019. β-Agarase immobilized on tannic acid-modified Fe3O4 nanoparticles for efficient preparation of bioactive neoagaro-oligosaccharide. *Food Chemistry*, 272, 586–595.

Xu, J., Sun, J., Wang, Y., Sheng, J., Wang, F., & Sun, M. 2014. Application of iron magnetic nanoparticles in protein immobilization. *Molecules*. 19(8), 11465-11486.

Yang, S. T., Huang, H., Tay, A., Qin, W., Guzman, L., & Nicolas, E. C. 2007. Extractive fermentation for the production of carboxylic acids. *Bioprocessing for value-added products from renewable resources*. Elsevier, 421-446.

Zainuri, M. 2017. Hematite from natural iron Stones as microwave absorbing material on x-band frequency ranges. *IOP Conference Series: Materials Science and Engineering.* 196(1), 101-108.

Zhu, Y. T., Ren, X. Y., Liu, Y. M., Wei, Y., Qing, L. S., & Liao, X. 2014. Covalent immobilization of porcine pancreatic lipase on carboxyl-activated magnetic nanoparticles: Characterization and application for enzymatic inhibition assays. *Materials Science and Engineering.* 38, 278–285.

Zydney, A. L. 1998. Protein separations using membrane filtration: new opportunities for whey fractionation. *International Dairy Journal*. 8(3), 243–250.