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by Eviomitta Rizki Amanda

Method Validation of Silica Dispersive Solid Phase Extraction Combined with Spectrophotometer UV-Vis for the Determination of Allopurinol in Herbal Medicine

Validasi Metode Ekstraksi Fasa Padat Terdispersi menggunakan Silika Kombinasi Spektrofotometer UV-Vis untuk Analisa Allopurinol dalam Jamu

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ABSTRACT

A facile sample preparation method based on silica dispersive solid-phase extraction combination with spectrophotometer UV-Vis for the extraction of allopurinol in herbal medicine was successfully developed. Silica was used as a solid sorbent. The extraction process was carried out by inserting and dispersing silicas in a 30 mL sample solution that contained allopurinol, then stirred using a hot plate stirrer. At the end of the extraction process, silicas were collected and desorbed using ethanol by utilizing a vortex. The desorption solution was analyzed by spectrophotometer UV-Vis at a maximum wavelength of 250 nm. Several essential parameters such as silica mass, extraction time, desorption time, and pH of sample solution were optimized. The results showed that the optimum extraction condition was achieved: silica mass. 0.8 grams; extraction time, 45 minutes; desorption time, 2 minutes; and pH of sample solution, pH 7. The optimum extraction condition was then applied for the standard curve and analyzed of allopurinol in herbal medicine samples. The results of the method validation method were obtained the correlation coefficient (R^2), 0.9961; the detection limit, 0.6871 ppm; the quantitation limit, 2.2902 ppm, the percent of recovery (% R) in the range of 96.42-110.25%, percent coefficient of variation (% CV) in the range of 0.0361-0.1322%. The application method in 3 real samples showed that the concentrations of allopurinol were 56.0221 ppm, 54.8706 ppm, and 63.6719 ppm, respectively. The values of % R in the analysis of real samples by using the spiking method were obtained in the range of 49.52-89.74%.

Keywords: Allopurinol, dispersive solid phase extraction, herbal medicine, silica, spectrophotometer UV-Vis.

ABSTRAK

Metode preparasi sampel menggunakan ekstraksi fasa padat terdispersi kombinasi spektrofotometer UV-Vis untuk ekstraksi allopurinol dalam sampel jamu berhasil dikembangkan. Silika digunakan sebagai fasa padat yang berperan sebagai adsorben. Proses ekstraksi dilakukan dengan mendispersikan silika dalam 30 mL larutan sampel yang berisi standard allopurinol, kemudian diaduk dengan hotplate stirrer. Pada akhir proses ekstraksi, silika dikumpulkan dan didesorbsi menggunakan pelarut etanol dengan bantuan vortex. Larutan hasil desorpsi dianalisis menggunakan spektrofotometer UV-Vis pada panjang gelombang maksimum 250 nm. Beberapa parameter penting dioptimasi dengan hasil optimasi menunjukkan bahwa massa optimum silika 0.8 gram, waktu ekstraksi optimum 45 menit, waktu desorpsi optimum 2 menit, dan pH larutan sampel optimum pH 7. Kondisi ekstraksi yang optimum kemudian diaplikasikan untuk pembuatan kurva standar dan analisa allopurinol pada sampel jamu. Hasil validasi metode menunjukkan bahwa koefisien korelasi (R^2) 0.9961; limit deteksi 0.6871 ppm; limit kuantitasi 2.2902 ppm; persen recovery (%R) pada rentang 96.42%-110.25%; dan persen koofisien variasi (%KV) pada rentang 0.0361-0.1332%. Aplikasi metode pada 3 sampel jamu menunjukkan bahwa konsentrasi allopurinol dalam sampel jamu masing-masing 56.0221 ppm, 54.8706 ppm dan 63.6719 ppm. Nilai %R dari analisa sampel yang diperoleh menggunakan metode standar adisi berada dalam rentang 49.52%-89.74%.

***Kata kunci**: Allopurinol, ekstraksi fasa padat terdispersi, jamu, silika, spektrofotometer UV-Vis.*

Introduction

Herbal medicine is one of the famous alternative medicine in Indonesia. There is a lot of traditional herbal medicine in Indonesia containing herbs and plant extract. Herbal medicines are trusted to maintain health performance and treat diseases (Elfahmi et al., 2014). However, the use of herbal medicine without certainty dosage can bring negative effects on human health. In the recent few years, the consumption of herbal medicine has increased in Indonesian society which has triggered an abuse of chemical drugs in herbal medicine. Chemical drugs have been added to some herbal medicine to enhance the therapeutic effect.

Meanwhile, according to the regulation of the National Agency of Drug and Food Control, herbal medicine should not contain chemical drugs including synthetic chemicals or isolated compounds from medicinal plants (BPOM, 2021).

Allopurinol is one of the chemical drugs which is usually added into herbal medicine for chronic gout treatment (Sivera et al., 2014). Allopurinol is a xanthine oxidase inhibitor drug that will inhibit xanthine oxidase enzyme to produce uric acid (Singh et al., 2017). Long time consumption of allopurinol with uncontrolled dosage will cause several negative effects such as diarrhea, drug

fever, and hematological abnormalities (Pratiwi et al., 2019). Therefore, monitoring and determination of allopurinol in herbal medicine are important to prevent the toxicity effect of allopurinol.

A different analytical method based on spectrometric, chromatography (Ilango et al., 2003), capillary electrophoresis (Kou et al., 2006), and electrochemical detection method have been developed for allopurinol detection (Ladmakhi et al., 2020; Reinders et al., 2007; Rezaei & Rahmanian, 2011). However, since these methods are selective and sensitive, these methods also have several disadvantages such as time-consuming, tedious, requiring expensive instruments, and toxic solvents (Kou et al., 2006; Pratiwi et al., 2019). Another is that the sample preparation method also becomes an important part of the analytical method besides the instrumentation. Sample preparation methods based on green analytical chemistry (GAC) are needed to clean up and preconcentrate analytes from complex matrices. Solid-phase extraction (SPE) is a popular and common technique for selective and rapid sample preparation methods in the analysis of pharmaceuticals and drugs (Kamaruzaman et al., 2017). SPE has good performance such as high percentage of analyte recovery, analyte concentration, highly purified extract, ability to extract analyte over a wide polarity range, ease of automation, compatibility with instrumental analysis,

and reduced use of organic solvents (Jagadeesan et al., 2016).

A quick and simple extraction method of SPE derivatives, namely dispersive solid-phase extraction (DSPE) is carried out with dispersed silica as solid sorbent for preconcentration of the target analytes from the sample solution. The unique and interesting property of this method is that the silica particles are directly dispersed in the sample solution, so they can be in direct contact with the analytes. This condition can improve extraction efficiency and achieve good extraction recovery. Silica is abundant material with low environmental toxicity and good absorbance performance. It serves in a negative surface charge above pH 2, allowing for strong adsorption of cations under neutral conditions, and subsequent release of adsorbates in moderately acidic washes (Piątek et al., 2020). Silica is widely applied as sorbent for solid-phase multi residues extraction (Casado et al., 2016; Li et al., 2017; Speltini et al., 2017). According to the performance, silica has been applied in a lot of fields such as for the adsorption of dyes, drug molecules, protein, and heavy metals (Barczak, 2019; Han et al., 2011; Li et al., 2019). In this work, silica was applied as a solid sorbent for extraction and preconcentration of allopurinol in herbal medicine samples by dispersive solid-phase extraction. Several important parameters including the mass of silica, extraction time, desorption time, dan sample pH have

been investigated. The best extraction conditions, the performance of the developed method was validated.

Research Method

Materials and Instruments

All chemicals used were analytical grade. All solutions were prepared using aqua demineralization from Brata Chem. Allopurinol was obtained from First Medipharma. Sodium hydroxide, hydrochloric acid, Silica (SiO$_2$), and ethanol were obtained from Merck. Instruments used were hotplate stirrer (Bione), vortex (Thermo Scientific). Spectrophotometer UV-Vis Genesys 10S (Thermo Scientific).

Preparation of Silica Sorbent

Preparation of silica sorbent as follow Ramadani (2018). Silica sorbents were prepared by dipping SiO$_2$ in hydrochloric acid 1M. Then, the solution was heated and stirred for 60 minutes then continued to dry overnight until the silica powders were completely suspended. Suspended silicas were separated from the filtrate and washed using demineralized water until to get neutral pH. Silicas were dried in the oven with a temperature of 100 °C for 6 hours.

Silica Dispersive Solid Phase Extraction (DSPE)

Stock solutions of allopurinol at a concentration of 1000 µg/mL were prepared in methanol and were stored in the refrigerator. The working solution of allopurinol for studying the extraction performance was prepared by dissolving the standard solution of allopurinol as the model analytes at a concentration of 6 µg/mL in demineralized water. The experimental silica DSPE setup is illustrated in **Figure 1**.
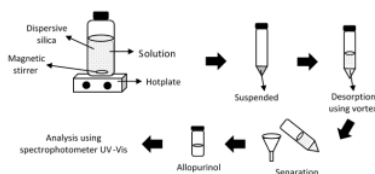
Figure 1. Set-up experimental Silica DSPE

The water sample (30 ml) was transferred into 50 ml Beaker glass. Furtehrmore, a magnetic stirrer and silica powder were placed into the sample. The extraction process was started by stirring the sample solution at 800 rpm. At the end of the extraction process, silicas were collected and desorbed using ethanol by utilizing a vortex. The desorption solution was analyzed by spectrophotometer UV-Vis at a wavelength of 250 nm. Several important parameters such as silica mass, extraction time, desorption time, and pH of sample solution were optimized.

Validation of Analytical Method

The developed method was evaluated for linearity, recovery, coefficient variation, the limit of detection (LOD), and the limit of quantification (LOQ) before being applied to the real sample analysis.

Sample Analysis

Three kinds of herbal medicines for gout arthritis in various brands was collected from a local retail shop. The sample was determined by qualitative analysis (thin layer chromatography) before applied for quantitative analysis using the silica DSPE method. The samples (positive containing allopurinol) were dissolved in demineralized water. Suspended particles and filtrate were separated by filtration. The filtrate was collected and transferred into Beaker glass. Then, the samples were extracted using silica DSPE.

Results and Discussion

Activation of Silica Sorbent

The addition of hydrochloric acid into SiO_2 aimed to remove metal oxides that blocked the surface and porous of SiO_2. This treatment could increase the capacity of porous and surface area for adsorption. Chemical treatment using acid or basic had a function to open the porous, remove the purityy, and rearrange the exchanged atom (Al Muttaqii et al., 2019). The addition of acidic solution into SiO_2 also could increase the hydrophobicity of SiO_2 that occurs the decreasing of water adsorption (Lu *et al.*, 2009).

Optimization of Silica DSPE.

The optimization procedure was carried out using demineralized water samples spiked with allopurinol to give a concentration of 6 µg/mL (*n*=3).

Mass of silica is one of the important parameters to evaluate the absorption capacity of the silica DSPE. Various mass of silica in the range of 0.6 gram - 1 gram was investigated toward the extraction efficiency. The results showed that the lowest mass of silica (0.6 gram) gave the lowest extraction efficiency. On the other hand, a silica mass of 0.8 grams showed the best extraction efficiency. Therefore, a silica mass of 0.8 grams was chosen for subsequent studies. The silicas played an adsorbent role in this study. The absorbance of allopurinol increased with the increase of the mass of silica and reached an optimum absorbance in 0.8 gram (**Figure 2**).
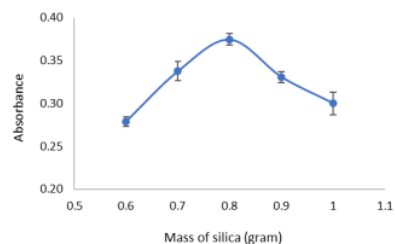

Figure 2. Optimization of the mass of silica

Extraction efficiency improved with the increasing amount of silica. This may be due to the enhancement in the active sites and surface area. The increasing number of active sites on the surface of the adsorbent should be sufficient to trap the total amount of the target compound (Sowa et al., 2018). Activated silica using acidic solution could open the size of porous and surface area. It was also increased the hydrophobicity of silica, which was

decreasing water sorption and increasing analyte sorption. However, the larger amount of silica could decrease the extraction efficiency because a higher mass of silica triggered collision between particles, thus it could release the adsorbed analyte (Lu *et al.*, 2019). Therefore, the mass of silica of 0.8 gram was adopted in the subsequent experiments.

The bond strength of allopurinol in silica sorbents is time-dependent. The partition of the analyte between the solution and the sorbent is a dynamic process and precise timing is required to obtain equilibrium (Pashaei et al., 2017). Extraction times in the range of 15 to 75 minutes were investigated to achieve the optimum equilibrium time. The optimum equilibrium time was reached in 45 minutes (**Figure 3**).
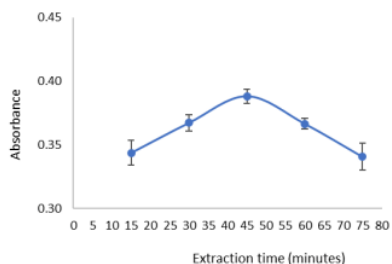

Figure 3. Optimization of extraction time

The longer extraction time cause allopurinol tended to be entrapped in closed interstitial spaces between aggregates and caused incomplete desorption (Loh et al., 2013). Therefore, an extraction time of 45 minutes was chosen for subsequent experiments.

Desorption time is one of the important parameters to achieve good efficiency by determining the time required for mass transfer of analytes from sorbent to the organic phase (desorption solvent). Hence, it was optimized by increasing the shaking time from 1 to 5 minutes. The Vortex method was used to desorb allopurinol from the silica sorbent. It showed that the maximum desorption time of the analyte was achieved within 2 minutes of a vortex (**Figure 4**).
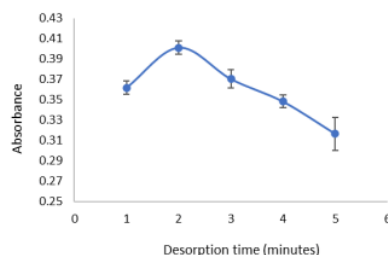

Figure 4. Optimization of desorption time

This indicated that 2 minutes is sufficient to elute allopurinol from the surface of the silica sorbent. Desorption time has closely related to the partition of analytes between desorption solvent and sorbent to obtain equilibrium conditions. Longer desorption time decreased the efficiency might be due to the saturation of desorption solvent. The decrease in absorbance may also be caused by re-adsorption of the target analyte from the sorbent to the sample (Rozaini et al., 2019). Therefore, a desorption time of 2 minutes was chosen for subsequent experiments.

The pH of the sample solution plays an important role to get the best extraction efficiency because it can influence the determination of the molecular or ionic form of the target analyte and the charge of the silica sorbent. Thus, in this experiment, the pH of the sample solution was carried out in the pH range of 3 to 11. As the results, it can be shown that the maximum extraction efficiency of the silica for allopurinol was obtained at pH 7, whereas the lowest efficiency was at pH 3 (**Figure 5**).
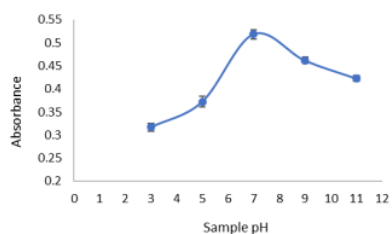

Figure 5. Optimization of sample pH

Method Validation

Method validation was carried out based on the calibration curve of allopurinol in demineralized water under optimum extraction conditions. The analytical evaluation was carried out based on the coefficient of correlation (R^2), the limit of detection (LOD), the limit of quantification (LOQ), % recovery (%R), and % coefficient variation (%KV). The results were shown in **Table 1**.

The results of the method validation method were obtained the correlation coefficient, 0.9961; the detection limit, 0.6871 µg/mL; the quantitation limit, 2.2902 µg/mL, the percent of recovery (% R) in the range of 96.42-110.25%, percent coefficient of variation (% CV) in the range of 0.0361-0.1322%.

Tabel 1. Method validation data of silica DSPE

Parameter	Value
Calibration range (µg/mL)	2 - 10
R^2	0.9961
LOD (µg/mL)	0.6871
LOQ (µg/mL)	2.2902
Recovery (%)	96.42 − 110.25
RSD* (%)	0.0026 − 0.0043
KV* (%)	0.0331 − 0.1323

*RSD = Relative standard deviation, KV = coefficient variation

Analysis of Real Sample using Silica DSPE

The Silica DSPE was applied for the determination of allopurinol in herbal medicine samples. Before quantitative identification, herbal medicine samples were evaluated by the qualitative identification thin layer chromatography (TLC) method. The results were shown in **Table 2**. The positive samples were determined the concentration of allopurinol using silica DSPE method combination with spectrophotometer UV-Vis.

Table 2. Qualitative analysis of allopurinol using TLC method

Sample	Retardation factor (Rf)		Result
	Control	Sample	
A	0.5125	0.4925	+
B	0.5125	0.5025	+
C	0.5125	0.4925	+
D	0.5125	0.2625	-
E	0.5125	0.8125	-

Table 3. Quantitative analysis of allopurinol using silica DSPE-Spectrophotometer UV-Vis

Sample	Concentration of allopurinol (µg/mL)*, %RSD	[20] %R and % RSD Spike		
		2 µg/mL	6 µg/mL	10 µg/mL
A	56.0221; 0.0102	49.52; 0.0094	68.55; 0.0081	80.50; 0.0574
B	54.8706; 0.0306	88.17; 0.0161	73.82; 0.0182	78.04; 0.0191
C	63.6719; 0.0227	89.74; 0.0377	75.39; 0.0791	84.82; 0.0369

*) Dilution factor ten times

The quantitative results were shown in **Table 3.** The results showed that between five samples of herbal medicine, there are three samples positive containing allopurinol as chemical drugs in herbal medicine, namely sample A, sample B, and sample C. Silica DSPE method was selective, efficient, and suitable for quantitative analysis of allopurinol in herbal medicine samples, with the %R in spiking method in the range of 49.52 – 89.74. The results of the decrease in %R indicated that other components in the herbal medicine inhibited the silica porous silica. This makes the ability of silica to absorb analytes also decreases

Conclusion

The present study revealed that silica DSPE is suitable for the determination of chemical drugs in herbal medicine. This method has eliminated classical [19] separation techniques such as liquid-liquid extraction and solid-phase extraction. This method is capable to stand [5] as an alternative green analytical method for the miniaturization of solid-phase extraction.

Acknowledgment

Reference

Al Muttaqii M, Birawidha DC, Isnugroho K, Yamin M, Hendronursito Y, Istiqomah AD, Dewangga DP. 2019. Pengaruh aktivasi secara kimia menggunakan larutan asam dan basa terhadap karakteristik zeolit alam. Jurnal Riset Teknologi Industri. 13(2): 266.

Barczak M. 2019. Functionalization of mesoporous silica surface with carboxylic groups by Meldrum's acid and its application for sorption of proteins. Journal of Porous Materials. 26(1): 291–300.

Badan Pengawas Obat dan Makanan Peraturan No. 14 Tahun 2021. 2021. Persyaratan Teknis Bahan Kosmetika. BPOMRI. 11. 1-16.

Casado N. Morante-Zarcero S, Pérez-Quintanilla D, Sierra I. 2016. Application of a hybrid ordered mesoporous silica as sorbent for solid-phase multi-residue extraction of veterinary drugs in meat by ultra-high-performance liquid chromatography coupled to ion-trap tandem mass spectrometry. Journal of Chromatography A. 1459: 24–37.

Dalli I, Ramdhani D, Hasanah AN. 2017. Design of indicator strip using polystyrene (PS) and polymethylmethacrylate (PMMA) for detection of diclofenac sodium in traditional pain relief herbal medicines. Indonesian Journal of Chemistry. 17(1): 71–78.

Elfahmi, Woerdenbag HJ, Kayser O. 2014. Jamu: Indonesian traditional herbal medicine towards rational phytopharmacological use. Journal of Herbal Medicine. 4(2): 51–73.

Han L, Terasaki O, Che S. 2011. Carboxylic group functionalized ordered mesoporous silicas. Journal of Materials Chemistry. 21(30): 11033–11039.

Ilango K, Valentina P, Lakshmi KS. 2003. Spectrophotometric determination of Finasteride in tablet formulation. Indian Drugs. 40(2): 122–123.

Jagadeesan KK, Wierzbicka C, Laurell T, Sellergren B, Shinde S, Ekström S. 2016. Multiplexed MALDI-MS arrays for screening of MIP solid phase extraction materials. Journal of Chromatography B: Analytical Technologies in the Biomedical and Life Sciences. 1021: 213–220.

Kamaruzaman S, Sanagi MM, Yahaya N, Wan Ibrahim WA, Endud S, Wan Ibrahim WN. 2017. Magnetic micro-solid-phase extraction based on magnetite-MCM-41 with gas chromatography–mass spectrometry for the determination of antidepressant drugs in biological fluids. Journal of Separation Science. 40(21): 4222–4233.

Kou HS, Lin TP, Chung TC, Wu HL. 2006. Micellar electrokinetic capillary chromatographic method for the quantitative analysis of uricosuric and antigout drugs in pharmaceutical preparations. Electrophoresis. 27(12): 2293–2299.

Ladmakhi HB, Chekin F, Fathi S, Raoof JB. 2020. Electrochemical sensor based on magnetite graphene oxide/ordered mesoporous carbon hybrid to detection of allopurinol in clinical samples. Talanta: 211, 120759.

Li Y, He J, Zhang K, Liu T, Hu Y, Chen X, Wang C, Huang X, Kong L, Liu J. 2019. Super rapid removal of copper, cadmium and lead ions from water by NTA-silica gel. RSC Advances. 9(1): 397–407.

Li Y, Huang C, Yang J, Peng J, Jin J, Ma H, Chen J. 2017. Multifunctionalized mesoporous silica as an efficient reversed-phase/anion exchange mixed-mode sorbent for solid-phase extraction of four acidic nonsteroidal anti-inflammatory drugs in environmental water samples. Journal of Chromatography A. 1527: 10–17.

Loh SH, Sanagi MM, Wan Ibrahim WA, Hasan MN. 2013. Multi-walled carbon nanotube-impregnated agarose film microextraction of polycyclic aromatic hydrocarbons in green tea beverage. Talanta. 106: 200–205.

Lu S, Ma Y, Zhu C, Shen S, He Q. 2009. The effect of hydrophobic modification of zeolites on CO_2 absorption enhancement. Chinese

Journal of Chemical Engineering. 17(1): 36–41.

Lv Y, Deng Q, Row KH, Zhu T. 2019. Silane coupling agents modified silica and graphene oxide materials for determination of sulfamerazine and sulfameter in milk by HPLC. Food Analytical Methods. 12(3): 687–696.

Nasir ANM, Yahaya N, Zain NNM, Lim V, Kamaruzaman S, Saad B, Nishiyama N, Yoshida N, Hirota Y. 2019. Thiol-functionalized magnetic carbon nanotubes for magnetic micro-solid phase extraction of sulfonamide antibiotics from milks and commercial chicken meat products. Food Chemistry. 276: 458–466.

Pashaei Y, Ghorbani-Bidkorbeh F, Shekarchi M. 2017. Superparamagnetic graphene oxide-based dispersive-solid phase extraction for preconcentration and determination of tamsulosin hydrochloride in human plasma by high performance liquid chromatography-ultraviolet detection. Journal of Chromatography A. 1499: 21–29.

Piątek J, de Bruin-Dickason CN, Jaworski A, Chen J, Budnyak T, Slabon A. 2020. Glycine-functionalized silica as sorbent for cobalt(II) and nickel(II) recovery. Applied Surface Science. 530: 147299.

Pratiwi R, Septyani RN, Febriany R, Saputri FA, Nuwarda RF. 2019. Design and optimization of colorimetric paper-based analytical device for rapid detection of allopurinol in herbal medicine. International Journal of Analytical Chemistry. 2019: 4682839.

Ramadani K. 2018. Sintesis dan karakterisasi silika gel dari limbah kaca untuk menurunkan kesadahan air. Saintifik. 4(2): 179.

Reinders MK, Nijdam LC, van Roon EN, Movig KLL, Jansen TLTA, van de Laar MAFJ, Brouwers JRBJ. 2007. A simple method for quantification of allopurinol and oxipurinol in human serum by high-performance liquid chromatography with UV-detection. Journal of Pharmaceutical and Biomedical Analysis. 45(2): 312–317.

Rezaei B, Rahmanian O. 2011. Nanolayer treatment to realize suitable configuration for electrochemical allopurinol sensor based on molecular imprinting recognition sites on multiwall carbon nanotube surface. Sensors and Actuators, B: Chemical. 160(1): 99–104.

Rozaini MNH, Semail NF, Saad B, Kamaruzaman S, Abdullah WN, Rahim NA, Miskam M, Loh SH, Yahaya N. 2019. Molecularly imprinted silica gel incorporated with agarose polymer matrix as mixed matrix membrane for separation and preconcentration of sulfonamide antibiotics in water samples. Talanta. 199: 522–531.

Rozaini MNH, Yahaya N, Saad B, Kamaruzaman S, Hanapi NSM. 2017. Rapid ultrasound assisted emulsification micro-solid phase extraction based on molecularly imprinted polymer for HPLC-DAD determination of bisphenol A in aqueous matrices. Talanta. 171: 242–249.

Singh JA, Ramachandaran R, Yu S, Curtis JR. 2017. Allopurinol use and the risk of acute cardiovascular events in patients with gout and diabetes. BMC Cardiovascular Disorders. 17(1): 1–9.

Sivera F, Andrés M, Carmona L, Kydd ASR, Moi J, Seth R, Sriranganathan M, Van Durme C, Van Echteld I, Vinik O, Wechalekar MD, Aletaha D, Bombardier C, Buchbinder R, Edwards CJ, Landewé RB, Bijlsma JW, Branco JC, Burgos-Vargas R, Van Der Heijde DM. 2014) Multinational evidence-based recommendations for the diagnosis and management of gout: Integrating systematic literature review and expert opinion of a broad panel of rheumatologists in the 3e initiative. Annals of the Rheumatic Diseases. 73(2): 328–335.

Sowa I, Wójciak-Kosior M, Strzemski M, Sawicki J, Staniak M, Dresler S, Szwerc W, Mołdoch J, Latalsk, M. 2018. Silica modified with polyaniline as a potential sorbent for matrix solid phase dispersion (MSPD) and dispersive solid phase extraction (d-SPE) of plant samples. Materials. 11(4): 467.

Speltini A, Maraschi F, Govoni R, Milanese C, Profumo A, Malavasi L, Sturini M. 2017. Facile and fast preparation of low-cost silica-supported graphitic carbon nitride for solid-phase extraction of fluoroquinolone drugs from environmental waters. Journal of Chromatography A. 1489: 9–17.

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microextraction based on an agarose-chitosan-multiwalled carbon nanotube composite film combined with HPLC-UV for the determination of nonsteroidal anti-inflammatory drugs in aqueous samples", Journal of Separation Science, 2018
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      Samples", Water, Air, & Soil Pollution, 2020
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