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Mass Balance and Yield Analysis of Apple (*Malus sylvestris*) Cider Drink Production in Batu City

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A B S T R A C T

Batu City is recognised as one of Indonesia's primary apple production centres, boasting significant potential for the development of fruit-based processed products. This study aims to analyze the mass balance and yield at each stage of the apple juice production process to obtain optimal production efficiency. The production process involves washing, crushing, filtering, mixing, cooking, and packaging. The mass balance was analyzed based on the principle of mass balance, while the yield was calculated from the ratio of output to input at each process stage. The results showed that the filtering process produced the lowest yield of 91.6% due to the waste of apple pulp, while the crushing and mixing process showed a yield of 100%. The mass balance calculation showed a match between the input and output masses at each process stage. This study emphasizes the importance of applying process engineering principles in food processing to increase efficiency, reduce material waste, and ensure production sustainability.

Contribution to Sustainable Development Goals (SDGs):
SDG 12-Responsible Consumption
SDG 9-Industry, Innovation, and Infrastructure
SDG 8-Decent Work and Economic Growth
SDG 2-Zero Hunger

1. INTRODUCTION

1.1. Research Background

Batu City is known as one of the leading apple producers with very high production levels. The annual apple harvest in Batu City can reach 17,050 tons per hectare. This high apple production in Batu City has led to the development of various apple-based products, such as apple pie, apple chips, and apple juice. Apple cider is a form of fruit processing that aims to extend the shelf life of apples by utilizing apple extract

Apple cider beverages are made through several stages sorting, washing, crushing, filtering, extraction, mixing, and packaging. The apple cider manufacturing process requires mass balance and yield calculations and analysis to determine the amount of incoming and outgoing material flow. The basic principle of a mass balance is that the incoming mass equals the outgoing mass [1]. The existing mass balance calculations yield yield efficiency values for each process. By applying a mass balance, optimal production efficiency can be achieved, potential waste or leaks in the process can be identified, and raw material usage can be optimized, ensuring quality and sustainability [2].

1.2. Literature Review

1.2.1. Manalagi Apple

The Manalagi apple (*Malus sylvestris*) is a local apple variety widely consumed in Indonesia. This apple originates from Malang and is known for its distinctive sweetness, even when unripe, and its fragrant aroma. The fruit has a light green-yellowish skin when ripe, with a diameter of approximately 5-7 cm and a weight of 75-100 grams per fruit [3]. Manalagi apples have whitish-yellow flesh with a water content of up to 84.05%. Their texture is firmer than Anna and Rome Beauty apples. Every 100 grams of Manalagi apples contain 4.5g of fructose, 6.96g of reducing sugars, 8.29g of total sugars, 6.53g of antioxidant activity, and 6.60mg of vitamin C [4]. Apples can be enjoyed fresh or processed into various products such as applesauce, apple juice, apple syrup, and apple cider drinks [5]. Apple juice is one of the processed apple products widely consumed by the public. This juice is obtained through a pressing or extraction process from filtered fruit. Apple juice is widely sold in the market as a drink rich in various nutrients [6]. According to SNI 3719:2022, fruit juice drinks are drinks obtained by mixing unfermented fruit juice from one or more types of fruit with drinking water, with or without carbonation, with or without other food ingredients and food additives, processed with or without pasteurization or sterilization. Fruit juice itself is obtained through a pressing or extraction process from filtered fruit. It is a liquid produced from the edible part of the fruit, which has been washed, crushed, clarified (if necessary), with or without pasteurization, and packaged ready for direct consumption [7]

The highest flavonol content is generally found in vegetables such as onions and broccoli, as well as in fruits such as apples, cherries, and berries. Apples are known to contain various phytochemical compounds such as phloridzin and chlorogenic acid, which function as powerful antioxidants. The average phenolic compound content in six apple cultivars includes: quercetin glycosides of 13.2 mg per 100 grams of fruit, vitamin C of 12.8 mg per 100 grams, procyanidin B of 9.35 mg per 100 grams, chlorogenic acid of 9.02 mg per 100 grams, epicatechin of 8.65 mg per 100 grams, and phloretin glycosides of 5.59 mg per 100 grams. The total antioxidant capacity of a whole apple with its skin is approximately 83 pmol of vitamin C equivalents, meaning that a single serving of apple (100 grams) has antioxidant activity equivalent to approximately 1500 mg of vitamin C, even though the actual vitamin C content in 100 grams of apple is only approximately 5.7 mg. The flavonoid composition of apples varies greatly between varieties and is also influenced by the stage of fruit ripeness [8].

*1.2.2 **Mass Balance and Yield***

A mass balance in an industrial process system is a quantitative analysis that encompasses all material flows entering, leaving, accumulating (storing), and wasting within the system. The purpose of this calculation is to determine unknown process variables based on known variables. In the context of process engineering, these variables can include mass, volume, flow rate, chemical composition, pressure, and temperature. The primary principle underlying the equations in a mass balance is the law of conservation of mass, which states that mass cannot be created or destroyed; it can only change form or change location 9 (Nisak et al., 2024). Thus, it can be seen that

$$Input - Output = Accumulation$$

By implementing a mass balance, companies can ensure optimal production efficiency, identify potential waste or leaks in the process, optimize raw material usage, and ensure quality and sustainability [2]. Mass balance calculations also serve as the basis for determining the yield value of the processing process *[10]*. According to Ref. [1], yield is the ratio between the amount of product produced (output) and the amount of raw materials used (input) in a processing process. The higher the yield percentage, the greater the product yield obtained from the raw materials used. Yield calculations are typically performed using a specific formula to determine the efficiency of a production process. Several factors influence yield, including extraction method, solvent type, temperature, time, particle size, and the sample-to-solvent ratio [11]. Thus, it can be seen that.

Process yield = Output/Input × 100%

1.3. Research Objective

This study aims to comprehensively analyze the mass balance at each stage of the apple cider manufacturing process and evaluate the resulting yield.

2. MATERIALS AND METHODS

The research was conducted from March to April 2025 at PT. Batu Bhumi Suryatama in Batu City, East Java. The tools and materials used in this research included a basin, analytical balance, digital balance, knife, and spoon. The materials used included manalagi apples, water, granulated sugar, lemon juice, and apple flavoring

The apple cider production process begins with sorting the raw materials, namely namely apples, washing, crushing the apples, filtering, mixing, cooking, packaging in cups, cooling, checking for leaks, and packaging in cardboard boxes. During the mixing process, other ingredients are added, including sugar solution, malic acid, citric acid, sodium benzoate, and filtered apple juice. All ingredients are mixed using a mixer machine with the help of a screen when pouring minutes to ensure the homogeneity of the sugar solution into the machine. The mixing process lasts for 10 to 15 minutes to ensure the homogeneity of the ingredients. Cooking is carried out in a heating tank for approximately one hour, with the main goal of extending the product's shelf life through a sterilization process. When the heating temperature reaches 80°C, caramel is added. The heating process is continued until the temperature reaches 100°C, then the heater is turned off. Before the packaging process, the apple cider is cooled first until the temperature drops back to around 70°C. After reaching this temperature, the product is flowed through a pipe to the filling and sealing machine for the packaging process. The apple cider packaging process is carried out after the cooking stage with a filling volume of 120 ml per package. An overview of the apple juice production process can be seen in Figure 1.

2.1. Mass Balance and Yield

The mass balance calculation begins by weighing the ingredients used using a digital balance. The second stage involves weighing the incoming and outgoing materials during the sorting process. The third stage involves weighing the incoming and outgoing materials during the washing process. The fourth stage involves weighing the incoming and outgoing materials during the crushing process. The fifth stage involves weighing the incoming and outgoing materials during the screening process. The sixth stage involves weighing the incoming and outgoing materials during the mixing process. The seventh stage involves calculating the incoming and outgoing materials during the cooking and packaging processes. Once the incoming and outgoing mass balances for the entire apple cider production process are known, the mass balance and yield calculations can be performed.

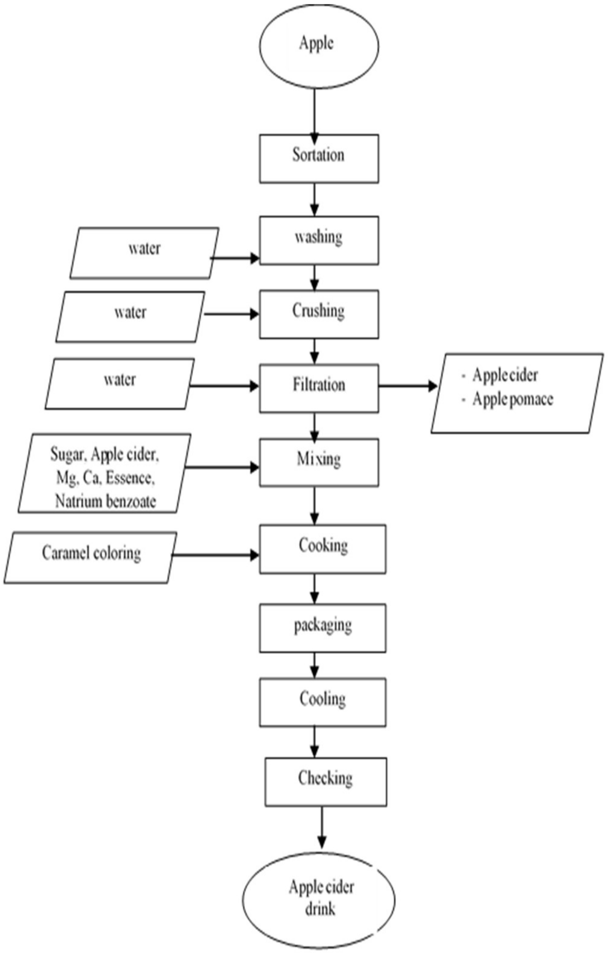

Figure 1. Diagram of the apple juice production process

2.2. *Observation Procedure*

Mass balance calculations serve as the basis for determining the yield value of the processing process [10]. According to Ref. [1], yield is the ratio between the amount of product produced (output) and the amount of raw materials used (input) in a processing process. The higher the yield percentage, the greater the product yield obtained from the raw materials used. The mass balance is illustrated in Figure 2.

Inflow (I) = Outflow + Accumulation

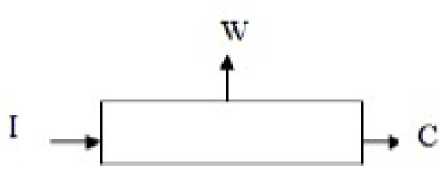

Figure 2. Mass balance

According to Ref. [1], yield refers to the proportion between the amount of final product (output) and the quantity of raw materials (input) utilized in a processing operation. A higher yield percentage indicates a greater amount of product obtained from the same amount of raw material. Yield calculations are performed using a specific formula to determine the efficiency of a production process. Several factors influence yield, including extraction method, solvent type, temperature, time, particle size, and the ratio between sample and solvent [11] Yield is a critical parameter for assessing the efficiency of a processing system, particularly in the fields of food technology, agriculture, and manufacturing. It is commonly expressed as a percentage and calculated using the formula:.

Process yield = Output/Input × 100%

In industrial applications, optimizing yield is essential for improving cost-effectiveness, enhancing productivity, and maximizing profitability

3. RESULT AND DISCUSSION

3.1. *Mass Balance*

Mass balance calculations are performed by weighing all raw materials used in the process. Weighing is performed at each stage of apple cider production, both at the beginning and end of the process, to obtain data on the initial and final weights. This allows for analysis of the mass balance within the system. Furthermore, mass balance calculations also serve as the basis for determining the yield value of the processing process. The results of the mass balance analysis conducted in the apple cider production process align with the mass balance principles of a system. This is demonstrated by the identical inlet and outlet mass values for each process [12]. This also aligns with the statement by [9], who stated that the main principle underlying the formulation of equations in a mass balance is the law of conservation of mass, which states that mass cannot be created or destroyed; it can only change form or change location. The mass balance calculations for the apple cider production process are shown in Table 1.

Table 1. Results of the Mass Balance Calculation of Apple Juice Drinks

No	Process	Input	Output
1	Washing	Fresh apple = 5.1 kg Water = 10 L	clean apple = 4.9 kg Water = 10 L dirt = 0.2 kg
	Total	15.1 kg	15.1 kg
2	crushing	Clean apple 4.9 kg = 3.92 L[1)] (with apple density 0.8kg/L)[2)] water 10 L	Apple juice = 13.92 L
	Total	13.92 kg	13.92 kg
3	Filtering	Apple juice 13.92 L water 10 L	Apple pomace 2 kg Apple cider 21.92 L
	Total	23.92 kg L	23.92 L
4	Mixing	Ma 0.35 L Ca 0.3 L Essence 0.166 L Natrium Benzoat 022 L Sugar 120 L Apple cider 21.92 L water 357.064 L	Apple cider drink 500 L
	Total	500 L	500 L
5	Cooking	Apple cider drink 500 L	Apple cider drink 500 L

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		Caramel coloring 0.2 L	Dissolved Caramel Coloring 0.2 L
	Total	500.2 L	500.2 L
6	Packaging	Apple cider drink 500 L	Apple Cider Drink Cardboard Packaging= 171 Pack = 171 x 24 cup /pack = 4104 Cup x 0.12 L / cup = 492.48 L Leftover Apple Cider Drink = 45 cup x 0.12 L / cup = 5.4 L + = 497.88 L = 498 L Bellow Standar = 15 cup Leaking = 11 cup standard = 19 cup + = 45 cup Apple cider drink that is wasted during the filling and sealing process in the cup 2 L
	Total	500 L	500 L

During the material preparation process, the incoming and outgoing masses of apples were equal. No waste was generated during the material preparation process. The incoming material was 5.1 Kg, resulting in an output of 5.1 Kg. In the material preparation process, the input and output were equal because no mass was wasted from the input mass.

The input for the washing process was 5.1 kilograms of fresh apples washed with 10 litres of water, resulting in an output of 4.9 kilograms of clean apples, 10 litres of water, and 1.1 kilograms of debris. During the washing process, the apples were separated from debris such as small stalks and leaf debris.

The mass balance for the apple crushing process using a blender used 4.9 kg of apples (equivalent to 3.92 L) with an apple density of 0.8 kg/L and 10 L of water. This process produced 13.92 L of apple juice.

The mass balance for the filtration process used 13.92 liters of apple juice and 10 liters of water. In the filtering process, the apples will be separated into apple juice and apple pulp which is not used in the next process. The output of this filtration process produced 2 kg of apple pulp and 21.92 liters of apple juice.

The input ingredients for the blending process were 21.92 liters of apple juice, 357 liters of water, 120 liters of sugar solution, 0.2 liters of sodium benzoate as a preservative, 0.166 liters of essence, 0.3 liters of calcium to improve color stability, and 0.35 liters of magnesium carbonate ($MgCO_3$). The addition of $MgCO_3$ acts as a precipitating agent to remove cloudiness from the juice. The $MgCO_3$ reacts with the organic acids in the apple juice to form a precipitate, which can then be removed through filtration or precipitation, resulting in a clearer juice. The output from the blending process was a total of 500 liters of apple juice.

During the cooking process, 500 litres of apple juice were used and 0.2 litres of caramel colouring were added. The heating process is carried out in a heating tank for approximately one hour, with the primary goal of extending the product's shelf life. The cooking process is carried out at a temperature of 100°C. This process can kill microbes, ensuring the product is safe and suitable for consumption. The output of this cooking process is 500.2 liters of ready-to-pack apple cider.

In the final packaging process, the apple cider is sealed using an automatic continuous sealer. 500 liters of apple cider are packaged in 120 ml cups, resulting in 4,198 cups of ready-to-dispense apple cider. During this packaging process, 2 liters of apple cider are wasted due to poor machine efficiency. This waste comes from 15 products with leaking packaging and 11 products that are below standard.

3.2. Apple Cider Production Yield

The yield at each stage of the apple cider production process is calculated by comparing the weight of the final product with the weight of the raw materials used at the beginning of the process. This measurement aims to assess the effectiveness of a process in producing the product [13]. The yield at each stage of the apple cider production process is measured to determine the effectiveness of a process in producing a high product weight. The higher the yield, the higher the resulting product weight [14]. The apple cider yield at each stage is shown in Table 2.

Table 2. Results of the Calculation of Yield for Making Apple Juice Drinks

No	Process	Yield (%)
1	washing	96,07%
2	Apple crushing	100%
3	Filtration	91,6%
4	Mixing	100%
5	Cooking	99,96%
6	Packaging	99,6%

In the first process, 5.1 kg of apples were washed, resulting in an apple yield of 96.07%. This process included 3.93% wasted impurities, amounting to 0.2 kg. In the subsequent crushing process, also known as juicing, the yield reached 100%. During the process of filtering 13.92 L of apple juice, a yield of 91.6% was obtained, with 9.4% of the apple pulp remaining unused, totaling 2 kg. The mixing process yielded 100% and the cooking process of 500 L of apple juice with the addition of 0.2 L of caramel coloring resulted in a yield of 99.96%, with 0.04% being attributed to the dissolved caramel coloring. Finally, the packaging process of 500 L of apple juice drinks where the yield was obtained at 99.6% with 0.4% being 2 L of apple juice drinks that were wasted during the filling and sealing process in the cup. Based on the results of the process yield calculations, the apple juice filtration or extraction process yielded the lowest yield. This is because the process produces 2 kg of apple pulp, or 9.4% of the apple juice, resulting in significant weight loss. Meanwhile, the highest process yield occurred during the apple crushing and mixing processes. This is because the apple crushing process is controlled by staff, thus minimizing weight loss. No material is wasted during the mixing process, resulting in no weight loss.

4. CONCLUSION

This study demonstrates that the application of mass balance analysis and yield calculations to apple juice production provides a deeper understanding of the efficiency and sustainability of the production process. The crushing and blending processes demonstrated optimal efficiency with a yield of 100%. In comparison, the filtration process was the critical point with the lowest yield (91.6%) due to material loss in the form of pulp. The mass balance calculations also indicate that all process stages adhere to the principle of conservation of mass, with balanced input and output mass values. These findings provide an important basis for optimizing fruit juice processing based on a process engineering approach. Further studies are needed to evaluate technological interventions that can minimize material loss and increase yield, particularly at the extraction stage

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