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The Study of Selection Bottle Packaging For Carbonated Beverages

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ABSTRACT. The growth of the packaged beverages market in Indonesia is overgrowing. One sector of packaged beverages is carbonated beverages and bottled water. The main problem with packaged beverages containing dissolved gasses is maintaining product quality during shelf life. Packaging materials and packaging lids cause a decrease in dissolved gas levels in beverages. Therefore, this study aims to analyze leaks in polyethylene terephthalate and glass bottles so that can use them to estimate the shelf life of the product. This study uses water, 3 types of glass bottles, and 1 type of plastic bottle. Bottles filled with water with various filling volumes of 40%v/v, 60%v/v, and 80%v/v were then analyzed for bottle leakage for 8 days. The results showed that effectively used a glass bottle with a volume of 250mL filled with more than 80%v/v, this was because it had the least leakage rate compared to others. In addition, this bottle has an attractive visual, easy lablabelingnd the size is not too large (ergonomic).

1. INTRODUCTION

The global packaged beverages market's growth continues to increase [1]. In 2011, sales of packaged beverages globally reached 233 billion litres and increased to 290 billion litres in 2014 [2]. Likewise, the packaged beverages industry in Indonesia is also growing rapidly. Packaged beverages have the meaning of water that is processed using certain technologies, packaged, and consumed directly [3]. The world beverages market is generally divided into four sectors. The first sector is brewed beverages, such as tea, coffee, or malt. The second sector is milk-based beverages, either plain or flavoured white milk. The third sector is soft beverages divided into bottled water, carbonated beverages, dissolved beverages (such as squash, syrup, and powder), juices, and still beverages. While the fourth sector is alcoholic beverages [4].

Beverages with dissolved CO_2 and O_2 are types of soft beverages [4]. Carbonated water was first discovered in 1741 by mixing sodium bicarbonate and began to be sold for medical purposes in 1767. Meanwhile, in the late 1760s, carbonated water with CO_2 was discovered [5]. The principle of the solubility of CO_2 and O_2 in liquids is applied in manufacturing oxygenated water and carbonated beverages [6]. The solubility of gases is influenced by the nature of the gas, the nature, solvent (such as salinity and sugar content), the solution's temperature, and the room gas's partial pressure [7]. Mohammadian [8] studied the solubility of CO_2 in NaCl solution at a pressure of 21.3 MPa and a temperature of 80ºC at 1,147 CO_2 dissolved/mol.kg^{-1}, the solubility of CO_2 will decrease with increasing salt content in water. Similar studies were conducted with various solutions of sucrose, glucose, fructose, and glycerine [9]. Calix et al [10], conducted a study on the solubility of CO_2 at 40ºC in orange juice, apple juice is lower than in mineral water. The solubility of O_2 in sugar solution will decrease as the amount of solids in water increases [11]. In the production of soft beverages, the solubility of CO_2 increases as the internal pressure in the soda bottle increases [12].

One of the determinants of the quality of carbonated beverages and oxygenated water is the decrease in gas content in the product. Packaging materials and packaging lids cause a decrease in dissolved gas levels in beverages. Ayu et Al. [13], reported that decrease of oxygen levels in oxygenated water is caused by the bottle caps not being tight and the pores on the packaging walls not being smooth. The level of CO_2 gas in carbonated beverages in PET bottles is lower than in glass packaging and cans [14]. According to Kemp [15], CO_2 leakage in sparkling wine is 0.12-0.68 mL/day, which is influenced by the permeability properties of the bottle cap.

Packaging plays an important role in maintaining product quality before consumers consume it [16]. In addition to protecting the product from environmental factors (such as temperature, humidity, and oxygen), the packaging also functions to provide product information [17]. Beverage packaging often found in the market is made of polyethylene terephthalate (PET), glass, aluminium cans, and cardboard [18]. The determination of the packaging material to be used must meet several requirements, namely that it can block the transfer of gases (O_2, CO_2, water vapour), have resistance to high temperatures, and have mechanical strength [19].

Therefore, this study aims to determine the choice of bottle packaging materials for carbonated beverages.

2. MATERIALS AND METHODS

The main ingredient of this research is water. Other additives used are CO_2 gas (Sodafresh), HI3818 solution (Hanna Instrument), and phenolphthalein (Hanna Instrument). The equipment used for bottle leakage tests is glass bottles (250mL, 280mL, 750mL), PET bottles (330mL), containers, measuring cylinder, pipettes, ruler, and thermometer. The equipment for the injection of CO_2 into water is a soda maker (Sodafresh), and the analysis is a CO_2 test kit with the titration method.

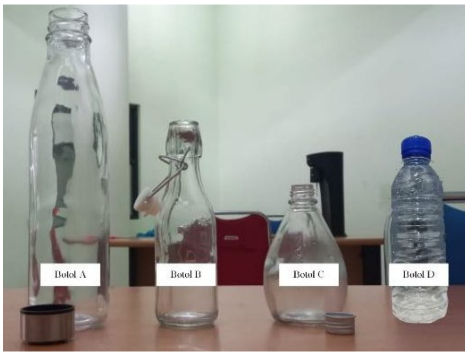

Figure 1. Type of bottle used

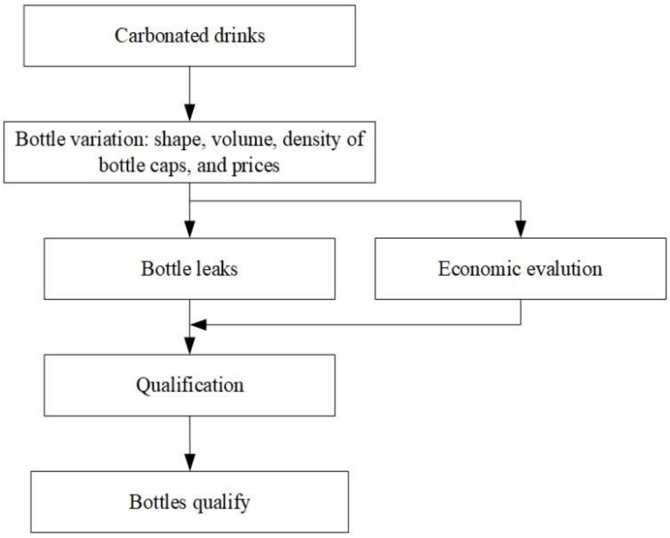

Figure 2. Framework used

The main stage of the research is the selection of bottles that will be used for carbonated drinks that consider the level of leakage and the level of solubility of CO_2 gas in water, with a flow chart for each stage presented in Figure 2. In this research, two variations of the type of bottle material. Namely glass and PET, as well as variations in bottle filling volume 40%v/v, 60%v/v, and 80%v/v. One of the factors that can determine the shelf life of a product is the determination of packaging.

Two stages of research were carried out with the following research steps:

2.1 Bottle selection stage

The bottle selection is based on a water leak test. The bottle that has the slightest leakage is considered to have no leakage. In addition, it also considers the type of material used, volume, shape, and price which are presented in Table 1.

Table 1. Various kinds of bottles used

Material		Volume, ml	Price, IDR	Source
	Bottle A	750	22.500	Agung Jaya Botol
Glass	Bottle B	250	10.000	Agung Jaya Botol
	Bottle C	280	8.500	Agung Jaya Botol
PET	Bottle D	330	1.300	Agung Jaya Botol

2.2 Bottle leak test

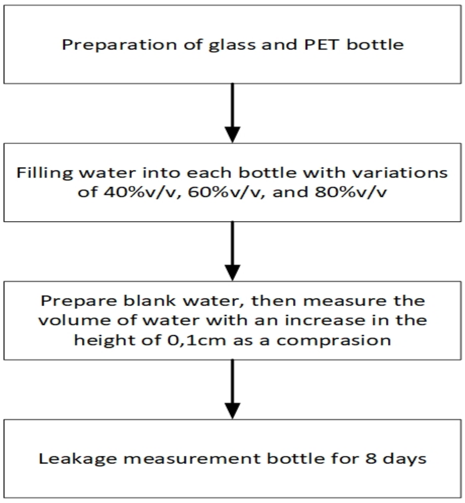

Figure 3. Bottle leak test process flow diagram

Glass bottles with various shapes and volumes. Bottle A (750mL), bottle B (250mL), and bottle C (280mL) three each; meanwhile, three PET bottles (bottle D) have a volume of 330mL (Figure 1) filled with water. Filling water into each bottle uses a volume variation of 40%v/v, 60%v/v, and 80%v/v. Prepare blank water by filling the bottle with a volume of 40%v/v, 60%v/v, and 80%v/v, and place the bottle on the table. Blank water aims to guide the water level during initial filling and determine the volume using a measuring cylinder for every 0.1cm increase.

The bottle that has been filled with water is then put into a container filled with water (Figure 4). The leakage rate of the bottle was measured for 8 days using a ruler and compared with the water level data from the blank water bottle.

Figure 4. Bottle leak test experiment illustration

2.3 Analysis of solubility of CO2 in carbonated water

The selected bottle is filled with water and injected with CO2 gas using a soda maker. Temperature variations in the production of carbonated water are 10ºC, 28ºC, 40ºC, and 50ºC. The freshly produced carbonated water was then measured for CO2 solubility using the titration method by taking 5 ml of carbonated water, adding 2 drops of pp indicator, and then titrated using HI3818 solution. Data on the solubility of CO2 in carbonated water will be used to compare the solubility of CO2 that has been stored for 8 days.

2.4 Analysis of Aesthetics and labelling

In this discussion, a literature study data collection technique is used, where the data collected is based on the results or data that already exists in journal books, magazines and other sources. According to Sugiyono (2005:238) states that the literature method is a collection of records of events that already exist in the form of writing, visuals, or someone's work.

In making the packaging design, there are several factors to consider, namely conceptual, psychological, and functional. Conceptually, a packaging product design must relate to the type of product being sold so that it can be packaged attractively without being separated from the type of product being sold. According to the psychological aspect, there is an emotional that drives consumer buying interest rather than other rational reasons. In the packaging design there are functional advantages of the product, both in terms of weight, material, and the effectiveness of the product in its use.

2.5 Analysis of Economy

Economic factors are an important consideration in determining which bottles to choose for commercial production. In this study, the cost of mass production of carbonated drinks was calculated for the selected bottles. Determination of the price of carbonated drinks per bottle is based on the profits earned and a market survey of the prices of carbonated drinks.

3. RESULTS AND DISCUSSION

3.1 Leakage test

Conducted bottle leakage test with volume variations in bottle A (750mL), bottle B (250mL), bottle C (280mL), and bottle D (330mL) as well as variations in bottle filling volume (40%v/v, 60%v/ v, and 80%v/v) for 8 days at room temperature (around 28ºC). Based on Figure 4, the leakage rate can be calculated from the change of liquid level which is converted into volume according to the diameter of each bottle. Bottles filled with 80%v/v and above does not leak. Bottles A, B, and C. Bottle B will leak 0.19mL/day if the bottles are filled with less than 80%v/v. Bottle C leaks 0.40mL/day if the bottle is filled less than 60%v/v, and bottle D leaks 0.48mL/day. This is because bpttles with a higher air ratio will increase the pressure in the bottle and air in the bottle will try to force it out..

According to Kurniawati [20], glass packaging has the advantage of not reacting (inert), being an excellent barrier to solids, liquids, and gases, and can be reused (*reusable*). As for the weakness, glass material is easy to break and is not good for products that are sensitive to exposure to ultraviolet light. Glevitzky [21], in his research stated that PET bottles used for carbonated beverages had CO_2 gas leaks 30 % through the lid and 60% through the wall.

Research conducted by Da Cruz et al [22], showed that dissolved oxygen levels in yoghourt probiotic beverages packaged in plastic bottles were higher than in glass packaging.

According to Licciardello's research [23], carbonated beverages stored in 2 litre PET bottles lose 0.3 gas volume (GV) of CO_2 for 3-4 days due to gas diffusion into the bottle, then the rate of CO_2 loss will decrease every week.

Glass packaging has an efficient barrier to minimizing environmental influences that could result in food deterioration, quality loss, or even lack of food safety. Glass packaging also provides the preservation of the sensory characteristics of food, such as flavour, texture, aroma, and carbon dioxide (for carbonated beverages) [24]. Based on the data obtained, plastic seals are installed on the bottles to reduce the level of leakage and maintain product hygiene (Figure 5).

Table 2. The result of bottle leakage at filling volume 40%, 60%, and 80%, with variations in bottle A, B, C, and D

Day	Height of The Liquid in The Bottle (cm)											
	A			B			C			D		
	40%	60%	80%	40%	60%	80%	40%	60%	80%	40%	60%	80%
1	8,5	12,4	16,6	5,1	7,2	9,6	3,7	5	6,9	5,8	8,65	11,5
2	8,5	12,4	16,6	5,1	7,2	9,6	3,7	5	6,9	5,85	8,7	11,5
3	8,5	12,4	16,6	5,15	7,2	9,6	3,75	5	6,9	5,85	8,7	11,5
4	8,5	12,4	16,6	5,15	7,2	9,6	3,75	5	6,9	5,85	8,7	11,5
5	8,5	12,4	16,6	5,2	7,2	9,6	3,75	5,05	6,9	5,85	8,7	11,5
6	8,5	12,4	16,6	5,2	7,2	9,6	3,8	5,05	6,9	5,85	8,7	11,5
7	8,55	12,4	16,6	5,25	7,2	9,6	3,8	5,05	6,9	5,85	8,7	11,5
8	8,55	12,4	16,6	5,25	7,2	9,6	3,85	5,05	6,9	5,85	8,7	11,5

3.2 Solubility of carbon dioxide

The solubility of carbon dioxide gas (CO_2) in the solution is affected by pressure and temperature [25]. This research used CO_2 gas with a purity of 99%, which was injected into the water with temperature variations of 10ºC, 28ºC, 40ºC, and 50ºC. Gas CO_2 injected into water at a temperature of 10ºC has the highest solubility level compared to the others, which is 2,132.24 ppm (Figure 6). This is accordance with research by Weibe [25] regarding the solubility of CO_2 in water at a pressure of 150 atmospheres with temperature variations from 12 - 40ºC, which has the highest yield of CO_2 dissolved in water with a temperature of 12ºC compared to CO_2 38.39 mg/g water. The increase in water temperature will cause the release of CO_2 gas from the water, and CO_2 gas will be more easily soluble in low-temperature water [26].

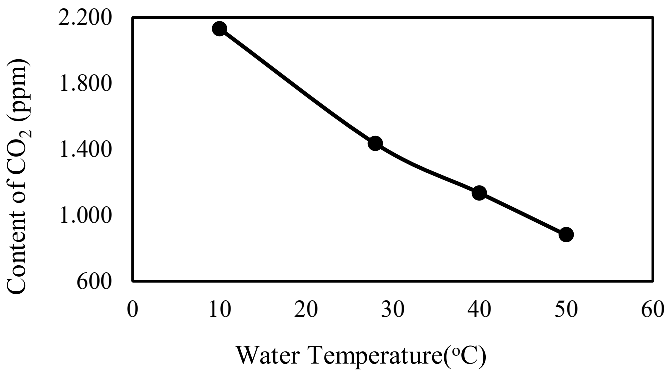

Figure 5. Effect of Temperature on CO_2 losses

3.3 Aesthetics and labelling

Packaging is an important component of modern lifestyles. Different types of beverage packaging play a vital role in production, preservation, distribution, and marketing [27]. Bottle packaging design can affect consumer attractiveness [28]. According to Herdiana (2014), the bottle shape that consumers prefer is a bottle with a small and high diameter mouth to reduce the possibility of liquid spilling, and the bottle cap is coated with rubber so that the density is maximized so that there is no leakage. *Labelling* is an attempt to provide brief information about the product. In addition to increasing consumer interest in buying a product, it also avoids making mistakes in purchasing [29]. Bottle B has a cylindrical shape equipped with a cap-type cap. So this bottle has an attractive appearance and is easy to label.

3.4 Economic evaluation

According to Yani [30], the raw material costs incurred in producing glass bottles are cheaper than PET bottles, namely 2,267 IDR /kg for glass bottles and 12,150 IDR –14,400 IDR /kg for PET resin. However, in one production glass bottles are more expensive, this is because glass bottles require 300g/unit of raw materials and 28g/unit for PET bottles, so the incurred cost for glass bottles are Rp680/unit, and PET bottles are 340-403 IDR /unit. The energy cost required for glass bottles is greater than for PET bottles, this is due to the different properties of the raw material, namely the melting point of silica sand is higher than plastic [31]. Processing reuseable packaging, the costs required to handle PET bottle waste are much higher than glass bottles. This is because processing PET bottle waste requires many steps [30]. So glass bottle packaging is considered economical because it can be used repeatedly, which is good for the environment [32].

This research uses 3 types of glass bottles that vary in shape, volume, and price. Bottle A (750mL) has a cylindrical shape equipped with a screw cap for 22,500 IDR /bottle. Bottle B (250mL) has a cylindrical shape with a vacuum cap equipped with a wire for 10,000 IDR /bottle. Bottle C (280mL) is shaped like a lamp equipped with a screw cap for 8,500 IDR /bottle. The bottle's shape significantly affects consumers' purchase intentions for beverage products [33]. Based on the shape of the bottle and the price, bottle B can be chosen as the carbonated soft drink packaging. Estimate incurred cost per day to produce carbonated beverages that operate in batch include fixed costs, packaging, raw materials, and other supporting costs (Table 2). Based on the calculations in Table 2, the selling price of carbonated beverages is 11,500 IDR /unit.

Table 3. Production Cost per Day

Description	Quantity	Unit price, IDR	Total price, IDR
1. Purchase of equipment	1	20,000,000	20,000,000
2. Land rental	1,500 m^2	1,000,000	1,500,000,000
Fixed capital investment			**1,520,000,000**
Raw material: 3. CO_2 gas	1.78 kg	18,000	32,000
4. Water	-	-	-
Packaging: 5. Glass bottle 250mL	481 pcs	10,000	4,814,815
6. Plastic seal	481 pcs	60	9,630
7. Label	481 pcs	20	28,889
Variable cost			**1,524,885,333**
8. Electric	110.88 kWh	1,245	690,062
9. Research and development (3%FCI)			45,600,000
Total cost			**3,091,207,395**
Selling price	481 pcs	11,500	5,537,037

To determine whether carbonated beverages' selling price is worth competing with other brands, we compare the selling prices of carbonated beverages that are often found in the market with variations in packaging materials and volume (Table 3).

Table 4. Comparison of the price of carbonated beverages in the market

Merk	Packaging	Volume, mL	Price, IDR
Aqua reflection sparkling	Glass bottle	380	20,500
Zoda	Glass bottle	250	4,500
Polaris soda water	Cans	330	5,900
Schweppes	Cans	330	6,300

4. CONCLUSION

Soft drink packaging is better to use glass materials, because it has a small leakage rate in both liquid leak test and CO_2 leak test. Bottle B, which has a volume of 250mL, can be used as beverages packaging because it has attractive visuals, is easy to label, has a relatively low leakage rate of 0.19mL/day, and is not too large so that the product can be used up in one drink to prevent the occurrence of product quality decline. Beside that, bottle B also has a fairly affordable price. It is hoped to develop this research further to determine the shelf life of carbonated beverages.

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