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Development of apples as functional food and raw material for the food and beverage industry

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ABSTRACT

Apples are a source of antioxidants, vitamins, and essential minerals for humans. They have high phenolic content and potential as an anti-diabetic agent. Indonesia ranks fifth globally in the number of diabetes mellitus (DM) sufferers, with 19.5 million cases. This number is projected to increase to 28.6 million by 2045 if no intervention occurs. The objectives of this study are: (1) to utilize apple products in an "apple dip" beverage; (2) to test the bioactive compound activity of the apple dip product; and (3) to assess the feasibility of the business. The urgency of this research lies in: (1) increasing the added value of apple products and farmers' income; and (2) reducing the prevalence of diabetes in Indonesia. Antioxidant activity was tested using the DPPH method, expressed as the IC50 concentration. Additionally, total flavonoid and phenolic contents were analyzed. Economic aspects were evaluated using Net Present Value (NPV), Benefit-Cost (B/C) ratio, Internal Rate of Return (IRR), and Payback Period. The research results indicated that apples have an IC50 value of 30.25 ppm, classified as strong antioxidant activity. The total flavonoid content was 37.20 mg QE/g, and phenolic content reached 258.94 mg GAE/g. The feasibility analysis showed a Net Present Value of Rp647,177,295.08, indicating the present value exceeds the initial investment. The Benefit-Cost Ratio was 8.3, the Internal Rate of Return was 179%, and the Payback Period was 2 years.

Contribution/Originality: This study contributes to existing literature by formulating an innovative "apple dip" beverage with proven bioactive and economic potential. It is among the few studies exploring apples as anti-diabetic agents, using new estimation methods and an original formula to assess antioxidant activity and business feasibility within an integrated analytical framework.

1. INTRODUCTION

Apples are a source of antioxidants (Adyanthaya, Kwon, Apostolidis, & Shetty, 2010; Eissa, Fadel, Ibrahim, Hassan, & Abd Elrashid, 2006), vitamins, and minerals essential for humans, including vitamins A, B1, C, and several minerals such as calcium, phosphorus, and iron. Apples also have a high phenolic content (Sun, Chu, Wu, & Liu, 2002) and have potential as an anti-diabetic agent (Adyanthaya, Kwon, Apostolidis, & Shetty, 2009). Apples contain pectin, with 100 grams of apple containing 0.70 grams of pectin. Administering apples at a dose of 3 x 100 grams can lower blood glucose levels in patients with diabetes mellitus (DM) (Muhith & Setyowati, 2014).

Indonesia is the fifth country in the world with the highest number of diabetes mellitus (DM) sufferers, with 19.5 million people affected. This number is estimated to increase to 28.6 million by 2045 if not addressed promptly, given

its high prevalence. In 2023, according to the Ministry of Health's records, the prevalence rate was 11.7 percent and continues to rise. Foods that can lower blood glucose levels include fruits and vegetables high in fiber. Apples are one of the fruits with a high fiber content.

DM is a chronic metabolic disorder caused by insufficient insulin production by the pancreas. Insulin is a hormone that regulates blood sugar levels. There are two main categories of DM: type I and type II. Type I DM is characterized by insufficient insulin production, while type II DM is caused by the body's ineffective use of insulin (Ministry of Health of the Republic of Indonesia, 2015).

The high prevalence of DM can be attributed to various factors, including genetic or hereditary factors, obesity, advanced age, gender, lifestyle changes, poor dietary habits, insulin resistance, medications that affect blood glucose levels, lack of physical activity, pregnancy, smoking, alcohol consumption, and stress (Muflihatin, 2015). One of the risk factors for Type II diabetes is age; the risk of diabetes increases with age due to a decline in the function of two bodily organs, leading to a reduction in pancreatic beta cells and decreased sensitivity of tissue cells. The age group at risk for Type II diabetes is 46–64 years old, as glucose intolerance occurs due to the aging process (Irawan, 2010). DM can cause complications in various body systems. Complications of DM include liver damage, vascular damage, eye damage, kidney damage, and nerve damage (neuropathy), as well as an increased risk of heart disease, hypertension, and stroke (World Health Organization (WHO), 2014).

Foods that can lower blood glucose levels are those derived from fruits and vegetables that are high in fiber. The flavonoid content in apples, such as procyanidins, catechins, epicatechins, and quercetin, can inhibit LDL cholesterol oxidation and have high antioxidant activity (Damayanti, 2016). Procyanidins play a role in reducing blood lipids by inhibiting protein secretion and ester synthesis. Catechins and epicatechins form soluble cholesterol deposits and increase fecal cholesterol excretion, thereby damaging the bile micelle system in the intestinal lumen. The increased expression and activity of LDL receptors are caused by fecal cholesterol excretion, which reduces cholesterol absorption and liver cholesterol concentration. Quercetin inhibits the production of lipoproteins and reduces lipid peroxidation (Herlina & Sitanggang, 2010).

A medium-sized apple weighing approximately 150 grams contains about 10 milligrams of quercetin, which is a significant dose. Apples are more than just sources of fiber and sugar. Apples containing quercetin can form antioxidants equivalent to 1,500 mg of vitamin C. Eating an apple daily can reduce cholesterol levels by 8–11%, and cholesterol reduction can reach 16% when consuming two apples a day (Boyer & Liu, 2004). The aim of the study was to test the activity of bioactive compounds in apple-based products. The urgency of the research is to curb the prevalence of diabetes mellitus (DM) in Indonesia.

2. RESEARCH METHOD

The research titled "Development of Apples as Functional Foods and Raw Materials for the Food and Beverage Industry" is a specific and holistic study. Specific refers to the fact that the subjects of the research are farmers and apple products. Holistic refers to the fact that the study not only covers phytochemical aspects but also economic aspects. Researchers and research subjects interact within a specific time and context. The research employs three approaches simultaneously: qualitative, quantitative, and experimental.

For the antioxidant activity, vitamin C, and color tests, they were conducted at the Industrial Engineering Laboratory of Malang State University. The technology for processing apples into "Apel Celup" involved drying technology (cabinet dryer) and crystallization at Dhilanmesindo SME in Bumiaji District, Batu City. The product was analyzed for its bioactive compounds, including antioxidant activity using the DPPH method, vitamin C content via spectrophotometry, and moisture content through thermogravimetry. To determine antioxidant activity, the following formula was used.

$$\% \text{ Inhibisi} = \left(1 - \frac{As}{Ak}\right) \text{ x } 100$$

Description: Ak = Control absorption.

As = Sample absorption.

The chemicals used for testing antioxidant activity include ascorbic acid (AA) and gallic acid (AG) from Merck, quercetin from Sigma, 2,2-diphenyl-1-picrylhydrazil (DPPH) from Sigma, phosphate buffer pH 6.6 (0.2 M), 1% potassium hexacyanoferrate solution, 10% trichloroacetic acid solution, 0.1% iron (III) chloride solution, 1 mM iron (II) chloride tetrahydrate solution, and 2.5 mM ferrozin. Additionally, distilled water, aquabides, and methanol from Merck were used. The materials used in vitamin C testing were water, 50 mg vitamin C tablets, betadine, and spiritus. From an economic perspective, the data were analyzed using Net Present Value, B/C ratio, Internal Rate of Return, and Payback Period.

1. Net present value (NPV)

$$NPV = \sum_{t=0/1}^{n} \frac{B_t - C_t}{(1+i)t} \quad (1)$$

Description:

Bt = Benefits in year t.

Ct = Costs in year t.

t = Year of business activity (t = 0, 1, 2, 3,,, n).

I = Discount rate (%).

If NPV > 0, then the project/business is feasible, and vice versa.

2. Net benefit cost ratio (Net B/C)

$$\text{Net B/C} = \frac{\sum_{t=0/1}^{n} \frac{B_t}{(1+i)^t}}{\sum_{t=0/1}^{n} \frac{C_t}{(1+i)^t}} \quad (2)$$

Description:

Bt = Gross profit (gross income) in year t.

Ct = Gross costs (total business costs) in year t.

I = Applicable interest rate.

If Net B/C > 1, then the project/business is feasible, and vice versa.

3. Internal rate of return (IRR)

$$IRR = i_1 + \frac{NPV_1}{NPV_{1-NPV_2}} x\, i_2 - i_1 \quad (3)$$

Description:

i1 = Interest rates that have a positive NPV.

i2 = Interest rates with negative NPV.

NPV1 = NPV is positive.

NPV2 = NPV is negative.

If IRR > discount rate, then the project/business is feasible, and vice versa.

4. Payback period (PP)

$$PP = \frac{I}{Ab} \quad (4)$$

Description.

I = Required investment cost (Rp).

Ab = Net benefits obtained per year.

If PP <Business age, then the business is viable, and vice versa.

3. RESULTS AND DISCUSSION

Phytochemical screening of apple dip (Malus domestica) is a stage of identifying secondary metabolite content that aims to provide an overview of the compounds found in apple dip samples. The results of the phytochemical screening of apple tea are presented in Table 1.

Table 1. Results of phytochemical screening.

Parameters	Contents
Alkaloid	+
Flavonoid	+
Tanin	+
Steroid	+
Terpenoid	-
Saponin	-

Based on the results of the phytochemical screening, it was found that apple tea samples contain various bioactive compounds such as alkaloids, flavonoids, and tannins, while terpenoids and saponins were not detected in the samples. This is consistent with previous research indicating that tea contains these compounds, which act as antioxidants and provide health benefits (Fauziyah, Darmawati, & Purwanto, 2022). Various studies have shown that tea consumption has the potential to provide protective effects against a number of degenerative diseases, including cardiovascular disease, obesity, type 2 diabetes mellitus, liver disorders, and cancer (Xu et al., 2020).

Apple consumption has become global, with approximately 71% of total consumption being in fresh form, while the remaining 20% is processed into various products to enhance economic value and utilization (Dhyani, Bahukhandi, Rawat, Bhatt, & Rawal, 2018). Apples are known as one of the primary sources of antioxidants, particularly due to their high flavonoid content, which has been associated with various health benefits, including anti-inflammatory, cardioprotective, hepatoprotective, antidiabetic, and anticarcinogenic activities (George & Rupasinghe, 2017; Loung, Fernando, Rupasinghe, & Hoskin, 2019). Meanwhile, alkaloids and tannins can lower blood glucose by inhibiting glucose absorption in the intestines, thereby reducing the amount of glucose entering the bloodstream, stimulating glycogen synthesis, and inhibiting the α-glucosidase enzyme (Kumari & Jain, 2012; Widiastuti, Ardiansyah, Nurcahyani, & Silvinia, 2021). In this study, apple dip was chosen as the consumption medium because it is similar to tea, which is the second most consumed beverage in the world after water, and has been known for over 2000 years (Hodgson & Croft, 2010). The combination of apple's bioactive compounds and tea's characteristics as a popular consumption medium is expected to enhance the functional potential of the resulting product.

To determine the presence of its metabolite compounds, antioxidant activity testing was conducted based on the ability to neutralize DPPH free radicals and expressed in terms of IC50 concentration (Gonzales, Villena, & Kitazono, 2021). In addition, the total flavonoid and phenolic content were analyzed, as both are major antioxidant components (Starowicz, Achrem–Achremowicz, Piskuła, & Zieliński, 2020). The results of the IC50, total flavonoid, and total phenolic tests for apple tea are presented in Table 2.

Table 2. Results of antioxidant activity, total flavonoid, and total phenolic tests.

Parameters	Contents	Units
IC_{50}	30.25	ppm
Flavonoid Total	37.20	mg QE/g
Phenolic Total	258.94	mg GAE/g

Based on the results of the antioxidant test analysis, apple tea showed an IC_{50} value of 30.25 ppm, which falls into the category of very strong antioxidant activity. This value was obtained from the calculation of the DPPH free radical scavenging activity graph measured against the sample concentration (Zielińska, Baraniak, & Karaś, 2017). A

lower IC50 value indicates higher antioxidant activity in the sample (Geremu, Tola, & Sualeh, 2016; Kumar, Sandhir, & Ojha, 2014). Thus, this value represents the percentage inhibition obtained against the concentration of the solution used in testing. This indicates that apple dip has a very strong capacity to scavenge DPPH free radicals when compared to other compounds or extracts with lower antioxidant activity.

The IC_{50} test results in this study are consistent with previous studies on the antioxidant activity of apple extracts. The green apple extract study showed an IC_{50} value of 31.26 ppm, while the apple extract nanoparticle showed an IC_{50} value of 12.16 ppm. These results reinforce the notion that apple extracts, whether in the form of fresh fruit, conventional products, or nanoparticle formulations, possess very strong antioxidant potential (Rusita & Purwasih, 2019; Utami et al., 2023).

Antioxidants are bioactive compounds that have the ability to inhibit or neutralize the negative effects of free radicals and oxidative stress in the body. Free radicals, on the other hand, are unstable reactive molecules due to their unpaired electrons. Their presence in excessive amounts can cause damage to cells, DNA, and proteins, which may ultimately lead to various degenerative diseases and accelerate the process of premature aging (Chaudhary et al., 2023; Martemucci et al., 2022). The mechanism of action of antioxidants involves donating electrons to stabilize free radicals, thereby preventing cellular structural damage, reducing oxidative stress, and contributing to the prevention of various diseases (Balta et al., 2022; Blokhina, Virolainen, & Fagerstedt, 2003; Sharifi-Rad et al., 2020).

The main group of antioxidants consists of phenolic compounds, which are organic chemical compounds that contain at least one phenol group. Examples of these compounds include tannins (hydrolyzable and condensed), flavonoids, and lignans. The phenolic compound content in this study reached 258.94 mg GAE/g, indicating a fairly high concentration. The high phenolic content is closely associated with increased antioxidant activity, which has the potential to reduce the risk of coronary heart disease and protect against neurodegenerative disorders (Giacalone et al., 2015). Additionally, the phenolic content in apples plays a role in preventing obesity through the stimulation of brown adipogenesis (Zou, Wang, Li, Liu, & You, 2020). The phenolic content in this study was significantly higher than in previous studies on ethanol extract encapsulates of apple peel, which had a value of 59.46 mg GAE/g, indicating that apple-dipped products have greater potential as a natural antioxidant source (Chandra, Yusasrini, & Puspawati, 2024).

The antioxidant activity of flavonoids is determined by their chemical structure. The more phenolic hydroxyl groups present in their structure, the higher the antioxidant activity they contain. Flavonoids themselves are a group of phenolic compounds known to have various health benefits. One of the most dominant types of flavonoids, quercetin (65.5%), has been shown to significantly inhibit the formation of advanced glycation end products (AGEs) mediated by methylglyoxal (MGO), thereby playing a role in preventing cancer, hyperglycemia, heart disease, and aging (Sampath, Rashid, Sang, & Ahmedna, 2017; Sampath, Zhu, Sang, & Ahmedna, 2016). The results of the total flavonoid content analysis in this study showed a concentration of 37.20 mg QE/g, which is significantly higher than previous studies on encapsulated ethanol extracts of apple peel with a flavonoid content of 4.91 mg QE/g.

Flavonoids act as exogenous antioxidants that can react directly with free radicals, converting them into more stable and less reactive compounds (Ullah et al., 2020). The antioxidant potential of flavonoids is higher than that of vitamins C and E. However, due to their low bioavailability and instability during digestion in the gastrointestinal tract, flavonoids are not absorbed in their original form but rather in the form of metabolites (Procházková, Boušová, & Wilhelmová, 2011; Teng et al., 2023).

Various epidemiological studies have shown that apple consumption is negatively correlated with the incidence of chronic diseases such as cardiovascular disease, lung disorders, and cancer (Kalinowska, Bielawska, Lewandowska-Siwkiewicz, Priebe, & Lewandowski, 2014). A meta-analysis indicates that flavonoid intake, particularly from tea at 100 mg/day, can reduce the risk of death from cardiovascular disease (CVD) by 4%, as well as lower systolic blood pressure and heart rate by 0.6 mmHg and 0.5 mmHg, respectively (Alkerwi, Sauvageot, Crichton, & Elias, 2015; Grosso et al., 2017). Another study reported that apple flavonoids can modulate intestinal inflammation and inhibit

α-glucosidase activity, thereby potentially reducing the risk of type 2 diabetes development (De Oliveira et al., 2019). Thus, the combination of antioxidant content in apples has significant potential in preventing various degenerative diseases, and the selection of a consumption medium in the form of tea is expected to enhance the economic value and functional potential of the resulting product.

This product is available in four flavors, namely original, mint, cinnamon, and lemon, which provide consumers with a choice of flavors while expanding the market segment that can be reached. The product is packaged in the form of apple dips @ 2.5 grams/bag and packaged in 20 bags/box with a selling price of Rp. 25,000.00/box.

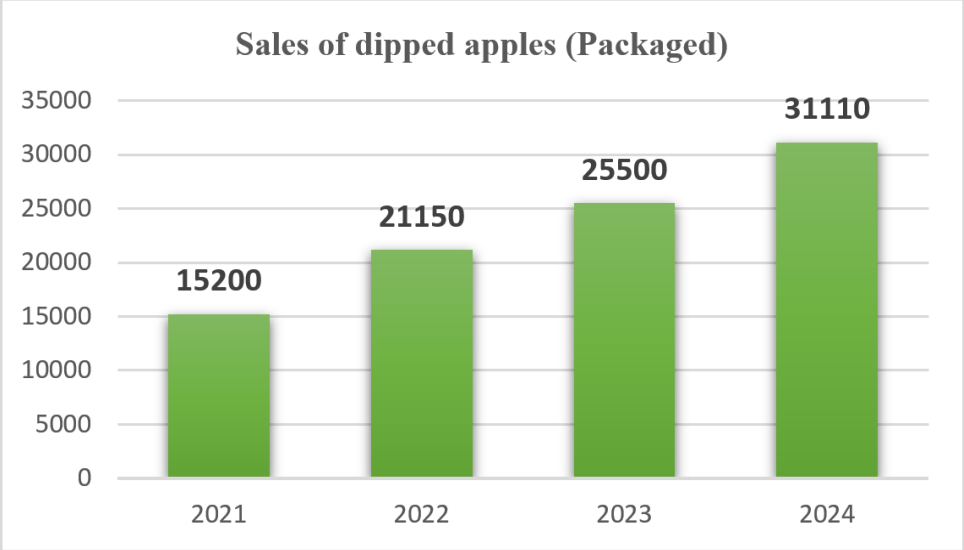

Figure 1. Sales of Apple Dip products during the period 2021–2024.

Figure 1 illustrates the sales of apple dip products during the period 2021–2024. Net Present Value is an investment assessment that calculates the difference between the present value of an investment and its current value. NPV calculations are based on present value calculations with expected returns based on a specific discount rate. If the NPV is positive, the investment is acceptable (Villanueva, Martins, Catapan, & Vicentin, 2022). Using a discount rate of 5%, the NPV value obtained is Rp647,177,295.08, indicating that the "Apel Celup" business is financially viable and has the potential for profitable returns.

The break-even point is the point at which total revenue equals total costs. There are two types of BEP calculations: BEP based on production volume and BEP based on price value calculations (Soesilowati, Mutiara, Fauzan, Prihatini, & Zulfia, 2024). In the context of the "Apel Celup" business, the BEP occurs when production reaches 13,113 packages with a BEP price value of Rp 295,039,479. This indicates that the break-even point can be achieved at a production scale that is sufficiently realistic, given that annual sales exceed the BEP production volume.

Meanwhile, the Net Benefit Cost Ratio for "Apel Celup" is 8.3, which means that every Rp1 invested will generate Rp8.3 in net benefits. Furthermore, the Internal Rate of Return is 176.9%, which significantly exceeds the discount rate and indicates a fairly high return on investment. Finally, the payback period measures how long it takes to recover the initial investment from the cash flow generated by a business (Soesilowati, Prajanti, Lestari, Muklis, & Zulfia, 2024). The "Apple Dip" business has a payback period of 2.07 years, or approximately two years from the initial investment.

These results indicate a relatively short period of time for return on initial capital, and then, after two years, the business can begin to generate net profits. Thus, from a financial perspective, the "Apel Celup" product has high profit projections, a relatively fast return period, and cost efficiency, making this business have great potential for growth and sustainability. This business has the potential to become an innovative local economic model with positive impacts on resource management and job creation, particularly in the Batu City area.

4. CONCLUSION

The research results show that apples have an IC_{50} value of 30.25 ppm, indicating very strong antioxidant activity, with a total flavonoid content of 37.20 mg QE/g and a phenolic content of 258.94 mg GAE/g. The feasibility analysis of the "Apple Dip" business yielded a Net Present Value of Rp647,177,295.08, indicating that the present value is greater than the initial investment, with a Benefit-Cost Ratio of 8.3, an Internal Rate of Return of 179%, and a Payback Period of 2 years. This means that the "Apple Dip" business is viable to continue, both from a nutritional and financial perspective.

The recommended suggestion is to increase the production capacity of "Apel Celup" through product diversification and to strengthen the management of the raw material supply chain via a smart business model ecosystem.

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