INTRODUCTION

CHAPTER I

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Cocoa (*Theobroma cacao* L.), originally native to the Amazon basin in South America, was introduced to India in the early 20th century. It is officially categorized as a plantation crop, alongside coffee, tea, and rubber. Cocoa beans are the primary ingredient in confectioneries, beverages, chocolates, and other edible products. However, India's commercial cocoa sector has minimal impact on international export markets, with most processed cocoa products consumed domestically. India's favourable tropical climate offers significant potential for cocoa cultivation. In India, Kerala was the leading state in promoting cocoa cultivation. At present, the global production and consumption of cocoa is around 27 lakh MT, compared to this, India's production is meager i.e. 10,000 MT (DCCD, 2021).

The sharp increase in cocoa prices has been driven by concerns over unfavourable weather conditions in West Africa, a major cocoa-growing region and the primary supplier to the European Union (EU). According to the World Bank, global cocoa production is expected to decline by 14% in the 2023-24 season, falling to 4.2 million metric tons (MMT) from 4.9 MMT in 2022-23. This drop is largely due to reduced output in Côte d'Ivoire and Ghana, which together contribute nearly 60% of the world's cocoa supply. The situation has been exacerbated by strong seasonal demand, as consumers stocked up on chocolates and cakes for the holidays, leading to a global shortage. Food and beverage manufacturers are increasingly concerned, with several major companies already lowering their profit forecasts (Food Navigator, 2025).

Cocoa pulp is primarily composed of water, sugars, acids, and pectin. The sugars in cocoa pulp include sucrose, fructose, and glucose. Citrate is the predominant organic acid, which lowers the pH of the pulp. Other non-volatile organic acids, such as malic, tartaric, and oxalic acids, are present in amounts less than 0.1%. Potassium is the most abundant mineral in cocoa pulp, and ascorbic acid is the most prevalent vitamin, making up 97% of the total vitamin content (Pettipher, 1986).

While processing cocoa for chocolate production, the cocoa beans along with pulp has to be fermented; during which the mucilage needs to be removed and generally wasted. This mucilage which are rich in nutrients, if collected hygienically can be utilized for production of value added health drinks such as low alcoholic, nutrient rich wine which would enable the farmers to increase the utilization potential thereby fetch remunerative price for the commodity.

The process of making wine, or vinification, which begins with the selection of fruit and subsequent fermentation into an alcoholic beverage, is an excellent illustration of the biotechnological advancement in beverage production. The type of yeast called Saccharomyces is typically employed in fermentation, which turns fruit juice sugars into organic acids and alcohol. Cocoa pulp juice has been effectively utilized in the production of vinegar, beer, and jelly. Additionally, removing the pulp from the beans can enhance the quality of the seeds by lowering their acidity. The procedure entails removing the mucilage from cocoa beans, fermenting the mucilage with *Saccharomyces cerevisiae* as a starter, and assessing the wines' microbiological, physicochemical, and sensory qualities (Ngangonum *et al*., 2022).

The term "wine aging" encompasses a series of reactions that occur after the wine is bottled and is often called reductive aging because it takes place in the absence of oxygen. When using cocoa pulp to produce wine, the quality of the wine is crucial as it determines its commercial value. The primary quality characteristic is the aroma and flavour of the wine. While factors like nutrient content are specific to the product, the development of distinctive flavour and aroma in the wine is primarily achieved through the aging process. During wine aging, various reactions lead to notable changes in the wine's organoleptic properties. One of the most apparent changes is in the color of the wine, which is related to alterations in the phenolic content. The phenolic compounds in wine are categorized into two groups: flavonoids and non-flavonoid phenolic compounds. The alterations in phenols in wines during and after production occur through several mechanisms, including the breakdown of anthocyanins, interactions between tannins and proteins, reactions between tannins and polysaccharides, formation of cations, oxidation and polymerization of procyanidins, and the formation of anthocyanin copigments (Hatice and Ezgi, 2017).

Wine aging is an important stage in the wine production, which determines the final quality of the product. It is a time consuming process and can cause loss of time and money. Application of new techniques for accelerated wine aging could produce high quality wines, shortens the length of aging time and allow wines to be placed on the market more quickly.

Hydrodynamic cavitation is an innovative method that can be used to speed up the aging process of wine. Hydrodynamic cavitation (HC) is a process where high energy is released in a flowing liquid when bubbles implode due to a decrease and subsequent rise in local pressure. Food and beverage industries have been using the principle of HC to homogenize, pasteurize, break down, or mix food macromolecules. The aging effect is associated with the cavitation process and the growth and collapse of micro-sized bubbles.

HC is created by directing a liquid through a small orifice or constriction, which increases its kinetic energy. The phenomena include nucleation, bubble growth, and bubble collapse. There is a point known as the vena contracta where the flow area of the liquid reaches its minimum. The throttling must be adequate to lower the pressure below the threshold at the vena contracta, resulting in the formation and release of millions of cavities. Later, as the pressure decreases and the liquid expands, the cavities collapse. A sharp shock wave of energy is emitted into the surroundings when the energy is released. This shockwave creates a strong microscopic mixing effect. The mechanism is similar to acoustic cavitation, with the primary difference being in temperature and pressure conditions. The intensity of the collapse of individual cavities is significantly lower than that produced by ultrasound. Proper adjustment of the geometry and operating parameters allows for effective control over both the intensity and the number of cavitation events (Asaithambi *et al*., 2019).

Based on the above, it can be hypothesized that applying hydrodynamic reactions will result in a pressure drop and involve processes such as nucleation, bubble growth, bubble implosion, and the release of sharp shock waves. These effects lead to microscopic mixing, turbulence, and the formation of free radicals, which increase the reactivity of wine compounds, thereby accelerating the production of characteristic aroma and flavour compounds that typically develop through conventional aging. Additionally, this method minimizes evaporative losses. The process is also straightforward, energy-efficient, and easily scalable, unlike other accelerated aging techniques such as ultrasonics, gamma irradiation, electric fields, and micro-oxygenation. Considering these aspects, this study was undertaken to subject the cocoa mucilage wine for hydrodynamic cavitation treatment under various conditions and to examine the physicochemical changes after the treatments with following objectives.

- To develop and evaluate a hydrodynamic cavitation reactor system for accelerated aging of low alcoholic cocoa mucilage wine and to optimise the process parameters.
- To characterize the accelerated aged cocoa mucilage wine in comparison with fresh and aged wine