



# Meta-Analysis of Volatile Compounds from Vinegar Produced by the Slow Method and the Fast Method

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## ARTICLE INFO

### Article History:

Received: September 2021

Final Revision: 14 December 2021

Accepted: 15 December 2021

Online Publication: 10 January 2022

## KEYWORDS

Aroma profile, Vinegar production technology, Acetate Ester, Alcohol, Volatile Acid

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## ABSTRACT

Volatile compounds are one of the important characteristics of vinegar, where the content and composition of these compounds is an account for the aroma profile of vinegar. The difference in production technology used in making vinegar produces vinegar with different characteristics. There are two general methods commonly used in the production of vinegar, namely the slow method and the fast method. This meta-analysis was used to conclude several studies that examined the differences in volatile compounds in vinegar produced through the slow methods and the fast methods. From this study, it can be seen that comparison of volatile compounds characteristics in vinegar produced by the slow method and the fast method where the slow method tends to produce vinegar with a high concentration of acetate ester group and alcohol group, and the fast method tend to produce vinegar with a high concentration in a volatile acid group.

## 1. INTRODUCTION

### 1.1. Research Background

Vinegar is a sour liquid that is widely used throughout the world. Vinegar is commonly used as an additional ingredient in cooking or consumed directly because it is believed to have many health benefits. In addition, vinegar can also be used as a preservative agent and cleaner. FAO (Food and Agriculture Organization of the United Nations) and WHO (World Health Organization) define vinegar as an edible liquid which is exclusively produced from starchy and/or sugary raw materials through two sequential processes, namely alcoholic fermentation and acetic acid fermentation. There have been many studies conducted on vinegar. This includes microorganisms, production technology, health functions, and the compounds contained in them [1]. One of that compound is volatile compound. Several major and minor volatile compounds, account for a vinegar's final aroma [2].

From a technological point of view, there are 2 methods of vinegar production, namely the slow method and the fast method.<sup>[3]</sup> Opinions on the better method also vary. There have been many studies that describe the use of each of these methods in various types of vinegar. However, there is no general

description that shows the characteristics of volatile compounds from each method. For this reason, a study that examines this is needed.

A method is needed to conclude the results of several existing studies to see a general picture of the phenomenon that occurs. One of the methods commonly used to conclude the results of these studies is meta-analysis. Meta-analysis can be defined as a systematic study accompanied by statistical techniques to calculate the conclusions of several research results.<sup>[4]</sup> The use of meta-analysis in combining several studies will avoid bias that can occur in systematic reviews, because of the statistical techniques used to formally calculate the combined effects of several studies.

### 1.2. Literature Review

In vinegar production using the slow method or also called the traditional method and the surface method, acetic acid bacteria are grown on the surface of wood shavings and provides oxygen at the surface. In the fast method or also called the industrial method and the submerged method, oxygen is supplied in fermentation to accelerate industrial production. In addition, the difference between these two methods is in the length and temperature of fermentation. The slow method usually uses a temperature of 25° C with a fermentation time of 2 months. The

fast method usually uses a temperature of 30° C with a fermentation time of 20-24 hours [5] The following is the mechanism of the fermentation process that occurs in vinegar production.

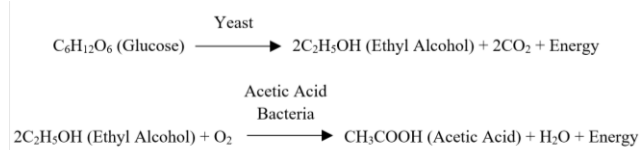


Fig. 1. Vinegar Production Mechanism [6]

### 1.3. Research Objective

This study aims to know the comparison of volatile compounds characteristics in vinegar produced by the slow method and the fast method.

## 2. MATERIALS AND METHODS

### 2.1. Search strategy and eligibility criteria

The literature used in this study is an article that discusses the production of vinegar using the slow method and the fast method. Articles are obtained from databases such as science direct, research gate, google scholar, and others. The keywords used are ("comparative" OR "comparison") AND ("vinegar production" OR "vinegar fermentation") AND ("surfaced method" OR "slow method") AND ("submerged method" OR "fast method").

The literature selection stages in this study followed the PRISMA (Preferential Reports for Systematic Reviews and Meta-Analyses) guidelines [7] as shown in Fig. 2.

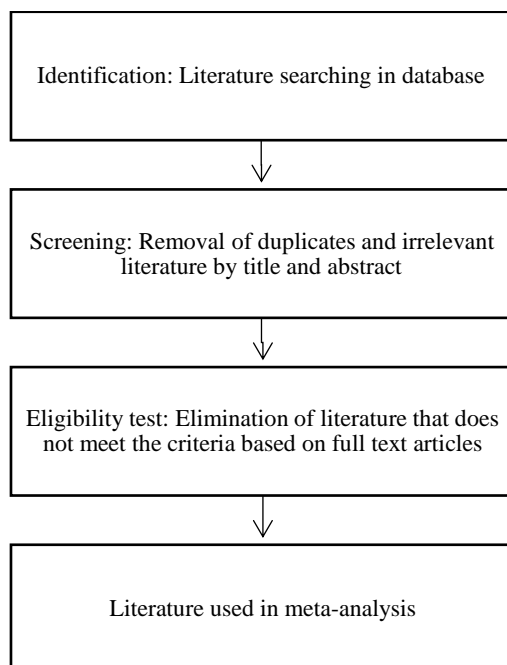


Fig. 2. Literature Search Process Flowchart

The articles used are articles that meet the following criteria: 1. Published in English as a full text article; 2. Direct comparison between the slow method and the fast method; 3. Stated as "slow method" (reported as slow method, surfaced method, traditional method) and "fast method" (reported as fast method, submerged method, industrial method, modern method).

### 2.2. Statistical analyses

The effect size was calculated from mean difference and standard deviation of each literature. Each volatile compound was compared in units of µg/L. Summary were calculated using random-effects model. Mean difference ± 95% CI was used to show the effect size.

The meta-analysis statistical procedure was conducted by Review Manager 5.4. P value < 0.05 was considered as the level for statistically significant.

## 3. RESULT AND DISCUSSION

### 3.1. Included Studies

The following is a list of studies that met the specified criteria and were used in this meta-analysis.

Table. 1 List of Included Studies used in Meta-Analysis

Author	Year	Vinegar Type
Callejon et.al	2009	Red wine vinegar
Al Dalali et.al	2019	Zhenjiang aromatic vinegar
Al Dalali et.al	2020	Sichuan vinegar
Turhan and Canbas	2016	Dimrit grape vinegar

### 3.2. Meta-analysis of acid group in vinegar

The results of the meta-analysis of volatile compounds in the acid group in vinegar produced by the fast production method contain isovaleric acid and octanoic acid compounds with concentrations that tend to be higher than those produced by the slow production method. Meanwhile, the acetic acid content of vinegar produced by the slow production method tends to be higher than the fast production method. However, the two things were not statistically significantly different.

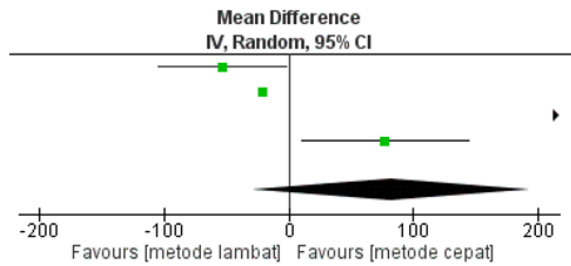
The hexanoic acid content in vinegar produced by the fast production method tends to be higher than the slow production method, and this is also statistically significant. Hexanoic acid gives a description of the acid, mold, and sour aroma [10].

In general, vinegar produced by the fast production method contains higher concentrations of volatile acid groups than the slow production method. This is in accordance with the study of [10] which states that acid compounds and ester compounds have a greater contribution to the aroma profile of vinegar produced through modern (fast) production methods and [2] study which states that vinegar produced by fast methods has a higher level of acidity compared to vinegar produced through the slow production method.

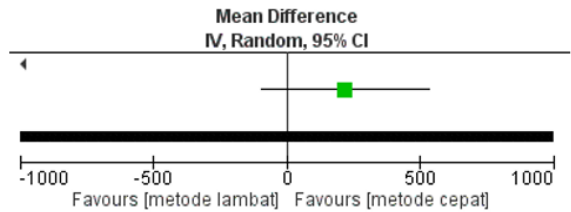
### 3.3. Meta-analysis of aldehyde group in vinegar

The results of the meta-analysis of volatile compounds of the aldehyde group showed that vinegar produced by the slow production method tends to contain benzaldehyde compounds with higher concentrations than the fast method. However, this was not statistically significantly different. Meanwhile, vinegar produced by the fast production method tends to contain a higher concentration of 2-phenyl-2-butenal than the slow production method, and this is also not significantly different statistically.

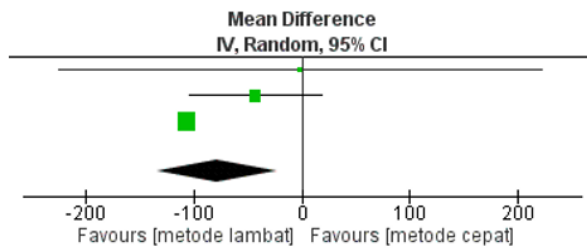
## Acetic acid



## Isovaleric acid



## Hexanoic acid



## Octanoic acid

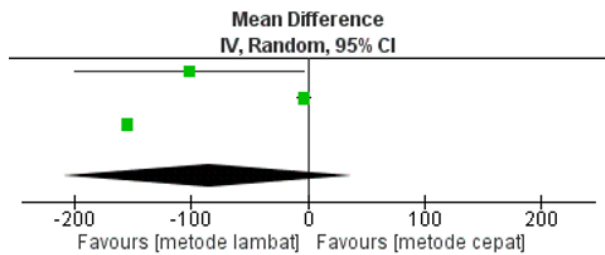
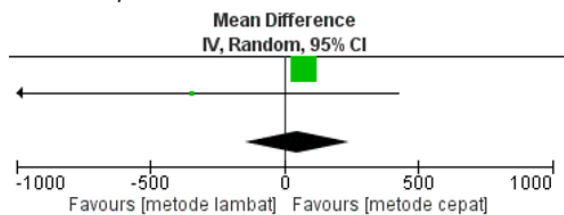


Fig. 3. Forest Plot of Acid Group in Vinegar

## Benzaldehyde



## 2-phenyl-2-butenal

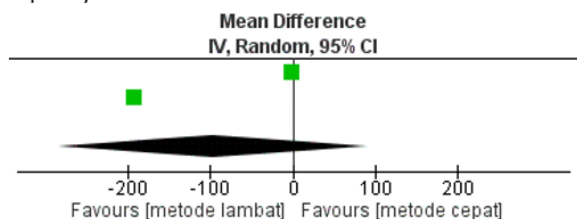


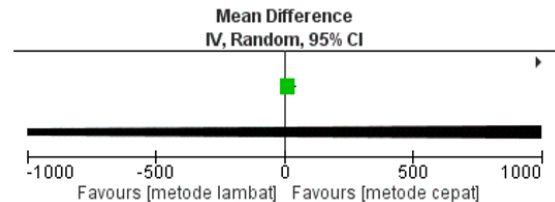
Fig. 4. Forest Plot of Aldehyde Group in Vinegar

## 3.4. Meta-analysis of acetic ester group in vinegar

The results of the meta-analysis on volatile compounds of the acetate ester group showed that vinegar produced through the slow production method contained methyl acetate, isobutyl acetate, and isoamyl acetate compounds with concentrations that tended to be higher than those produced by the fast production method. However, this was not statistically significantly different.

Meanwhile, vinegar produced by the fast production method contained a higher concentration of 2-phenethyl acetate compared to the vinegar produced by the slow production method, and this was also statistically significantly different. The compound 2-phenethyl acetate provides a description of the sweet, honey and floral aroma [10,11]. However, this is not in line with the study of [10] which describes that vinegar produced through traditional (slow) production methods has higher sweet and floral aroma characteristics than vinegar produced by modern (fast) production methods. This is because the volatile compound that gives the sweet and floral description is not only produced by 2-phenethyl acetate.

## Methyl acetate



## Isobutyl acetate

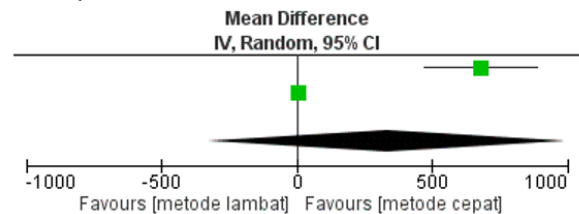


Fig. 5. Forest Plot of Acetic Ester Group in Vinegar

In general, vinegar produced by the slow production method contains acetate ester compounds with a higher concentration than the vinegar produced by the slow production method. This is in accordance with [2] which states that acetate esters are dominant in vinegar produced through the surface (slow) production method.

## 3.5. Meta-analysis of alcohol group in vinegar

The results of the meta-analysis for volatile compounds in the alcohol group in vinegar produced by the slow method contained of 2-methyl-1-butanol, 3-methyl-1-butanol, and benzyl alcohol with higher concentrations compared to vinegar produced by fast method. However, for 3-methyl-1-butanol and benzyl alcohol, there was no statistically significant difference. Meanwhile, the 2-methyl-1-butanol compound showed statistically significantly different results.

Vinegar produced by the rapid production method contains a higher concentration of 2-phenylethanol than the vinegar

produced by the slow production method. This is also significantly different statistically.

In general, vinegar produced by the slow method produces volatile compounds of the alcohol group with a higher concentration than vinegar produced by the fast method.

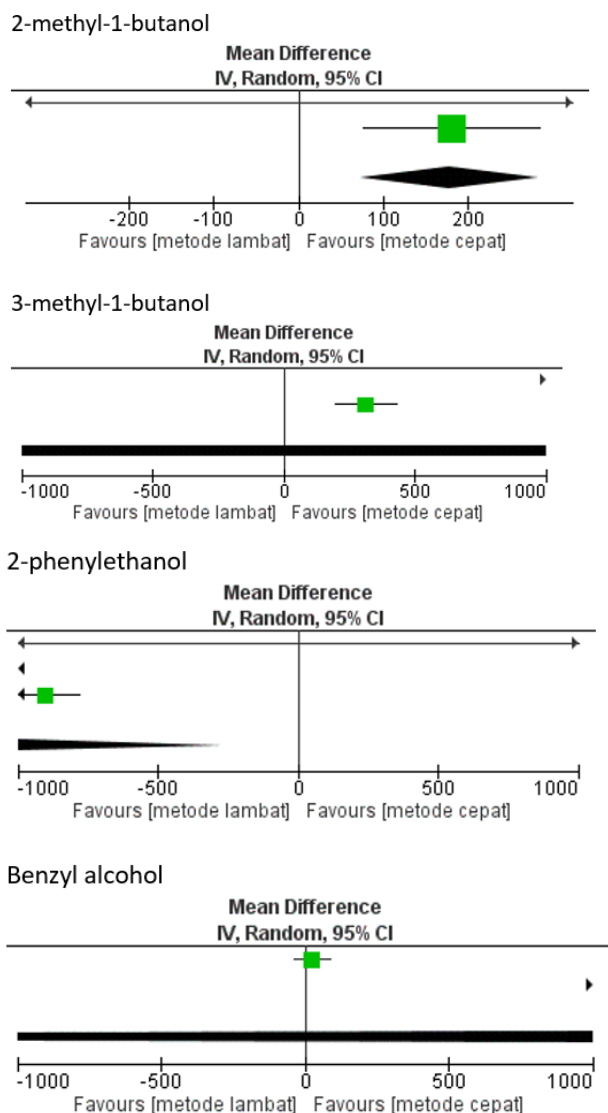


Fig. 6. Forest Plot of Alcohol Group in Vinegar

### 3.6. Meta-analysis of ethylic ester group in vinegar

The results of the meta-analysis of volatile compounds from the ethylic ester group showed that vinegar produced by the fast method contained ethyl lactate compounds with a higher concentration. Meanwhile, vinegar produced by the slow method contains ethyl acetate with a higher concentration. However, both are not statistically significant.

Ethyl acetate provides a description of the sweet aroma, this is in accordance with the study of Ref. [6] which shows that vinegar produced through traditional (slow) production methods has a higher sweetness than vinegar produced through fast production methods.

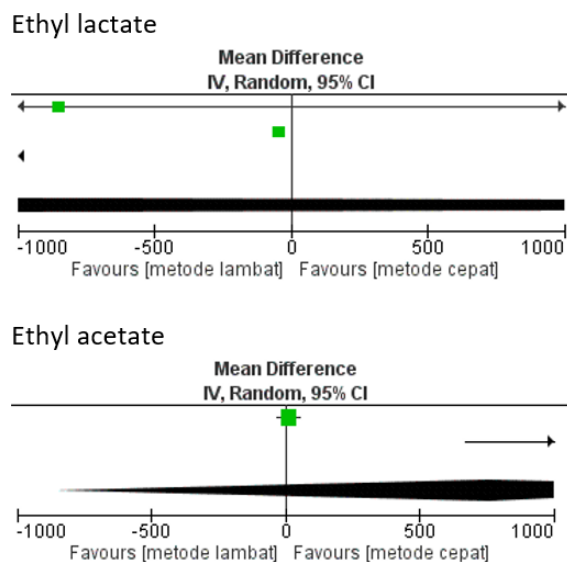


Fig. 7. Forest Plot of Ethylic Ester Group in Vinegar

### 3.7. Meta-analysis of lactone group in vinegar

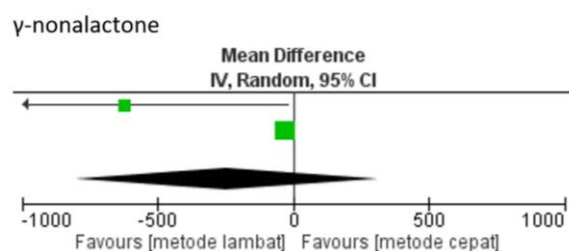


Fig. 8. Forest Plot of Lactone Group in Vinegar

The results of the meta-analysis of volatile compounds in vinegar produced through the fast production method contain  $\gamma$ -nonalactone compounds with concentrations that tend to be higher than the vinegar produced through the slow production method. However, this was not significantly different.

## 4. CONCLUSION

From this study it can be seen that comparison of volatile compounds characteristics in vinegar produced by the slow method and the fast method. Volatile acid group concentration tend to be higher in vinegar that produced by fast method. Acetate ester group and alcohol group tend to be higher in vinegar produced by slow method. In other groups of volatile compounds, the differences between the slow methods and the fast methods were not significantly different based on statistics.

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