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Photo removal of imidacloprid from neonicotinoids using Bamboo vinegar

Sevil Akçağlar
Department of Mechanical Engineering, Dokuz Eylül University, Buca, Izmi, Turkey

Corresponding Author: **Sevil Akçağlar**

Abstract
Although bamboo vinegar can be used as an antibiotic alternative on some bacterial communities due to its phenolic compounds, ketone and furfural ingredients, in this study the effects of increasing dilutions of bamboo vinegar to the photo-degradation of imidacloprid neonicotinoid was studied. The effects sun light and high-pressure mercury lamps on the photo-degradation efficiencies of imidacloprid pesticide were studied. Furthermore, the properties of initial imidacloprid dose, pH on the yields of imidacloprid were researched. The maximum photo-degradation yield was detected at 20 mg/L imidacloprid dose. 94% and 99.90% imidacloprid photo-degradation yields were detected when the bamboo vinegar diluted between 120 and 130 folds. High-pressure mercury lamp exhibited huge photo-degradation yields compared to sun light. The pH affects significantly the photodegradation yield of imidacloprid the photooxidation yield was low under acidic conditions while it was raised with increasing pH. Although bamboo vinegar exhibited a photo quenching property to on the imidacloprid neonicotinoid at low dilutions an improved photo-degradation yield was detected at high dilutions

Keywords: Imidacloprid, Neonicotinoid, Photo-Degradation, Bamboo Vinegar, pH, Sun Light, High-Pressure Mercury Lamp

1. Introduction
Neonicotinoid was use in the world for inhibits the insect, root uptake, aleyrodidae and delphacidae. This high treatment and degreased inhibitions properties [1]. Were activated with asetofolin receptors by paralyze the nervous of the insects. These compounds were extremely toxic to the nervous cause in death in the insects. These chemicals have composed were extensively utilize in the world [2, 3].

Neonicotinoids exhibited decreased inhibitors and have elevated performances to the agricultural substances like rice, potatoes and fruits [4].

Neonicotinoid insecticides were to the market with the production of pyrethroid insecticides. It was important to say that although these chemicals were extensively used their metabolic products is toxic to the human and to the food compounds. This extremely elevated the risks to the aquatic ecosystem and humans [5, 6].

In order to provide safe health, the EU was taken in consideration some legislation for the upper remaining limits in the environment for their utilization in agricultural lands. This limitation varied between 0.1 and 1 mg/kg [6]. Based on the toxicity studies of neonicotinoids the limit dose causing neonicotinoid toxicity of imidacloprid is 0.77 kg/L [2]. On the other hand, clothianidin dose performed toxicity in the immune system was 0.1 mg/L [8]; the limit dose of imidacloprid was 0.03 mg/L cause toxicity [9], genotoxicity and endocrine disruption [10]. Nowadays neonicotinoid concentrations in foods were higher than the maximum dose given for limit value in Turkey in the north region some leaves in the green tea were inhibited by imidacloprid. In the EU 15.8 of lettuces were contaminated with imidacloprid. In the US the vegetables were contaminated by imidacloprid 19.90% of vegetable during 1999 and 2015 [11, 12].

This imidacloprid with metabolic substance of imidacloprid was measured in the drinking water in the US. These pesticides cannot be cleaning with water since the plants are not suitable for the process. Neonicotinoids were begun to use in years 1990 and in 2022 were the most used insecticide for vegetables tea leaves and coffee beans [12-14]. Bamboo vinegar is a transparent liquid developed during higher of bamboo partial with non-aerated condition. It was contained a lot of chemical ingredients. The main ingredient was acetic acid [15]. It is fabricated from the dried bamboo with a flame was burning at 600-900 ºC for 4 days. Then it was cooling at 21 ºC and was get as charcoal. During process the vapor temperature decreased to 20 ºC and the remaining liquid was reused at bamboo vinegar. In other words, bamboo is a metabolic product of charcoal factory having excessive organic compounds such as acetic acid, polyphenols, alkaloids and ketones [16-17]. The resent assay containing the organic substances in bamboo vinegar was very limited. The commercial utilization of bamboo vinegar was begun in China and Japan by its utilization as insecticide. Among its components acetic acid and polyphenolic compounds present in wood vinegar were used to remove the gens and termiticides. This chemical has inhibitions properties to the fungus and to termites [17]. Bamboo vinegar accumulated during charcoal production and used effectively as addictive to the foods. However, it's important to note that is has some anti-inflammatory effect by reducing production of oxygenated compounds.

Limited studies were detected on the properties of bamboo vinegar. Therefore, this research was performed by my self-showed that imidacloprid was photodegraded under UV light with a yield of 67%. Based on this low yields it was aimed to determine the effects of initial imidacloprid concentrations (14 mg/L, 20 mg/L, 30 mg/L and 40 mg/L), pH levels (acidic, neutral and alkaline), light source (sun light and high-pressure mercury lamps), bamboo vinegar dilutions (25-150 folds) on the photo-degradation of imidacloprid was studied.

2. Materials and methods

2.1 Chemicals

Imidacloprid pesticide standard with purity of >99% of imidacloprid was purchased from Merck, Co, Darmstad Germany. Methanol was obtained from from Merck, Co, Darmstad Germany. Bamboo vinegar was obtained from a pickle production industry in Ayvalık, Turkey.

2.2 Measurement of imidacloprid in HPLC

Imidacloprid-neonicotinoid was mixed in methanol as dissolving compound to generate standard mixtures and measured high-performance liquid chromatography (HPLC) at increasing wavelength ultraviolet determine to the plots under stead-state. The Thermo-Acclaim 120 is an Agilent 1200 HPLC instrument with a C18 column (4.6 mm x 250 mm, 5 µm). Consisting from acetonitrile and distilled water by mixing dissolving organic material percentage.

2.3 Preparation of samples for photo-degradation for high-pressure mercury lamp

The imidacloprid doses were arranged as 14 mg/L, 20 mg/L, and 30 mg/L and 40 mg/L. 20 mL of every chemical was put to glass Erlenmeyer. 300 W power and high pressure at 3300–5700 Lux light intensities A mercury lamp was utilized. The quartz tube was put 5.0 cm away from the light source. The temperature of the reactor was arranged to 21 ºC. Every assay was performed 3-fold. A mercury lamp and sunlight were utilized to measure the effect of light sources to the photo-oxidation. The imidacloprid was prepared by adding 5mg/L to the distilled water and from every chemical 20 mL was put the quartz Erlenmeyer. The non-illuminated assays were accepted as control and the other hand all assays were performed under light at increasing duration.

2.4 Preparation of samples for photo-2degradation for sunlight

20 mg/L imidacloprid was added to the distilled water and illuminated to investigate the imidacloprid removals during photo-oxidation.

2.5 Effect of Ph

Imidacloprid was also diluted to 20 mg/L using diluted NaOH and HCl to obtain pH values of 3.0, 5.0, 7.0, 8.0, and 11.0 using a high-pressure mercury lamp for illumination.

2.6 Preparation of imidacloprid and bamboo vinegar mixture for photo-degradation studies

50 mg/L imidacloprid was dissolved in 900 mg/L methanol and combined with bamboo vinegar diluted between 25 and 150 times for a final imidacloprid dose of 20 mg/L. The mixed 15 mL solution was put in stoppered in a glass Erlenmeyer and set in a photo-oxidation reactor connected with 80 what mercury lamps away from 5 cm and with sunlight at hours between 12.00-1300 pm in a day. The temperature was 21 °C at a room temperature.

2.7 Calculation of photo-degradation efficiency of imidacloprid

The photo-oxidation of imidacloprid yield was measured by the equation given below:

$$\text{Photo-degradation rate (\%)} = \frac{Cd - C_l}{Cd} \times 100 \qquad (1)$$

where C_d (non-illuminated) and C_l (different assays) are the dose of samples.

2.8 Photo-oxidation kinetic of imidacloprid neonicotinoid

The photo-oxidation kinetic model of imidacloprid neonicotinoid in solution was defined by a first-order model formula:

$$C_t = C_0\text{-}e^{-kt} \qquad (2)$$

where C_0 and Ct are the imidacloprid dose at the beginning and after treatment in a t time respectively, and k is the photo-oxidation yield constant of imidacloprid.

2.9 Measurement of bamboo vinegar concentrations

The bamboo vinegar was extracted with an equivalent volume of acetic ether at 20ºC for 26 h and the part of acetic ether with compounds was mixed and stored for analysis. The chemicals were measured with an Agilent 7890 Agas chromatograph containing a detector.

The silica capillary column properties were (31 m×252 µm×0.25 µm). With this apparatus the bamboo vinegar was extracted and stored. The temperature varied between 50 °C, 100, 180 °C for 2 min, 1 min and respectively. The last temperature was 250 °C and the contacting time was 2 min. He was used at a flow rate 1.1 ml/min the tower of mass detector was adjust 70 eV at 230 °C. The compounds was determine from the retention times and organics disturbances. The dose was found from the peak areas of the compounds [15].

3. Results and discussion

3.1 Components of bamboo vinegar

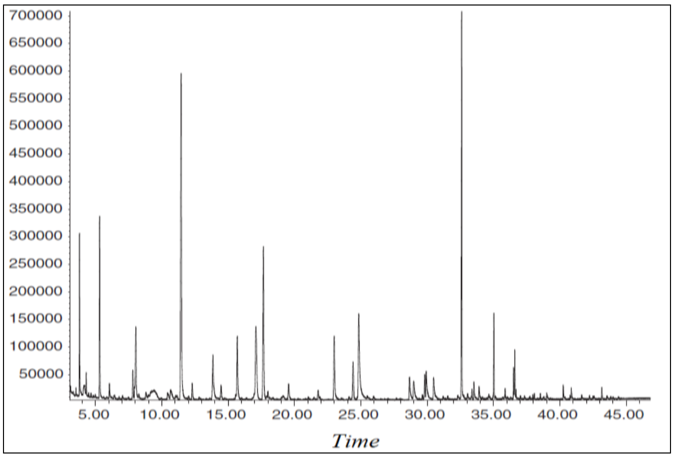

Fig 1: Components of bamboo vinegar

Fig 1 exhibited the organic compounds distributions of bamboo vinegar. Approximately 32 disturbances with maximum degrees were measured from the bamboo vinegar distilled in acetic ether. The ingredients of the organic defined from the peak areas were shown in the Table 1.

Composition of the components, calculated from the peak areas, appears in Table 1.

Table 1: Ingredients of bamboo vinegar

Names of chemical compounds	Compound percentage (%)
2-butanone	3.7
Hexanoic acid	0.3
Cyclopentanone	0.7
Furfural	5.8
2-furanmethanol	0.59
2-cyclopenten	1.3
Butyrolactone	3.7
2,5-Hexanedione	0.45
Phenol	19.8
3,5-dimethyl-2-furanone	2.7
3-methyl-2-cyclopenten-1-one	3.5
2-cyclopenten-1-one	0.68
2-Methyl-phenol	3.9
4-Methyl-phenol	5.2
2-Methoxy-phenol	8.2
2-hydroxy-2-cyclopenten-1-one	0.4
2,3-dimethyl-phenol	0.55
4-Ethyl-phenol	3.9
4-methyl-phenol	2.3
1,2-Benzenediol	7.1
1,2-benzenediol	1.4
2-ethylhexanoate	0.34
4-Ethylcatechol	0.60
Vanillin 0.7	0.60
4-methoxybenzoic acid	2.5
4(5H)-benzofuranone	0.80
5-methyl benzene	1.1
3,5-dimethoxyphenyl-ethanone	0.6
3,5-dimethoxy-, hydrazide benzoic acid	0.3
2-ethylhexanoate	0.3

The major organic components of bamboo vinegar consisted from polyphenol (such as phenol 18.1%, 2,6-dimethoxy-phenol 11.2%, 2-methoxyphenol 7.6%, 1,2-benzenediol 6.3%, 4-methyl-phenol 4.8%), ketonic (1-hydroxy-2-butanone 2.4%, 2-hydroxy-3-methyl-2- cyclopenten-1-one 3.2%, 2-methyl-2-cyclopenten-1-one 1.3%,) and furfural 5.9%.

3.2 Choosing of bamboo vinegar concentration on the photo-degradation of imidacloprid

In order to detect the bamboo vinegar concentration on the photo-degradation of imidacloprid the bamboo vinegar diluted between 25 and 150 times. Table 2 showed the photo-degradation rates of 20 mg/L imidacloprid versus bamboo vinegar dilutions. The photo-degradation duration was chosen as 20 min from the recent literatures [3]. It was found that bamboo vinegar reduced the photo-oxidation percentage of the imidacloprid at low dilutions. Imidacloprid removal increased when high-power mercury lamp and bamboo vinegar were diluted 25- and 150-fold. It was shown that bamboo vinegar had important negative impacts on the photo-oxidations of the imidacloprid pesticide, where the photo-oxidation percentage lowered for dilutions between 25 and 90 folds. However, at a Bamboo vinegar concentration diluted 100 times exhibited 80% photo-degradation for imidacloprid. 94% and 99.90% imidacloprid photo-degradation yields were detected at bamboo vinegar diluted 120 and 130 times, respectively. The maximum imidacloprid photo-degradation was found to be 99.90% at a dilution of 130 times. Further dilutions were not change the photo-degradation yield of imidacloprid.

The results showed that bamboo vinegar at low dilutions has a photo-quenching property to imidacloprid. The data obtained the study showed that bamboo vinegar is an important photo-oxidizing impact on imidacloprid when high power mercury irradiation was used.

Table 2: Variation of 20 mg/L imidacloprid photo-degradation yields versus bamboo vinegar dilutions after 20 min

Imidacloprid concentration (20 mg/L)	Bamboo vinegar dilutions fold	Imidacloprid The impact of bamboo vinegar was detected at low dilutions. Impact of the imidacloprid at the beginning dose on its photo-oxidizing. Photo-degradation efficiency (%)
20	without	67
20	25	16
20	35	20
20	45	22
20	50	24
20	65	26
20	80	45
20	90	56
20	100	80
20	120	94
20	130	99.90
20	140	99.90
20	150	99.90

3.3 Effect of the imidacloprid initial concentration on its photo-degradation

Fig 2 illustrates the yield constant of the photo-oxidation of imidacloprid at five increasing initial concentration at the beginning. The yield constant of the imidacloprid which is a neonicotinoid was not depended to the dose at the beginning. (15 mg/L, 20 mg/L, 30 mg/L and 40 mg/L). The half-live of imidacloprid was 12 min at an initial dose of 20 mg/L. High imidacloprid dose at the beginning were correlated with high imidacloprid concentrations. This exhibited that a huge among of photon competes and lower photon accumulation resulting in decreased photo-oxidation yield [18]. Furthermore, a lot of metabolic products generated from the imidacloprid photo-oxidation can inhibit light photons and this cause to lowering of electrons in the quantum. In addition, many intermediate products can form from imidacloprid photo-degradation and then compete for photons, thereby reducing the quantum yield of absorbed photons [18]. The maximum photo-degradation was found at 20 mg/L imidacloprid dose.

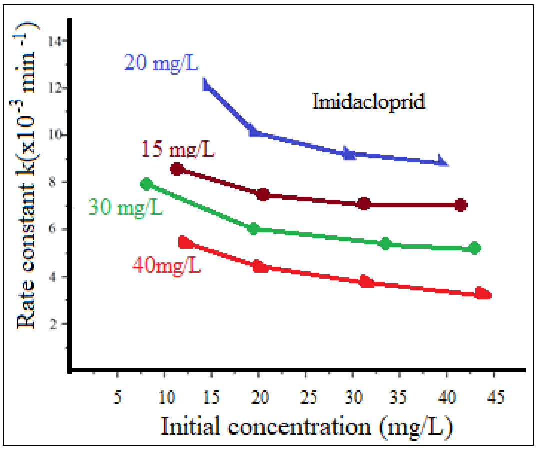

Fig 2: Impact of variation of imidacloprid doses on photo-oxidation

3.4 Effects of sun light and high-pressure mercury on the photo-degradation of imidacloprid

In order to detect impact of light type on the photo-oxidation imidacloprid was contacted with sunlight and mercury light [19]. The results showed that photo-oxidation performed less than two type of light. The photo-oxidation kinetic can be explained with first order model (Fig 3). The photo-oxidation yield under mercury lamp was elevated in the comparison with sunlight. Based on the linear equation the half-life of imidacloprid in sun light (21 min) was extremely higher than mercury lamp (14 min). As a result, the photo-oxidation ratio between sunlight as mercury lamps was found to be 2.71. This big variation can be attributed to the huge spectra of light and to the activated photons during imidacloprid absorption. The photon disturbances of mercury lamp varied between 180 nm and 990 nm; however, the huge adsorption peak for UV is 270 nm [20]. When mercury lamp was utilized the photo-oxidation of imidacloprid quickly performed. On the contrary since the emission peaks of sun light is short than UV area the imidacloprid activation occurred partly. The absorption yield of an electron under sunlight is significantly reduced compare to the mercury lamp this cause to reduce photo-degradation in sunlight [21].

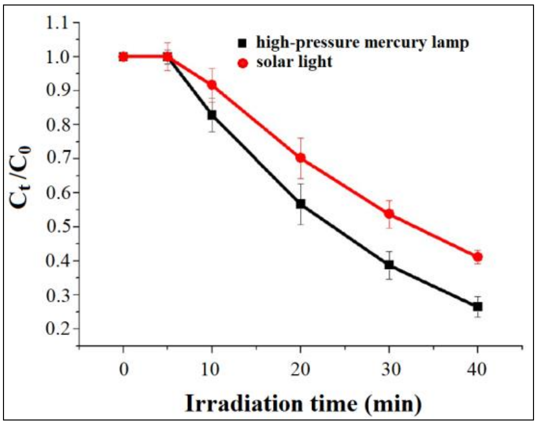

Fig 3: Impact of sun and mercury light on photo-oxidation of imidacloprid

3.5 Effect of pH on the photo-degradation of imidacloprid

The pH has an important impact on the photo-oxidation of carbonaceous organics. In this study, the pH values were adjusted to 3.0, 5.0, 7.0, 8.0, and 11.0 in order to detect pH effects on the photo-degradation of imidacloprid. As shown in Table 3. The photo-oxidation yield was lowered at low pH conditions; however, under high pH levels the photo-oxidation yields were elevated at pH 3.0 was reduced. OH, at high pH levels in the comparison of low pH conditions. The high removal rates under alkaline conditions can be attributed to the high imidacloprid removal. Under low pH data the imidacloprid activated at a wavenumber of 261 nm and this lowered photo-oxidation yield [22]. At high pH the huge photo-oxidation yield can be defined with elevated photons adsorption yield and proton production inactivated imidacloprid.

Table 3: Photo-degradation of imidacloprid at different pH values

Neonicotinoids	pH value	Kinetic equation $\ln C_t = \ln C_0 - kt$	Rate constant K min^{-1}	Half-life period $T_{1/2}$ min^{-1}
Imidacloprid	3.0	$\ln C_t = 2.1243 - 0.0128t$	0.01280	56.2
	5.0	$\ln C_t = 2.1665 - 0.0189t$	0.01890	34.0
	7.0	$\ln C_t = 2.1534 - 0.0210t$	0.02100	33.2
	8.0	$\ln C_t = 2.1681 - 0.0216t$	0.02160	31.6
	11.0	$\ln C_t = 2.1760 - 0.0221t$	0.02210	30.3

3.6 Photo-degradation metabolites of imidacloprid

The metabolic of imidacloprid during photo-oxidation were research. The metabolic disturbances were correlated with the major compounds. The photo-degradation product of 20 mg/L imidacloprid is 17 mg/L $C_7H_{14}N_2O_2$ (data not shown). These results agree with the data found by Ding *et al.* [23]. In the study it was suggested that an imidacloprid mass a chemical reaction absorb a photon under light. The process ends when the ring is broken. The photo-degradation products of the imidacloprid were investigated. The product peaks in the total ion flow diagram were compared to those in the parent standard total ion flow diagram. The mass spectra of the products were analyzed. The possible photo-degradation pathway proceeds via an imidacloprid molecule absorbing a photon under illumination, followed by N-N bond cleavage and NO_2 removal from the molecule. The C = N bond then combines with a hydroxyl radical (OH) in water to form a C = O bond via substitution reaction [24].

4. Conclusions

The photo-oxidation of imidacloprid was investigated in the presence of bamboo vinegar since the removal rate of imidacloprid was not effective when photo-degradation was carried out solely. It is known that bamboo vinegar can be used as an antibiotic for the death of some bacteria and insecticides. The photo-degradation half-lives of the imidacloprid were found to be optimal at an initial imidacloprid concentration of 22 mg/L. The photo-oxidation rates of the imidacloprid under high pressure mercury lamp irradiation were significantly elevated than those under sunlight irradiation. The photo-degradation yields were found to be smaller in low pH buffer however relatively high in alkaline and neutral buffer conditions. Imidacloprid photo-oxidation yields were found as 94% and 99.90% when the bamboo vinegar diluted between 120 and 130 folds.

5. References

1. Leiva JA, Nkedikizza P, Morgan KT, Kadyampakeni DM. Imidacloprid Transport and Sorption Nonequilibrium in Single and Multilayered Columns of Immokalee Fine Sand. PLoS One. 2017; 12:e0183767. Doi: https://doi.org/10.1371/journal.pone.0183767 PMID: 28837702
2. Junyu Lu, Wang Rui, Luan Jingyi, Li Yijun, He Xiwen, Chen Langxing, Zhang Yukui. A functionalized magnetic covalent organic framework for sensitive determination of trace neonicotinoid residues in vegetable samples. Journal of Chromatography A, 2020, 460898. Doi: 10.1016/j.chroma.2020.460898
3. Liang Rui, Tang Feng, Wang Jin, Yue Yongde, Gao Yulin. Photo-degradation dynamics of five neonicotinoids: Bamboo vinegar as a synergistic agent for improved functional duration. Plos one. 2019; 14(10):e0223708. Doi: 10.1371/journal.pone.0223708
4. Pastor-Belda M, Garrido I, Campillo N, Viñas P, Hellín P, Flores P, Fenoll J. Determination of spirocyclic tetronic/tetramic acid derivatives and neonicotinoid insecticides in fruits and vegetables by liquid chromatography and mass spectrometry after dispersive liquid-liquid microextraction. Food Chem. 2016; 202:389-395.
Doi: http://doi.org/10.1016/j.foodchem.2016.01.143
5. Yoshinori Ikenaka, Fujioka Kazutoshi, Kawakami Tomonori, Ichise Takahiro, Bortey-Sam Nesta, Nakayama Shouta MM, *et al*. Contamination by neonicotinoid insecticides and their metabolites in Sri Lankan black tea leaves and Japanese green tea leaves. Toxicology Reports. 2018; 5:744-749.
Doi: 10.1016/j.toxrep. 2018.06.008
6. Butcherine Peter, Benkendorff Kirsten, Kelaher Brendan, Barkla Bronwyn J. The risk of neonicotinoid exposure to shrimp aquaculture. Chemosphere, 2018. Doi: 10.1016/j. chemosphere.2018.10.19
7. Junyu Lu, Wang Rui, Luan Jingyi, Li Yijun, He Xiwen, Chen Langxing, Zhang Yukui. A functionalized magnetic covalent organic framework for sensitive determination of trace neonicotinoid residues in vegetable samples. Journal of Chromatography A, 2020, 460898. Doi: 10.1016/j.chroma.2020.460898
8. Kawahata I, Yamakuni T. Imidacloprid, a neonicotinoid insecticide, facilitates tyrosine hydroxylase transcription and phenylethanolamine N-methyltransferase mRNA expression to enhance catecholamine synthesis and its nicotine-evoked elevation in PC12D cells. Toxicology. 2018; 394:84-92. Doi: https://doi. org/10.1016/j.tox.2017.12.004 PMID: 29246838
9. Caron-Beaudoin E, Viau R, Sanderson JT. Effects of neonicotinoid pesticides on promoter-specific aromatase (CYP19) expression in Hs578t breast cancer cells and the role of the VEGF Pathway. Environ Health Perspect. 2018; 126:047014. PMID: 29701941
Doi: https://doi.org/10.1289/EHP2698
10. Wang X, Anadon A, Wu Q, Qiao F, Martinez-Larranaga MR, Yuan Z, *et al*. Mechanism of neonicotinoid toxicity: impact on oxidative stress and metabolism. Annu Rev Pharmacol Toxicol. 2018; 58:471-507. PMID: 28968193
Doi: https://doi.org/10.1146/annurev-pharmtox-010617-052429
11. Craddock HA, Huang D, Turner PC, Quiro´s-Alcala´ L, Payne-Sturges DC. Trends in neonicotinoid pesticide residues in food and water in the United States, 1999-2015. Environ Health. 2019; 18:7. PMID: 30634980
Doi: https://doi.org/10.1186/s12940-018-0441-7
12. Ichikawa Go, Kuribayashi Ryota, Ikenaka Yoshinori, Ichise Takahiro, Nakayama Shouta MM, Ishizuka Mayumi, *et al*. LC-ESI/MS/MS analysis of neonicotinoids in urine of very low birth weight infants at birth. PLOS ONE. 2019; 14(7):e0219208.
Doi: 10.1371/journal.pone.0219208
13. Mu J, Uehara T, Furuno T. Effect of bamboo vinegar on regulation of germination and radical growth of seed plants II: composition of Moso bamboo vinegar at different collection temperature and its effects. J. Wood Sci. 2004; 50:470-476.
14. Arsyad WOM, Basri E, Hendra D, Trisatya DR. Termite resistance of impregnated Jabon wood (Anthocephalus cadamba Miq.) with combined impregnant agents. Journal of the Korean Wood Science and Technology. 2019; 47(4):451-458.
15. Wang HF, Wang JL, Wang C, Zhang WM, Liu JX, Dai B. Effect of bamboo vinegar as an antibiotic alternative on growth performance and fecal bacterial communities of weaned piglets. 2012; 144(1-2):173-180.
Doi: 10.1016/j.livsci.2011.11.015
16. Bakir S, Devecioglu D, Kayacan S, Toydemir G, Karbancioglu-Guler F, Capanoglu E. Investigating the Antioxidant and Antimicrobial Activities of Different Vinegars. Eur Food Res Technol. 2017; 243:2083-2094.
17. Zhang HY, He P, Kang HB, Li HL. Antioxidant and Antimicrobial Effects of Edible Coating Based on Chitosan and Bamboo Vinegar in Ready to Cook Pork Chops. LWT. 2018; 93:470-476.
18. Li Y, Su PD, Li YD, Wen KJ, Bi GH, Cox M. Adsorption-desorption and Degradation of Insecticides Clothianidin and Thiamethoxam in Agricultural Soils. Chemosphere. 2018; 207:708-714. PMID: 29857203
Doi: https://doi.org/10.1016/j.chemosphere.2018.05.139

19. Residues from Tree Foliage in Streams-A Relevant Exposure Pathway in Risk Assessment? Environ Sci Technol. 2017; 51: 1785-1794. PMID: 28001052 Doi: https://doi.org/10.1021/acs.est.6b05213
20. Li W, Patton S, Gleason JM, Mezyk SP, Kenneth P, Ishida KP, *et al*. UV Photolysis of Chloramine and Persulfate for 1,4-dioxane Removal in Reverse Osmosis Permeate for Potable Water Reuse. Environ Sci Technol. 2018; 52:6417-6425. PMID: 29653056 Doi: https://doi.org/10.1021/acs.est.7b06042
21. Englert D, Bakanov N, Zubrod JP, Schulz R, Bundschuh M. Modeling Remobilization of Neonicotinoid Residues from Tree Foliage in Streams-A Relevant Exposure Pathway in Risk Assessment? Environ Sci Technol. 2017; 51:1785-1794. PMID: 28001052. Doi: https://doi.org/10.1021/acs.est.6b05213
22. Miao J, Sunarso J, Su C, Zhou W, Wang SB, Shao ZP. SrCo1-xTixO3-δ Perovskites as Excellent Catalysts for Fast Degradation of Water Contaminants in Neutral and Alkaline Solutions. Sci Rep. 2017; 7:44215. Doi: https://doi.org/10.1038/srep44215 PMID: 28281656
23. Ding SL, Wang XK, Jiang WQ, Zhao RS, Shen TT, Wang X. Influence of pH, Inorganic Anions, and Dissolved Organic Matter on the Photolysis of Antimicrobial Triclocarban in Aqueous Systems under Simulated Sunlight Irradiation. Environ Sci Pollut R. 2015; 22:5204-5211
24. Kurwadkar S, Evans A, Dewinne D, White P, Mitchell F. Modeling Photodegradation Kinetics of Three Systemic Neonicotinoids-dinotefuran, Imidacloprid, and Thiamethoxam-in Aqueous and Soil Environment. Environ Toxicol Chem. 2016; 35:1718-1726. Doi: https://doi.org/10.1002/etc.3335 PMID: 26660507