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# Nutritional Requirements and Fermentation Condition for Acetic Acid Production From Agricultural Fruit Waste

Studies on agricultural fruit waste fermentation for acetic acid production have focused on understanding its nutrient requirements. The present systematic literature review aimed to assess the potential and additional nutrients necessary for optimised acetic acid production from fruit waste. Fermentation conditions and techniques employed for the alcoholic and acetous fermentation stages were also evaluated to establish their significant effects on acetic acid yield.

**Keywords:** Acetic acid, Agriculture, Nutritional requirement, Waste

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## 1 Introduction

Acetic acid is a colorless and pungent liquid with the chemical formula  $\text{CH}_3\text{COOH}$  [1]. The substance is an organic compound widely employed in the food industry as a solvent, food acidity regulator, additive, and antimicrobial food preservative [1]. The primary acid component in vinegar is acetic acid, at a minimum of 4 % acetic acid by volume, water, and trace elements [2, 3].

The pharmaceutical industry utilizes acetic acid to manufacture pharmaceutical products, such as vitamins, antibiotics, and hormones [4]. The first known application of acetic acid in vinegar production was by the Babylonians in approximately 3000 BC [5]. Historical records indicated that the Babylonians utilized dates, figs, and beer to synthesize vinegar for culinary and medicinal purposes [6].

Acetic acid bioproduction can be classified into two-stage and simultaneous single-stage acetic acid fermentations (see Fig. 1) [7]. The two-stage process encompasses alcohol fermentation followed by acetous fermentation [7]. Alcohol fermentation occurs without oxygen and involves yeast converting sugars into ethanol, carbon dioxide, and other metabolic by-products [7]. Nevertheless, the process can be bypassed by incorporating acetic acid bacteria (AAB) and an ethanol-rich medium, resulting in immediate acetous fermentation [8]. Conversely, acetous fermentation necessitates bacteria that produce acetic acid by oxidizing ethanol [8].

Typically, fermentation is conducted in either a submerged or solid state [9]. In submerged fermentations, microbial cultures are incorporated into liquid media to obtain the desired product [9]. During acetic acid fermentation, AAB is suspended in the activating liquid and vigorous aeration provides oxygen per the bacterial requirements [9]. Submerged fermentation is employed for microbes with high moisture content dependency for growth [10]. Conversely, solid-state fermentations occur in the absence or near absence of free water [11]. The microbes in-

involved in the process are cultured in solid and moist media with moisture content up to 60 % (w/v) [10].

Fermentation-produced acetic acid is predominantly utilized for vinegar production. China possesses a long-standing tradition of manufacturing vinegar [12]. Annually, the nation produces approximately  $2.6 \times 10^6 \text{ m}^3$  of vinegar from various raw materials, primarily cereals, including rice, sticky rice, and wheat bran [13]. Cider vinegar is also commonly employed in several countries, including the United Kingdom, the United States, and Switzerland, as a flavoring agent and food preservative [14].

Fig. 2 illustrates the global acetic acid production in the form of vinegar. Vinegar is predominantly manufactured in Italy (37.80 %), the United States (10.10 %), South Korea (6.11 %), Spain (6.60 %), Germany (4.27 %), France (4.14 %), China (3.48 %), and Japan (3.18 %) (Observatory of Economic Complexity [OEC],

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