# STUDY OF REACTION PATHWAY AND KINETIC OF ESTRAGOLE ISOMERIZATION TO *CIS*-ANETHOLE AND *TRANS*-ANETHOLE

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**Abstract**

**Estragole isomerization in basic condition resulted *cis*- and *trans*-anethole. Hence, there were two reaction pathway of estragole isomerization i.e. parallel and consecutive. The reaction pathway gave information about reaction mechanism. Estragole isomerization was carried out in various kind and volume of solvent, base ratios, and at various time and temperature. The products were analyzed by GC-MS, and FTIR. The result showed that the estragole isomerization pathway in ethanol and ethylene glycol was parallel. The mechanism of estragole isomerization proceed through carbanion intermediate with $Ea_{total}$ of 178,6238 J/mol .**

Keywords: *estragole, cis-anethole, trans-anethole, isomerization pathway.*

## 1. INTRODUCTION

Selasih (*Ocimum basilicum*) essential oil contains 89.50% of estragole as its main component (Agusta, 2000). Estragole has $C_{10}H_{12}O$ molecular formula, 148,20 g/mol molecular weight, 216°C boiling point at 760 mmHg, 0,946 g/cm$^3$ density, liquid form in room temperature, and has an optic inactive characteristic (Guenther, 1990). This compound is an alilfenol derivate compound that is formed by shikimat pathway (fenilpropanoid) (Achmad, 1986), and can be isomerized to form anethole. Estragole isomerization is shown in Fig 1.

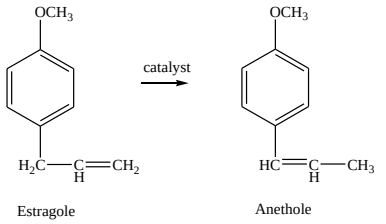


**Fig 1.** Estragole isomerization to anethole

There are several researches on estragole isomerization that have been conducted. Kishore and Kannan (2005) studied catalytic isomerization of estragole to anethole over hydrotalcites and HT-like compounds. Risnayeti and Mas'ud (1997) studied estragole isomerization mechanism using combined methode of site-specific natural isotropic fractionation and nuclear magnetic resonance. Sharma, *et. al* (2005) studied the isomerization of estragole to *trans*-anethole using metal complexes of Pd, Ru and Rh at 491 K and atmospheric pressure without using any solvent.

Although estragole isomerization has been carried out, but the study of pathway and kinetic of estragole isomerization has not been investigated yet.

Estragol isomerization resulted *cis*-anethole and *trans*-anethole. So, there were two complex reaction possibilities of estragole isomerization pathway; parallel and consecutive. Isaacs (1987) mentioned that kinetically product would be reversible, while the termodinamically product would be irreversible. In parallel and consecutive reactions, the kinetic product in general was obtained at relatively low temperatures and short reaction times, while the thermodynamic product was formed at higher temperatures and long reaction times (Isaacs, 1969).

## 2. EXPERIMENTAL

Estragole was procured from SIGMA-ALDRICH. Inc Singapure (code: CAS 140-67-0), and it was analyzed by GC-MS and FTIR for the characterization. Estragole isomerization was conducted in ethanol, ethylene glycol, and DMSO.

1.135 g of KOH *p.a* and 30 mL of solvent (ethanol, ethylene glycol or DMSO) were put into three necks round bottom flask that was fitted with thermometer. The reaction system was refluxed at room temperature and stirred until the base (KOH) was dissolved. 1 mL of estragole was added into the system and then it was refluxed for 6 hours while being stired. The reaction mixture was cooled and added 10 mL of aquades and HCl 25% until 2-3 pH. The reaction mixture was extracted with diethyl ether, washed with water, and dried by using $Na_2SO_4$. The product was evaporated using Buchi evaporator, and then analyzed by GC-MS and FTIR. The experiment was repeated with the variation of kind and volume of solvent, base ratios, times, and temperatures.

The conversions (% relative concentration) from GC chromatogram for each product were made into connection graph between relative concentration and time to observe a trend towards *cis*-anethole and *trans*-anethole formation.

## 3. RESULTS AND DISCUSSION

To determine estragole isomerization pathway, an investigation on the optimum condition of isomerization in ethanol and ethylene glycol have been carried out. GC-MS analysis of estragole showed that estragole has 99,522% purity (Fig 2).

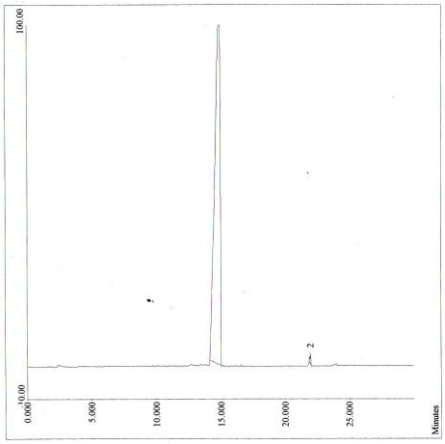


**Fig 2.** GC chromatogram of estragole

The experiment of estragole isomerization was carried out in various kind and volume of solvent, base ratios, and temperatures. The result showed that the optimum condition of estragole isomerization in ethanol solvent is in 10 mL of ethanol and 1:9 ratios of estragole-KOH at 99.5$^o$ C for 6 hours. The reaction product consists of 0% of estragole, 20,110% of *cis*-anethole and 75,695% of *trans*-anethole. While the optimum condition of estragole isomerization in ethylene glycol is in 30 mL of ethylene glycol and 1:3 ratios of estragole-KOH at 150°C for 6 hours. The product consists of 2,305% of estragole, 20,867% of *cis*-anethole and 65,616% of *trans*-anethole.

10 mL of ethanol and 1:6 ratios of estragole-KOH is used to determine estragole isomerization pathway in ethanol, and not with 1:9 ratios of estragole-KOH. Because, at 1:9 ratios of estragole-KOH, estragole isomerization pathway cannot be observed. The connection graph between relative concentration product and time of estragole isomerization in ethanol solvent with 1:6 ratio estragole-KOH at 88.5$^o$ C is shown in Fig 3.

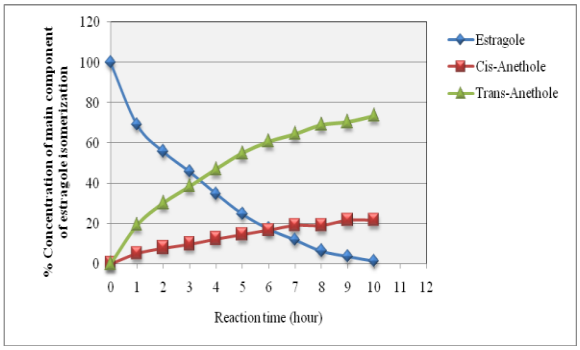


**Fig 3.** The connection between relative concentration (%) and time of estragole isomerization in ethanol solvent with 1:6 ratio estragole-KOH at 88.5$^{o}$ C

Figure 3 shows that on the estragole isomerization in ethanol, the amount of estragole decreased, while the amount of *cis*-anethole and *trans*-anethole increased with relatively steady composition ratios. Thus, the estragole isomerization pathway in ethanol was parallel.

A graph of –ln(C/Co) to reaction times for the first reaction order, a graph of 1/[C] to reaction times for the second reaction order, and a graph of [C] to reaction times for the zero$^{th}$ reaction order have been made to determine the order of estragole isomerization. R squared for the first, the second and the zero$^{th}$ reaction orders were 0,9769; 0,7812; and 0,9314 respectively. Hence, estragole isomerization in ethanol was the first reaction order, with $k_{total}$ of 0,3200.

The reaction pathway was also determined in ethylene glycol. The connection graph between relative concentration product and time of estragole isomerization in ethylene glycol with 1:3 ratio estragole-KOH at 150$^{o}$ C is shown in Fig 4.

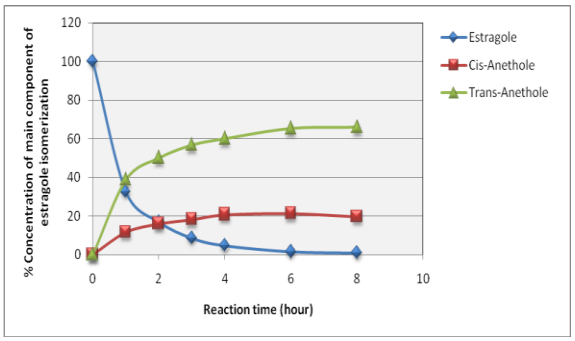


**Fig 4.** The connection between relative concentration (%) and time of estragole isomerization in ethylene glycol solvent with 1:3 ratio estragole-KOH at 150$^{o}$ C

As shown on the graph in Fig. 4, estragol isomerization pathway in ethylene glycol was parallel. It indicated that solvent did not change estragole isomerization pathway. Estragole isomerization in ethylene glycol is the first order reaction, with $k_{total}$ of 0,6628.

Estragole isomerization pathway, the acidity of hydrogen at $C_{\alpha}$ estragole, and kind of solvent are used to study the mechanism of estragole isomerization.

Estragole isomerization product increased along with the increasing amount of KOH. It means that the acidity of Hα in estragole is low. H protic on ethanol and ethylene glycol would inhibit carbanion intermediet formation. Because, H protic on ethanol and ethylene glycol was easier than Hα on estragole to react with $^{-}$OH.

Estragole isomerization in DMSO (Dimethyl Sulfoxide), aprotic solvent, was used to investigate the effect of H protic from solvent. The result showed that estragole isomerization in DMSO was easier than in ethanol and ethylene glycol. This experiment indicated that H protic on ethanol or ethylene glycol inhibit the reaction between Hα on estragole to react with $^{-}$OH. Estragole reasonance structure (Fig. 5) indicated that benzene ring has a negative charge that caused Hα on estragole to be less acidic.

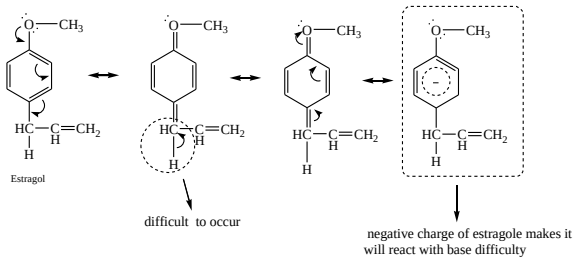


**Fig 5**. Resonance structure of estragole

The acidity of Hα at allylic group is the highest, compare to other H on estragole. So, $^{-}$OH will attack Hα on allylic group on estragole directly. This assumsion is in line with Risnayeti and Mas'ud (1997) experiment who mentioned that there is no H contribution from methoxy and aromatic groups in estragole isomerization process. Thus the estragole isomerization reaction doesn't occur through [1,3] sigmatropic rearrangement, but it occur through carbanion intermediate. Energy profile of estragole isomerization is shown in Fig. 6.

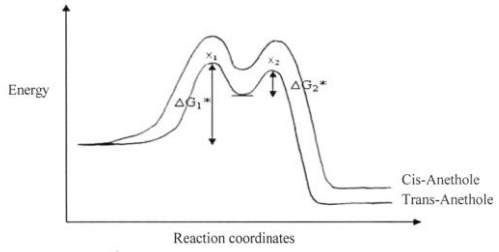


**Fig 6.** Energy profile of estragole isomerization

Total activation energy of estragole isomerization was determined by reaction in variation of time and temperature. The result showed that total activation energy of estragole isomerization is about 178,6238 J/mol.

Based on energy profile (Fig. 6), it can be seen that the stereo of intermediate carbanion is different (*cis* and *trans* forms). It is resulted from the rotation of C-C bond in allylic group. The mechanism of estragole isomerization is as follows:

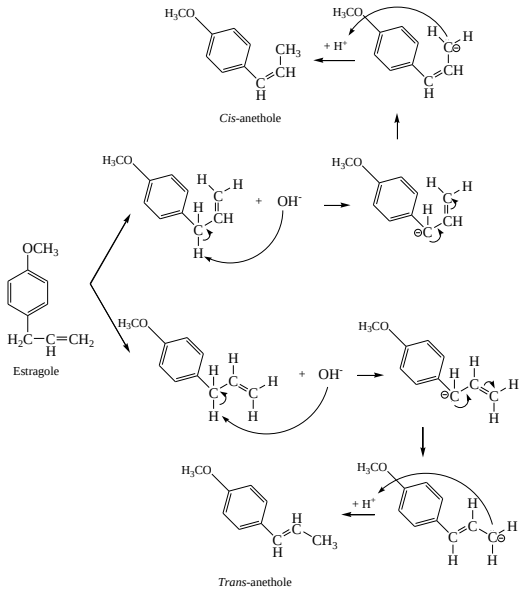


**Fig 7.** Estragole isomerization mechanism in parallel pathway

## 4. CONCLUSION

1. Ethanol and ethylene glycol can be used in estragole isomerization reaction as a solvent.
2. The optimum condition of estragole isomerization in ethanol is in 10 mL of ethanol with the proportion of estragole-KOH 1:9 at 99,5°C for 6 hours, whereas in ethylene glycol, optimum condition is in 30 mL of ethylene glycol with the proportion of estragole-KOH 1:3 at 150°C for 6 hours.
3. H protic on solvent inhibit estragole isomerization reaction.
4. Estragole isomerization pathway is parallel.
5. The mechanism of estragole isomerization via carbanion intermediate.

## REFERENCES

Achmad, S. A., 1986, *Buku Materi Pokok Kimia Organik Bahan Alam,* Universitas Terbuka, Jakarta.

Agusta, A, 2000, *Minyak Atsiri Tumbuhan Tropika Indonesia*, Institut Teknologi Bandung, Bandung.

Guenther, E., 1990, *Minyak Atsiri*, IV B, Universitas Indonesia Press, Jakarta.

Isaacs, N. S., 1969, *Experiments in Physical Organic Chemistry*, The Macmillan Co., London.

Isaacs, N. S.,1987, *Physical Organic Chemistry*, John Wiley & Sons Inc., New York.

Kishore, D., dan Kannan, S. 2006. "Catalytic Isomerization of Estragole to Anethole Over Hydrotalcites and HT-like Compounds". *Journal of Molecular Catalysis A: Chemical.* Vol **224**: 83-92

Risnayeti dan Mas'ud, Z.A., 1997, "Telaah Mekanisme Isomerisasi estragole-Anetol Dengan Metode Resonansi Magnet Inti-Fraksionasi Isotropik Alami Spesifik", *Buletin Kimia*, Chemistry Departement of Bogor Agricultural Institute, Bogor.

Sharma, S. K., Srivasta, V.K., Pandya, P.H., dan Jasra, R.V. 2005. "Solvent-Free Isomerization of Methyl Chavicol to *Trans*-Anrthole using Transition Metal Complexes as Catalysts". *Catalysis Communications.* Vol. **6**:205-209