International Journal of Applied Science and Engineering Review

ISSN: 2582-6271

Vol. 6, Issue.5, Sep-Oct 2025, page no. 60-67

To cite this article: Hargono Hargono*, Fikri Aditya Wisnu Pratama, Muhammad Nuzul Ramadani, Kristinah Haryani and Kevin Setiadi Seng (2025). EFFECT OF KCL ADDITION AND PACKING HEIGHT ON ETHANOL PURIFICATION USING ADSORPTIVE DISTILLATION WITH ZEOLITE STONES AND BIO RING SUPER PACKINGS, International Journal of Applied Science and Engineering Review (IJASER) 6 (5): 60-67 Article No. 247 Sub Id 372

EFFECT OF KCL ADDITION AND PACKING HEIGHT ON ETHANOL PURIFICATION USING ADSORPTIVE DISTILLATION WITH ZEOLITE STONES AND BIO RING SUPER PACKINGS

Hargono Hargono*, Fikri Aditya Wisnu Pratama, Muhammad Nuzul Ramadani, Kristinah Haryani and Kevin Setiadi Seng

Department of Chemical Engineering, Faculty of Engineering, Diponegoro University, Semarang Prof. Soedarto Street 13, Central of Java, 50239, Indonesia,

*Corresponding author: hargono@che.undip.ac.id

DOI: https://doi.org/10.52267/IJASER.2025.6507

ABSTRACT

Ethanol is a versatile biofuel and industrial solvent widely used in pharmaceuticals, cosmetics, food and beverages, and chemical industries. Achieving high-purity ethanol remains a challenge due to the formation of ethanol–water azeotropes, which limit conventional distillation methods. This study investigates the effectiveness of KCl-assisted adsorptive distillation using natural packing materials—zeolite stones and Bio Ring Super—in enhancing ethanol purification. The objectives were to examine the characteristics of the packing materials, evaluate the effects of KCl addition, and assess the influence of packing height on ethanol concentration. A 10% ethanol solution was distilled using columns packed with either zeolite or Bio Ring Super stones, with and without the addition of KCl (0 g and 10 g). The final ethanol concentration was measured using a pycnometer and alcohol meter. Results indicated that the addition of 10 g KCl significantly increased ethanol purity by promoting salting-out effects, which enhanced separation efficiency. Among the packing materials, Bio Ring Super exhibited superior performance compared to zeolite, yielding the highest ethanol concentration in the distillate. Moreover, the combination of KCl addition and optimized packing height further improved ethanol recovery, demonstrating a more energy-efficient and cost-effective approach compared to conventional methods. These findings highlight the potential of KCl- assisted adsorptive distillation with Bio Ring Super packing as a sustainable and effective strategy for producing high-purity ethanol from biomass, offering promising applications in biofuel and industrial sectors.

KEYWORDS: Ethanol purification, Adsorptive distillation, KCl addition, Bio Ring Super, Zeolite packing, Salting-out effect

1. INTRODUCTION

Ethanol plays a vital role across various sectors, including pharmaceuticals, industry, and renewable energy, with its use as a fuel increasingly favored due to its lower carbon emissions compared to fossil fuels. In Indonesia, dependence on imported oil remains high, with import volumes reaching 30.06 million tons from January to September 2022, marking a 16.89% increase compared to the previous year. This reliance is largely attributed to limited domestic refinery production, while fuel demand continues to rise in line with vehicle growth. As a renewable fuel derived from biomass, ethanol offers a cleaner and more sustainable alternative to petroleum-based fuels, supporting efforts to reduce fossil fuel dependency and mitigate climate change. Despite its advantages, ethanol purification remains challenging, particularly in achieving high purity from fermentation-derived bioethanol, which typically contains only 8–12% (v/v) ethanol and requires further processing to reach 95–98% purity [1]. Conventional purification methods, such as azeotropic distillation, adsorption, and membrane separation, are effective but often energy-intensive, costly, and environmentally burdensome due to chemical additives and potential waste generation. Therefore, developing more sustainable, energy-efficient, and cost-effective purification strategies is urgently needed to enhance ethanol production. This study aims to explore such methods, contributing to more economical and environmentally friendly ethanol purification technologies.

The increasing demand for ethanol across diverse industries—including pharmaceuticals, cosmetics, food and beverages, chemicals, education, and healthcare—has intensified the need for high-purity ethanol. Given the depletion of fossil resources, renewable alternatives derived from abundant natural feedstocks are becoming increasingly important. Industrial ethanol can be produced through ethylene hydration, glucose fermentation, or as a by-product of other processes. However, the ethanol content obtained through these methods generally fails to meet fuel-grade purity standards (99.5%). Conventional distillation only produces ethanol up to 97.2% due to the ethanol–water azeotrope, making advanced separation techniques necessary. One promising approach is saline extractive distillation, which involves adding salts such as KCl, NaCl, KI, or $CaCl_2$ to break azeotrope interactions without forming new azeotropes [2]. Recent studies, such as the work of [3] on cassava-based ethanol production, highlight the challenges of achieving high purity, as fermentation and distillation often yield relatively low ethanol concentrations. To overcome these limitations, further purification steps are essential. This study therefore investigates ethanol purification using saline extractive distillation with KCl addition, combined with zeolite stones and Bio Ring Super as packing materials. These natural and porous materials are expected to enhance separation efficiency, offering a more sustainable and effective pathway for producing high-purity ethanol from biomass sources. Accordingly, this study is conducted to investigate several key

ISSN: 2582-6271

Vol. 6, Issue.5, Sep-Oct 2025, page no. 60-67

aspects of ethanol purification through adsorptive distillation. First, it aims to identify the characteristics of zeolite stones and Bio Ring Super as potential natural packing materials. Furthermore, the effect of packing type on ethanol concentration is examined to evaluate their performance in enhancing separation efficiency. In addition, the influence of KCl salt addition on ethanol concentration is assessed to determine its role in breaking the ethanol–water azeotrope. Finally, the impact of packing height on ethanol concentration is analyzed to provide a deeper understanding of the operational parameters that govern the distillation process.

2. MATERIALS AND METHODS

2.1 Materials

The materials used in this study consisted of a 10% ethanol solution and distilled water (aquadest) as the primary liquid media. Natural packing materials, including zeolite stones and Bio Ring Super stones, were employed in the distillation column. Potassium chloride (KCl) was added as a salt agent with two variations: 0 g and 10 g, to investigate its effect on ethanol purification.

2.2 Methods

2.2.1 Preparation of Materials

A 10% ethanol solution was prepared by pipetting 142.86 mL of 70% ethanol, calculated based on the dilution formula to achieve the target concentration. Distilled water was then added gradually to a total volume of 1 liter (1000 mL) in a measuring cylinder. The solution was carefully mixed using a stirring rod or by gently swirling the cylinder until homogeneous. The ethanol concentration was subsequently measured using an alcohol meter.

2.2.2 Ethanol Distillation without KCl

For distillation without salt, 10% ethanol solution, zeolite stones, and Bio Ring Super were prepared. The packing materials were placed in the distillation column at the predetermined height. Water was added to the reflux tank, and the pump was turned on to circulate water through the condenser until the condenser column was filled to ensure effective condensation. Once the condenser was filled, 1000 mL of ethanol was added to the boiler, which was then heated to the distillation temperature of 78°C. The distillation process was allowed to proceed for approximately 120 minutes. The distilled ethanol was collected and its final concentration determined using an alcohol meter.

2.2.3 Ethanol Distillation with KCl Addition

For distillation with KCl, the procedure was similar, with the addition of KCl. The 10% ethanol solution, packing materials, and KCl were prepared. Packing materials were loaded into the column at the predetermined height. Water was added to the reflux tank, and the pump circulated water through the condenser until full. After the condenser was filled, 1000 mL of ethanol and the designated amount of KCl were added to the boiler, which was then heated to 78°C. Distillation was carried out for approximately 120 minutes, and the purified ethanol was collected to measure the final concentration using an alcohol meter.

2.2.4 Analysis of Final Ethanol Concentration

The ethanol concentration in the distillate was analyzed using a pycnometer. First, the empty pycnometer was weighed. Then, 10 mL of the distilled ethanol was transferred into the pycnometer of the same size. The pycnometer filled with ethanol was weighed, and its density was calculated. The final ethanol concentration was then determined by comparing the measured density with standard density data for pure ethanol. The final ethanol density in the distillate was calculated using Equation 1 and 2.

$$\rho_{\text{final ethanol}} = \frac{\left(m_{\text{picnometer+ethanol}} + m_{\text{picnometer}}\right)}{V_{\text{picnometer}}} \qquad (1)$$

The final ethanol concentration in the distillate was determined using Equation 2.

$$\frac{\rho_{\text{pure ethanol}}}{\rho_{\text{final ethanol}}} = \frac{\%_{\text{final ethanol}}}{\%_{\text{pure ethanol}}} \qquad (2)$$

3. RESULTS AND DISCUSSIONS

3.1 Effect of KCl Addition on Ethanol Purification

The addition of KCl in the adsorptive distillation process significantly enhanced ethanol purification. KCl acts as a salting- out agent, reducing the solubility of ethanol in water and promoting its separation from the azeotropic mixture. When combined with porous packing materials, such as zeolite stones and Bio Ring Super, the mass transfer between vapor and liquid phases is improved, leading to higher ethanol concentrations in the distillate, as shown in Fig. 1. Interestingly, the results showed that Bio Ring Super packing yielded higher ethanol concentrations compared to zeolite stones. This could be attributed to its unique structure, which allows for more uniform vapor flow, reduces channeling, and provides effective surface contact for adsorption, even though its microporosity is lower than that of zeolite. In contrast, zeolite stones, while providing higher surface area, may have caused localized vapor bypass or channeling, slightly limiting ethanol separation efficiency.

International Journal of Applied Science and Engineering Review

ISSN: 2582-6271

Vol. 6, Issue.5, Sep-Oct 2025, page no. 60-67

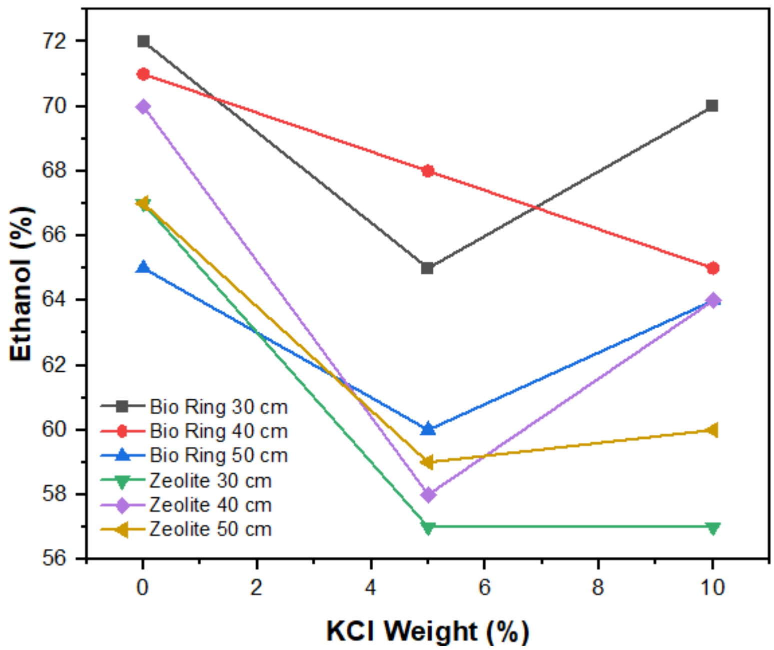

Fig. 1. Influence of KCl and packing materials on adsorptive distillation performance

As can be seen from Fig.1, the combination of KCl addition and Bio Ring Super packing not only increased ethanol purity but also indicates a potential for more energy-efficient and cost-effective distillation compared to conventional methods. These findings are consistent with previous studies demonstrating that inorganic salts, such as KCl, effectively disrupt azeotropic interactions, improving ethanol recovery [4]. Overall, Bio Ring Super packing with KCl addition presents a promising approach for sustainable, high-purity ethanol production from biomass.

3.2 Effect of Different Height of Packing on Ethanol Purification

The results clearly demonstrate that packing height plays a crucial role in determining ethanol concentration in the distillate during adsorptive distillation. For Bio Ring Super packing without KCl addition, the highest ethanol concentration (72%) was obtained at a packing height of 30 cm. Increasing the packing height to 40 cm and 50 cm led to slightly lower concentrations of 71% and 65%, respectively. Similarly, for zeolite packing, ethanol concentration was highest at 40 cm (70% without KCl), while lower or higher packing heights yielded lower ethanol concentrations. This trend indicates that an optimal packing height exists for maximizing ethanol separation efficiency, as can be seen in Fig. (2) a-c.

International Journal of Applied Science and Engineering Review

IJASER

ISSN: 2582-6271

Vol. 6, Issue.5, Sep-Oct 2025, page no. 60-67

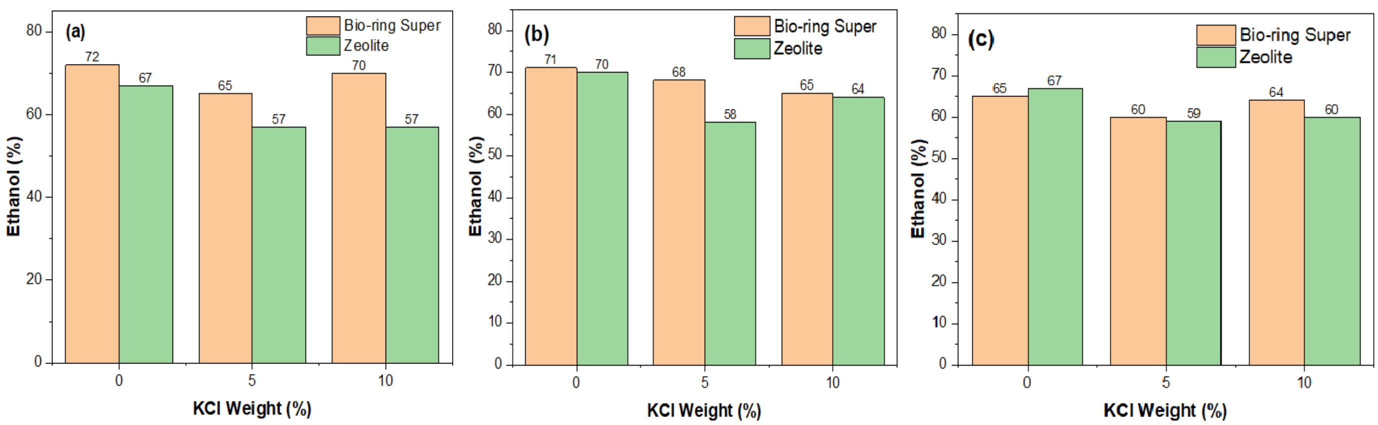

Fig.2. Influence of packing height on adsorption distillation performance (a) 30 cm; (b) 40 cm; (c) 50 cm

At lower packing heights, the column may provide insufficient surface area for effective vapor-liquid contact, limiting mass transfer and adsorption of ethanol onto the packing material. In contrast, excessively tall packing heights may increase flow resistance, induce channeling, or create uneven vapor distribution, reducing the effective contact between vapor and packing surfaces [5]. This effect was observed in both Bio Ring Super and zeolite packings, though Bio Ring Super consistently achieved higher ethanol concentrations compared to zeolite at equivalent heights. This superior performance may be attributed to the more uniform geometry and larger effective surface area of Bio Ring Super, which facilitates better vapor distribution and adsorption efficiency [6]. The addition of KCl interacts with packing height to influence ethanol concentration. For Bio Ring Super, adding 5 g of KCl at a 30 cm height slightly reduced ethanol concentration to 65%, while 10 g slightly increased it to 70%. At 40 cm, ethanol concentration decreased with KCl addition, reaching 68% and 65% for 5 g and 10 g KCl, respectively. At 50 cm, the effect was similar, with ethanol concentration ranging between 60% and 64%. For zeolite, the impact of KCl was generally more pronounced, with ethanol concentration dropping to 57% at lower heights and only recovering slightly at 10 g KCl for certain heights [7]. These results indicate that while KCl addition can enhance ethanol recovery by promoting the salting-out effect, its benefit is sensitive to column packing height, suggesting that both parameters must be optimized simultaneously for maximum ethanol purification. Overall, the findings indicate that an intermediate packing height (30–40 cm) combined with an appropriate KCl concentration is optimal for ethanol recovery, and that Bio Ring Super outperforms zeolite due to its favorable structural characteristics [8]. These results highlight the importance of careful column design and operational parameter selection in adsorptive distillation processes, particularly when aiming to maximize ethanol purity while minimizing energy consumption and process inefficiencies.

4. CONCLUSION

This study demonstrates that the purification of ethanol through KCl-assisted adsorptive distillation is significantly influenced by both the type of packing material and the packing height. The addition of KCl enhances ethanol separation via the salting-out effect, reducing ethanol solubility in water and disrupting the ethanol–water azeotrope, which results in higher ethanol concentration in the distillate. Among the packing materials tested, Bio Ring Super consistently outperformed zeolite stones, achieving the highest ethanol concentrations due to its uniform structure, better vapor distribution, and effective surface area for adsorption. Packing height also plays a critical role in the efficiency of ethanol separation. Optimal heights (30–40 cm) provided sufficient vapor-liquid contact for effective mass transfer, while excessively low or high packing heights reduced ethanol recovery due to insufficient surface contact or increased flow resistance and channeling. The interaction between KCl addition and packing height further highlighted the importance of carefully optimizing both parameters to maximize ethanol purity. Overall, the combination of KCl addition and Bio Ring Super packing at appropriate column heights offers a sustainable, energy-efficient, and cost-effective approach for producing high-purity ethanol from biomass, with promising applications in biofuel and industrial sectors.

REFERENCES

[1] I. P. Dewi and U. L. Agustin, "Formulation and Evaluation of Ethanol Extract Gel from Rimau Gerga Orange Peel (Citrus Reticulata Blanco)," 2024.

[2] A. Sato and T.-K. Itats, "Pemurnian Ethanol Secara Destilasi dengan Penambahan Garam KCl," no. 2, 2015.

[3] E. Lovisia, "Bioetanol dari Singkong sebagai Sumber Energi Alternatif," *SPEJ*, vol. 6, no. 1, pp. 8–14, Dec. 2022, doi: 10.31539/spej.v6i1.5007.

[4] Universitas Negeri Semarang, Indonesia *et al.*, "Modelling of Adsorptive-distillation of Ethanol-water Using Natural and Synthetic Zeolites as Adsorbent," *JPS*, vol. 29, no. Supp. 2, pp. 243–256, Jul. 2018, doi: 10.21315/jps2018.29.s2.19.

[5] M. Botshekan, A. Moheb, F. Vatankhah, K. Karimi, and M. Shafiei, "Energy saving alternatives for renewable ethanol production with the focus on separation/purification units: A techno-economic analysis," *Energy*, vol. 239, p. 122363, Jan. 2022, doi: 10.1016/j.energy.2021.122363.

[6] V. E. Efeovbokhan, J. D. Udonne, D. E. Babatunde, and S. E. Sanni, "The Effect of Column Height, Packing Materials and Azeotrope Separation on the Purity of Ethanol Sourced from Ogogoro (Local Gin)".

[7] E. Pérez-Botella, S. Valencia, and F. Rey, "Zeolites in Adsorption Processes: State of the Art and Future Prospects," *Chem. Rev.*, vol. 122, no. 24, pp. 17647–17695, Dec. 2022, doi: 10.1021/acs.chemrev.2c00140.

ISSN: 2582-6271

Vol. 6, Issue.5, Sep-Oct 2025, page no. 60-67

[8] M. K. Yadav, S. Agarwal, S. Verma, V. C. Srivastava, U. L. Štangar, and P. Kumar, "Simulation and optimization of a modified salt extractive distillation process for the production of anhydrous ethanol," *Results in Chemistry*, vol. 15, p. 102267, May 2025, doi: 10.1016/j.rechem.2025.102267.