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Effect ginger (*Zingiber* officinale Rosc.) extract addition on antioxidant activity, phenol total content, overrun, sensory, and shelf life of ice *puter*

[Efek penambahan ekstrak jahe (Zingiber officinale Rosc.) terhadap kandungan total fenol, aktivitas antioksidan, overrun, sensori dan masa simpan es puter]

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ABSTRACT

Ginger is known to contain various bioactive compounds, including phenolics (gingerol, shogaol, paradol). Several studies have shown that ginger extract is often added to ice cream to obtain healthier food products. Therefore, this study aims to analyze the result of adding ginger (Zingiber officinale Rosc.) extract with different concentrations on antioxidant activity, total phenol content, overrun, hedonic test, and shelf life of ice cream. A Completely Randomized Design (CRD) was used with four treatments and replicated 5 times, leading to a total of 20 experiment units. The experiment was conducted by adding ginger extract with different concentrations (0%, 0.5%, 1%, and 1.5%). Shelf-life prediction was carried out with three replicates, leading to 9 experiment units for different storage temperatures (-5 °C, -18 °C, -22 °C). The sample selected from the hedonic test, P1 (0.5%), was evaluated for 28 days with changes in parameters of free fatty acid and emulsion stability. This result shows that incorporating ginger extract at various concentrations significantly affects overrun. However, treatment P1 (0%) and P2 (0.5%) had no significant effect on color and aroma. The addition of ginger extract increased antioxidant activity and total phenol content. In addition, the ice puter added with 0.5% ginger extract was the ice putter most preferred by panelists and had a shelf life of 210 days at -22°C, based on changes in free fatty acid during storage.

Keywords: antioxidant, ice puter, ginger, phenol, shelf life

ABSTRAK

Jahe mengandung senyawa fenolik (gingerol, shogaol, paradol) yang merupakan senyawa bioaktif. Es puter dengan penambahan ekstrak jahe merupakan salah satu inovasi baru yang dapat menjadi alternatif produk pangan lebih sehat. Tujuan dari riset ini adalah dapat mengetahui efek dari penambahan ekstrak jahe (*Zingiber officinale* Rosc.) dengan konsentrasi berbeda terhadap aktivitas antioksidan, kadar fenol total, *overrun*, uji hedonik, dan penentuan umur simpan es puter. Penelitian dirancang menggunakan Rancangan Acak Lengkap (RAL) yang terdiri dari 20 unit percobaan hasil kombinasi empat perlakuan dengan lima ulangan. Perlakuan yang diberikan adalah penambahan ekstrak jahe dengan konsentrasi yang berbeda (0%, 0,5%, 1%, dan 1,5%). Pendugaan umur simpan menggunakan 3 ulangan sehingga menghasilkan 9 unit percobaan untuk suhu penyimpanan yang berbeda (-5 °C, -18 °C, -22 °C). Pengujian produk yang terpilih dari uji hedonik, yaitu P1 (ekstrak jahe 0,5%) dilakukan selama 28 hari dengan parameter asam lemak bebas dan stabilitas emulsi. Penambahan ekstrak jahe pada penelitian ini meningkatkan aktivitas antioksidan, kadar total fenol, dan menurunkan *overrun* pada es puter. Uji hedonik menunjukkan respon positif dari panelis terhadap karakteristik rasa dan aroma yang dihasilkan oleh penambahan ekstrak jahe. Es puter dengan ekstrak jahe 0,5% merupakan produk yang paling disukai panelis dengan masa simpan paling baik pada suhu -22°C yaitu 210 hari, berdasarkan perubahan parameter asam lemak bebas dan stabilitas emulsi.

Kata kunci: antioksidan, es puter, fenol, jahe, masa simpan

Introduction

Ice *puter* is a popular dessert known for its refreshing coconut flavor, soft texture, and distinctive aroma. Made primarily with coconut milk, it has larger ice crystals and a lighter taste than conventional ice cream (Kho et al., 2022), contributing to its growing popularity. Recent innovations have explored the incorporation of ginger (*Zingiber officinale* Rosc.), rich in phenolic compounds such as gingerol, paradol, and shogaol (Karseno et al., 2021) offers antioxidant and antimicrobial properties, and natural preservatives (Amin et al., 2022). Maceration is an efficient cold extraction technique for isolating ginger's active compounds, as it minimizes thermal degradation and yields a purer extract than traditional ginger juice (Srikandi et al., 2020). Ginger extract exhibited antioxidant, anti-inflammatory, and antimicrobial activity at various concentrations (0%, 0.5%, 1%, and 1.5%) (Rizal et al., 2020; Parumpa et al., 2024). The difference in the concentration between the various treatments also refers to the pre-study conducted. The addition of ginger extract may affect the quality of ice *puter,* which requires being enclosed. Ice *puter* with the addition of the spice is a new product, but is susceptible to chemical damage, such as oxidation, due to the high fat content. Oxidation activity is crucial because it causes changes in product quality and the formation of hazardous compounds. The shelf life of ice *puter* with the addition of ginger extract has not been determined. Good food products must have an expiration date on the packaging label (Tarmizi & Ulyah, 2017). This suggests the necessity of shelf life estimation using accelerated shelf-life testing (ASLT), particularly those based on the Arrhenius model, as they employ the acceleration principle at various storage temperatures.

Shelf-life estimation was performed to evaluate the effectiveness of ginger's bioactive compounds in preserving *ice puter.* This study aimed to investigate the effects of incorporating ginger extract in various concentrations on antioxidant activity, total phenolic content, overrun, sensory attributes, and the shelf life of *ice puter.* The results are expected to demonstrate the potential of ginger as a natural additive to improve product quality and support its development as a functional food, due to its rich antioxidant content (Marganingsih et al., 2018). The sensory assessment through a hedonic test, such as color, flavor, overall, textures, and aroma impression of the product, was involved in the experiment (Simanjuntak et al., 2022). The hedonic test results can provide insight into consumer acceptability of ice *puter* with ginger extract incorporation. The results are also expected to provide new insights into the development of more effective food product shelf-life evaluation methods, enabling the production of innovative products with optimal quality and safety.

Materials and methods

Materials and tools

The elephant ginger (*Zingiber officinale* Rosc.) from Semarang City was used as the primary material. Other materials include the coconut milk (Kara), young coconut water (Semarang City), granulated sugar (Rose Brand), CMC (Koepoe-Koepoe), mineral water, pro analysis ethanol (Supelco), 96% ethanol, pro analysis methanol (Supelco), 2,2-diphenyl-1-picrylhydrazyl (DPPH) reagent (Aldrich), distilled water, 0.05 N NaOH, PP indicator (Merck), and immersion oil (Indo Reagent).

The tools used included 3 decimal analytical scales (Sigma, America), measuring cylinders (Pyrex, Germany), measuring flasks (Pyrex, Germany), beaker glasses (Pyrex, Germany), Erlenmeyer flasks (Pyrex, Germany), test tubes (Iwaki, Indonesia), 25 ml burette, micropipette, and capped weighing bottles. There were also Teflon, gas stove, spatula, basin, bottles, tray, thermometer, chopper (Philips, Netherlands), blender (Philips, Netherlands), 40-mesh sieve, Whatman no. 42 filter paper, mixer (Miyako, Indonesia), rotary evaporator (Biobase, China), and vortex mixer (Thermolyne, USA). Lastly, UV-Vis spectrophotometry (Amtast, USA), homogenizer (Ika, Germany), ice cream maker (Hakasima, Japan), refrigerator (Sharp, Japan), freezer (Gea, Indonesia), centrifuge (Hettich, Germany), microscope (Olympus, Japan), glass slides, and questionnaire sheets were also included.

Research methods

This research began with a preliminary study, employing a Completely Randomized Design (CRD). This design involved four treatments and five replications, comprising 20 experimental units to evaluate parameters such as antioxidant activity, total phenol content, overrun, and hedonic evaluation. The treatment consisted of adding ginger extract with concentrations of 0% (P0, control), 0.5% (P1), 1% (P2), and 1.5% (P3). The subsequent step was estimating shelf life of the most preferred product by referring to the dominant quality parameters, namely free fatty acid and emulsion stability through the Arrhenius model approach by considering differences in keeping temperatures (-5 °C, -18 °C, and -22 °C) in 28 day with tests on days 0, 7, 14, 21, and 28. The shelf life prediction used 3 replications, resulting in 9 experimental units for the 3 different storage temperatures. The experiment was carried out at the Integrated Laboratory, comprising the Food Nutrition and Chemical Science Laboratory, Food Processing Engineering, and Agricultural Products Laboratory, of Diponegoro University.

Preparation of ginger extract

The preparation of ginger extract began with cleaning ginger, then it was sliced 2 - 3 cm thick and arranged in a tray. This was subsequently dried for 3 days, ground coarsely, and dried again for 2 days until dry. The dried ginger was mashed in a blender and subsequently sieved with a 40-mesh filter. The preparation for ginger extract referred to the modified study (Luhurningtyas et al., 2021) with the extraction method. A 200 g sample of powdered ginger was marinated with 96% ethanol at a 1:5 ratio, consisting of 1000mL of 96% ethanol and 750mL of solvent. Afterward, the mixture was then closed and left to stand at room temperature for 24 hours with intermittent stirring. After 24 hours, the mixture was screened, and the remaining residual was re-macerated by 250ml 96% ethanol for an additional 48 hours. The resulting filtrate was then filtered using Whatman No. 42 filter paper and subsequently concentrated using a rotary vacuum evaporator at 50-60 °C until it was thickened and weighed.

Preparation of ice puter with the addition of ginger extract

The preparation of ice *puter* with the addition of ginger extract followed a modified method based on the study by (Perdani et al., 2017). The preparation began with mixing melted coconut milk with mineral water at a 1:1 ratio (150 g) and granulated sugar (50 g), followed by heating the mixture until it reached a boil. Coconut water (150 g) was then added and stirred until the mixture was homogeneous. Once the dough reached room temperature, 2.1 g of CMC (0.6%) and the specified amounts of ginger extract were added: 0% (0 g), 0.5% (1.7605 g), 1% (3.521 g), and 1.5% (5.2815 g). The ingredients were then mixed at low speed for 5 minutes. The mixture was allowed to sit at 4 °C in a refrigerator for a minimum of 4 hours. The aged dough was homogenized using a homogenizer for 5 minutes at a speed of 12.000 rpm and put into an ice *puter* maker for 20 minutes, which was packed and frozen at -18 °C in the freezer.

Research parameters

The antioxidant activity test referred to by Szmejda et al. (2018) employed the DPPH method using UV-Vis spectrophotometry. The principle was to measure the percentage of Radical Scavenging Activity (RSA), or the ability of a substance to neutralize free radicals from other substances, by testing using the DPPH method. Total phenol analysis referred to Septiani et al. (2018), used the Folin-Ciocalteu method with UV-Vis spectrophotometry. This method is based on the formation of a blue-colored complex resulting from the reaction between the Folin-Ciocalteu reagent and phenolic compounds under alkaline conditions. Meanwhile, the overrun analysis, as outlined by Hossain et al. (2021), was conducted by comparing the weight of ice puter following the aging process with its weight after the churning and freezing stages using an ice puter machine. Hedonic assessment of ice *puter* with ginger extract was referred to by Nurlaela et al. (2020) with variables of taste, color, texture, and overall preference, to obtain the most preferred product treatment. Free fatty acid analysis was performed as a parameter to estimate the shelf life of ice *puter* with the addition of 0.5% ginger extract, as referred to by Paputungan (2021). The emulsion stability test was carried out using two methods: centrifugation, as described by Kolawole et al. (2022), and microscopic examination. The best result, based on the dominant quality of the three temperatures (5 °C, -18 °C, and -22 °C) at 0, 7, 14, 21, and 28 days, was used for the shelf life study with the Arrhenius model (Darniadi et al., 2021).

Data processing and analysis

This study utilized ANOVA (Analysis of Variance) as a parametric test. Significant effects were analyzed with DMRT (Duncan's Multiple Range Test) at α=5% for the overrun test. Antioxidant activity and total phenol content data were analyzed descriptively. The hedonic test was analyzed using the Kruskal-Wallis test, followed by the Mann-Whitney test at α=5% if significant differences were observed. Data were processed using SPSS 26.0, while shelf-life parameters were analyzed in Microsoft Excel 2019 by plotting the data as scatter diagrams with trendlines to determine the reaction order R2 value. Shelf-life estimation was calculated using the Arrhenius equation and explained descriptively.

Results and discussion

Antioxidant activity

Antioxidant activity test result of ice *puter* with the addition of ginger extract is shown in Table 1. The antioxidant activity increased with higher concentrations of ginger extract. The ginger extract demonstrated an antioxidant activity of approximately 60,93%, as determined using the DPPH assay, which increased at higher concentrations of ginger extract (Mahmudati et al., 2020). Ginger is rich in bioactive compounds like gingerol, shogaol, and zingerone, which possess strong anti-inflammatory and antioxidant effects (Sari & Nasuha, 2021). These antioxidants are capable of neutralizing DPPH free radicals by donating protons and electrons, resulting in the formation of DPPH-H, a more stable and less reactive compound (Herawati & Saptarini, 2020). DPPH is a purple free radical molecule that turns yellow upon reaction with antioxidants. The percentage inhibition of free radical activity by the sample determines antioxidant activity, which is expressed as % RSA. An elevated RSA value indicated a higher level of antioxidant activity of the sample.

Table 1. Antioxidant activity and phenol total of ice *puter* added with ginger extract

Treatment	Ginger Extract Concentration	Antioxidant Activity (%RSA)	Phenol total (mg GAE/g)
P0	0%	1.97 ± 0.90	0.65 ± 0.01
P1	0.5%	3.04 ± 0.25	0.73 ± 0.05
P2	1%	9.16 ± 1.19	0.75 ± 0.03
P3	1.5%	12.84 ± 1.12	0.76 ± 0.03

Note: Data were shown as mean values of duplicates. %RSA = % Radical Scavenging Activity

The phenol total of ice *puter* added with ginger extract is presented in Table 1. The more ginger extract added, the higher the phenol total. Ginger contains shogaol, which is derived from the conversion of gingerol, and has antioxidant activity (Tenda et al., 2023; Yang et al., 2024). The use of high-quality ginger raw materials contributed to the increase in total phenol content. However, a high-quality ginger extract was obtained, containing a significant amount of phenol compounds. The ginger used in this study was the elephant ginger type. The total phenol content in elephant ginger was 4.4% (Ramadhan et al., 2022), and it was a dry extract. However, the resulting extract contained a high concentration of phenolic compounds. The drying process broke down cell walls and deactivated destructive enzymes while

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maintaining phenolic compounds in the dry extract (Mustafa & Chin, 2023). Dry ginger had a stronger phenolic and antioxidant content than ginger in other forms (Ishfaq et al., 2022).

Overrun

Table 2 showed that all treatments significantly affected the overrun ($p < 0.05$) compared to the control (P0). However, the addition of ginger extract at 0.5 and 1% did not significantly affect the overrun. Higher concentrations of ginger extract resulted in a thicker, denser dough, which hindered the expansion of dough volume by making it more difficult to trap air (Pratama et al., 2020). An excessively thick dough increased the density of the particle structure, narrowing the spaces between particles and limiting the air's ability to penetrate the dough's surface, thereby preventing optimal expansion. As the dough became heavier, air trapped within the dough was more likely to escape, as the dough flowed more quickly to fill the air spaces, resulting in fewer air bubbles and a reduction in the overrun value (Nusa et al., 2019).

Table 2. Overrun ice puter with added ginger extract

Treatment	Ginger Extract Concentration	*Overrun* (%)
P3	1.5%	1.77 ± 0.28^{a}
P2	1%	2.30 ± 0.20^{b}
P1	0.5%	2.54 ± 0.28^{b}
P0	0%	3.52 ± 0.41^{c}

Note: *overrun* mean values in the same column followed by different lowercase superscript letters indicate a significant difference ($p<0.05$) in the DMRT test.

Hedonic

Table 3 showed that all treatments significantly affected the panelists' assessments of color, aroma, taste, and overall quality compared to the control (P0) ($p<0.05$). Ginger extract addition at 0.5 and 1% did not affect the panelists' assessment of color and aroma. The addition of more ginger extract caused a more striking color of the product (Rahman et al., 2023), which influenced the panelists assessment. Dried ginger tended to have a dark color, and this underwent a color change that caused its anthocyanin pigment to turn brown, and its carotenoid intensity decreased (Chen et al., 2023). Ginger had a distinctive aroma that tended to be spicy and contained oleoresins and essential oils that produced a spicy aroma (Badrunanto et al., 2024). The aroma of the ice *puter* with the addition of ginger extract can be specifically distinguished by the panelists who dislike (scores of 2.60-2.93) the spicy aroma. However, strangely, not all the aromas in the treatments were liked by the panellists. Cold temperatures could make the senses less sensitive to recognizing aromas (Legassa, 2020).

Table 3. Hedonic test of ice *puter* added with ginger extract

Treatment	Color	Aroma	Texture^{ns}	Taste	Overall
P0 (0%)	$2.20 \pm 0{,}85^{a}$	2.47 ± 0.63^{a}	3.17 ± 0.65	2.47 ± 0.97^{a}	2.57 ± 0.77^{a}
P1 (0.5%)	3.10 ± 0.66^{b}	2.93 ± 0.64^{b}	3.10 ± 0.80	3.20 ± 0.71^{b}	3.30 ± 0.65^{b}
P2 (1%)	3.27 ± 0.45^{b}	2.83 ± 0.38^{b}	3.1 ± 0.74	2.57 ± 0.68^{a}	2.67 ± 0.61^{a}
P3 (1.5%)	2.67 ± 0.71^{c}	2.60 ± 0.77^{ab}	3.17 ± 0.53	1.63 ± 0.61^{c}	1.90 ± 0.66^{c}

Note: Mean values in the same column followed by different lowercase superscript letters indicate a significant difference ($p<0.05$) in the DMRT test. Score/assessment criteria: 4=strongly like, 3=like, 2=dislike, 1=strongly dislike

None of the treatments had a significant effect on the texture of ice *puter* (*$p<0.05$*). This was due to the ginger extract containing little starch and many volatile compounds, which may not influence the formation of ice *puter* texture. Additionally, the extraction process involved repeated filtration during the maceration stage, resulting in a filtrate with minimal residue and sediment. The filtrate from maceration with ethanol and simplicia was filtered using a thin white cloth to separate the filtrate and residue (Alyidrus et al., 2022).

The higher addition of ginger extract results in a lower level of favorability among panelists due to its spicy taste. Ginger had a spicy taste because it contained gingerol and shogaol, and their derivatives, which caused a spicy taste (Srikandi et al., 2020). P1 was selected because it had a balanced taste between ice *puter* and ginger. The overall value was given by the panelists from all assessment criteria for color, aroma, taste, and texture quality (Rachmawati et al., 2023).

Decrease in the quality of ice puter during storage

Free fatty acid

The free fatty acid value increased during storage, with the highest increase at a temperature of -5 °C. According to the SNI 7381:2008, the allowable limit of free fatty acids, expressed as lauric acid in VCO products, is 0,2%. This showed that the quality of ice *puter* at the end of storage with 3 storage temperatures still fulfilled the SNI for VCO products. Based on Figure 1, free fatty acid levels increased more rapidly at -5 °C, likely due to the presence of fat in coconut milk. This contained saturated fatty acids with several short-chain and long-chain, with the highest fatty acid being lauric acid at 50,45% (Su'i et al., 2016). The presence of fatty acids in coconut milk is bound to glycerol. However, when these undergo a hydrolysis process by enzymes or microbes, these bonds could break down into free fatty acids (Su'i et al., 2022).

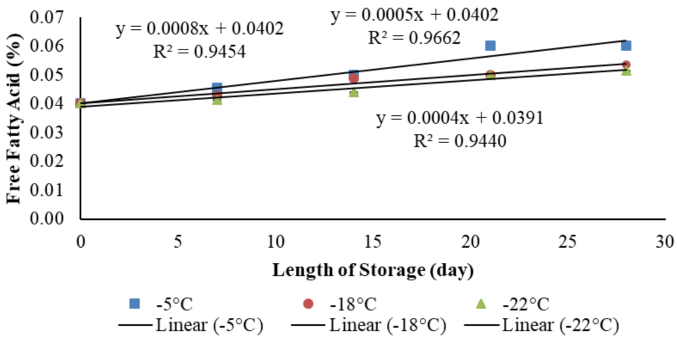

Figure 1. Graph of changes in free fatty acid during storage

Free fatty acids serve as an early indicator of fat damage and degradation in product quality. The presence of free fatty acids could accelerate the oxidation process in products due to their unstable nature. This was in line with Rusmalina (2018) that the presence of free fatty acid could accelerate fat oxidation, and ice *puter* was stored at low temperatures. Freezing temperatures could inhibit bacterial, enzymatic, and chemical reactions (Hanafi et al., 2021). Therefore, products stored at freezing temperatures tended to have lower hydrolysis levels than those stored at higher temperatures.

Emulsion stability

The emulsion stability value decreased during storage, with the highest decrease at a temperature of -5 °C. The emulsion stability value of ice *puter* during storage was still below the emulsion stability value for ice *cream* products at 100%. Based on Figure 2, emulsion stability decreased faster at –5 °C. Destabilization in ice *puter* was characterized by creaming, an increase in globule size, and oil-water phase separation. Emulsion instability problems, such as creaming, occurred due to the presence of gravitational force on phases with different densities (Tambun et al., 2023). The decrease in emulsion stability was partially attributed to physical changes, particularly the development of ice crystals. The changes in the formation of ice crystals and fat can cause internal pressure due to the volume expansion of water into ice, thereby breaking the spheres of emulsion droplets and enlarging globules (Miyagawa et al., 2016).

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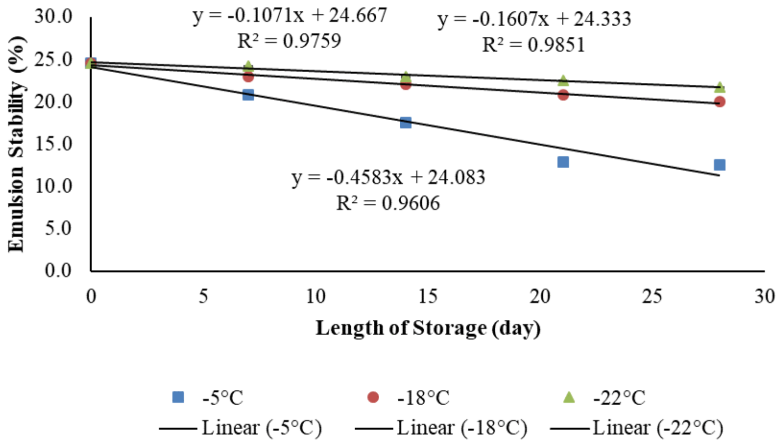

Figure 2. Graph of changes in emulsion stability during storage

The freezing rate affected the microstructure of the ice crystals in the products. A slow freezing rate could produce ice crystals with a larger size compared to a fast freezing rate (Tatontos et al., 2019). Slow freezing also formed more porous cavities, making it easier for rehydration, which could damage food cells (Sasmitaloka et al., 2020). An increase in free fatty acid could disrupt the emulsion stability in ice *puter*. The oxidation and hydrolysis processes could disrupt emulsion stability (Maramis et al., 2017).

The fat globule structure of the ice *puter* increased in size on day 28 at all three temperatures. Based on Figure 3, fat globules at -22 °C were smaller than those at -5 °C and -18 °C. Fat globule size was a key indicator of emulsion separation. Large globules tended to coalesce, causing the fat globule size to enlarge and emulsion separation (Setyopratiwi & Fitrianasari, 2021). Emulsion separation occurred due to instability at the flocculation stage, typically between non-uniform globules.

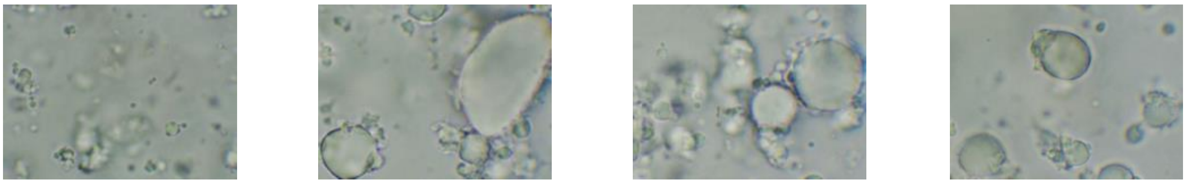

Figure 3. Results of fat globule structure test (a) day 0, (b) day 28 at -5 °C, (c) day 28 at -18 °C, (d) day 28 at of -22 °C

Determination of reaction order

The shelf life of ice *puter* with ginger extract was determined using the ASLT method, with free fatty acid and emulsion stability as critical parameters. Shelf-life estimation began by plotting 28-day quality changes to determine the reaction order (Darniadi et al., 2021). The acceleration method followed a semi-empirical model based on the Arrhenius equation, which employed either a zero-order reaction (where quality decline follows a linear line) or a first-order reaction (where quality decline follows an exponential line). The R2 approaching 1 was considered accurate because the data obtained was linear (Surahman et al., 2020).

Based on Table 4, the reaction order of the ice *puter* formulated using ginger extract, based on the parameters of free fatty acid and emulsion stability, had a greater R^2 value in the 1st order; however, the decrease rate of both parameters followed the 1st order. After the reaction order was determined, a linear regression equation was derived for each temperature. Then, a plot of the pre-exponential term (ln *k*) against the inverse temperature (1/T) was constructed, corresponding to the Arrhenius equation. This was a linear equation, y = a + bx, or $\ln k = \ln k_0 - (Ea/R)(1/T)$ (Surahman et al., 2020).

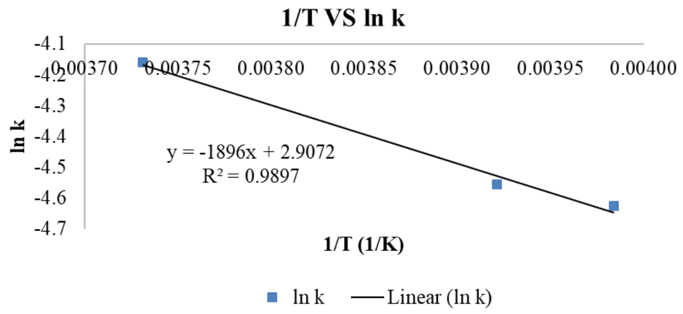

Figure 4. Correlation between ln k and 1/T (x) on free fatty acid parameters

Table 4. Reaction order analysis

Parameter	Temperature (°C)	R^2		Selected order
		Order 0	Order 1	
Free Fatty Acid	-5 °C	0.9454	0.9489	
	-18 °C	0.9662	0.9595	1
	-22 °C	0.9440	0.9499	
Emulsion Stability	-5 °C	0.9606	0.9626	
	-18 °C	0.9851	0.9904	1
	-22 °C	0.9759	0.9764	

Figure 4 showed the linear equation of the free fatty acid parameter, y = -1896x + 2.9072, obtained from the correlation graph between ln k (y-axis) and 1/T (x-axis). The Ea produced was 3765.456 cal/mol.

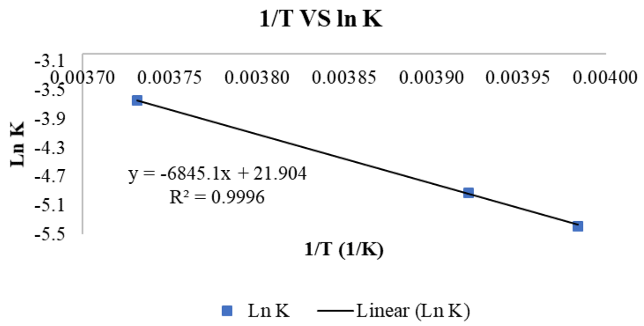

Figure 5. Correlation between ln k and 1/T(x) on the emulsion stability parameter

Figure 5 showed the linear equation of the free fatty acid parameter, y = -6845.1x + 21.904, obtained from the correlation graph between ln k (y-axis) and 1/T (x-axis). The Ea produced was 13594.3686 cal/mol.

Determination of shelf life

Shelf life determination began by identifying critical quality parameters that influenced changes in quality, as well as activation energy (Ea) obtained from the slope, and parameters that most significantly affected quality degradation during storage. Parameters with the lowest Ea were selected, as lower Ea indicates a faster reaction and quicker product deterioration (Efendi et al., 2021). Activation energy (Ea) represents the least amount of energy needed for particles to collide and initiate a reaction successfully, whereas the slope constant (k) indicates the correlation between quality degradation and storage (Arif, 2016).

Table 5. Arrhenius equation and activation energy (Ea)

Parameter	Arrhenius equation	R^2	Ea (cal/mol)	Slope
Free Fatty Acid	y = -1599.9x + 1.7955	0.9897	3765.456	-1896
Emulsion Stability	y = -6845.1x + 21.904	0.9996	13594.3686	-6845.1

Based on Table 5, the parameter with the lowest Ea value and the lowest slope (k) was free fatty acid. Accordingly, free fatty acid was selected as a critical parameter. The results of ice *puter*'s shelf life estimation formulated with ginger extract at 3 storage temperatures are shown in Table 6.

Table 6. Shelf life of ice *puter* with added ginger extract

Critical Parameters	Temperature (°C)	Shelf Life (days)
Free Fatty Acid	-5 °C	130 days
	-18 °C	186 days
	-22 °C	210 days

Based on Table 6, the higher storage temperature tends to decrease the shelf life. Therefore, the best storage temperature for ice *puter* products with the addition of ginger extract was -22 °C to get a longer shelf life. Shelf life at -5 °C, -18 °C, and -22 °C was 130 days, 186 days, and 210 days.

Conclusion

It is concluded that incorporating ginger extract at various concentrations significantly affects the overrun. In contrast, treatments P1 and P2 showed no significant effect on color and aroma. Increasing ginger extract concentration could increase antioxidant activity and total phenol content, but it decreases ice *puter* overrun. The shelf life of ice *puter* containing 0.5% ginger extract at -5 °C, -18 °C, and -22 °C was estimated to be 130, 186, and 210 days, respectively, based on changes in free fatty acid content.

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References

Alyidrus, R., Wahyuni, Nurhikma, A., & Nurrahmi, K. (2022). Aktivitas antibakteri ekstrak etanol batang laruna (*Chromolaena Odorata* L.) terhadap *staphylococcus aureus* dan *pseudomonas aeruginosa*. *Inhealth : Indonesian Health Journal*, 1(1), 62–70. https://doi.org/10.56314/inhealth.v1i1.20

Amin, F., Hasanuddin, A., Sugiarto, & Rugayah, N. (2022). Kadar protein, daya leleh dan uji organoleptik es krim dengan penambahan gelatin ceker ayam. *Jurnal Ilmiah Agrisains*, 23(3), 172–178. https://doi.org/10.22487/jiagrisains.v23i3.2022.172-178

Arif, A. B. (2016). Metode *accelerated shelf life test* (ASLT) dengan pendekatan *Arrhenius* dalam pendugaan umur simpan sari buah nanas, pepaya dan cempedak. *Jurnal Informatika Pertanian*, 25(2), 189–198. https://dx.doi.org/10.21082/ip.v25n2.2016.p189-198

Badrunanto, Wahyuni, W. T., Farid, M., Batubara, I., & Yamauchi, K. (2024). Antioxidant components of the three different varieties of Indonesian ginger essential oil: In vitro and computational studies. *Food Chemistry Advances*, 4(1), 1–11. https://doi.org/10.1016/j.focha.2023.100558

Chen, K., Yuan, Y., Zhao, B., Kaveh, M., Beigi, M., Zheng, Y., & Torki, M. (2023). Optimum drying conditions for ginger (*Zingiber officinale* Roscoe) based on time, energy consumption and physicochemical quality. *Food Chemistry: X*, 20(1), 1–14. https://doi.org/10.1016/j.fochx.2023.100987

Darniadi, S., Handoko, D. D., Sunarmani, S., & Widowati, S. (2021). Determination of shelf-life using accelerated shelf-life testing (ASLT) method and characterization of the flavour components of freeze-dried durian (*durio zibethinus)* products. *Food Research*, 5(1), 98–106. https://doi.org/10.26656/fr.2017.5(S2).006

Efendi, R., Ayu, D. F., & Nofaren, N. (2021). Pendugaan umur simpan rendang telur yang dikemas plastik *high density polyetilen* (HDPE) dan *aluminium foil* dengan teknik pengemasan berbeda menggunakan metode akselerasi. *Jurnal Teknologi dan Industri Pertanian Indonesia,* 13(1), 1–8. https://doi.org/10.17969/jtipi.v13i1.17093

Hanafi, S., Limonu, M., & Maspeke, N. P. (2021). Studi penggunaan kemasan vakum dan non vakum terhadap mutu olahan bola singkong sagela (*hot boss*) pada penyimpanan beku. *Journal of Food Technology*, 3(1), 10–18. https://doi.org/10.37905/jjft.v3i1.7302

Herawati, I. E., & Saptarini, N. M. (2020). Studi fitokimia pada jahe merah (*Zingiber officinale* Roscoe Var. Sunti Val). *Majalah Farmasetika*, 4(1), 22–27. https://doi.org/10.24198/mfarmasetika.v4i0.25850

Hossain, M. K., Petrov, M., Hensel, O., & Diakité, M. (2021). Microstructure and physicochemical properties of light ice cream: effects of extruded microparticulated whey proteins and process design. *Journal Foods*, 10(1), 1–14. https://doi.org/10.3390/foods

Ishfaq, M., Hu, W., Hu, Z., Guan, Y., & Zhang, R. (2022). A review of nutritional implications of bioactive compounds of Ginger (*Zingiber officinale* Roscoe), their biological activities and nano-formulations. *Italian Journal of Food Science*, 34(3), 1–12. https://doi.org/10.15586/ijfs.v34i3.2212

Karseno, Setyawati, R., Haryanti, P., & Yanto, T. (2021). Addition of selected ginger extract on total phenolic, antioxidant and sensory properties of the syrup coconut sap (Ginger – SCS). *Food Research*, 5(6), 283–289. https://doi.org/10.26656/fr.2017.5(6).750

Kho, M. , K., Reni Swasti, Y., & Sinung Pranata. (2022). Kualitas es puter dengan penambahan bubur kulit buah naga merah bagian dalam (*Hylocereus polyrhizus*) dan ekstrak pektinnya sebagai agen penstabil. *Jurnal Aplikasi Teknologi Pangan*, 11(4), 159–172. https://doi.org/10.17728/jatp.10440

Kolawole, O. M., Akinlabi, K. Q., & Silva, B. O. (2022). Physicochemical and stability profile of castor oil emulsions stabilized using natural and synthetic emulsifiers. *World Journal of Biology Pharmacy and Health Sciences*, 9(2), 60–73. https://doi.org/10.30574/wjbphs.2022.9.2.0043

Legassa, O. (2020). Ice cream nutrition and its health impacts. *International Journal of Food and Nutritional Science*, *7*(1), 19–27. https://doi.org/10.15436/2377-0619.20.2678

Luhurningtyas, F. P., Susilo, J., Yuswantina, R., Widhihastuti, E., & Ardiyansah, F. W. (2021). Aktivitas imunomodulator dan kandungan fenol ekstrak terpurifikasi rimpang jahe merah (*Zingiber officinale* Rosc. Var.Rubrum). *Indonesian Journal of Pharmacy and Natural Product*, 4(1), 51–59. https://doi.org/10.35473/ijpnp.v4i1.974

Mahmudati, N., Wahyono, P., & Djunaedi, D. (2020). Antioxidant activity and total phenolic content of three varieties of Ginger (*Zingiber officinale*) in decoction and infusion extraction method. *Journal of Physics: Conference Series*, *1567*(1), 1–6. 10. https://iopscience.iop.org/article/10.1088/1742-6596/1567/2/022028

Maramis, R. N., Kalonio, D. E., & Rindengan, E. R. (2017). Penggunaan lendir dari daun gedi merah (*Abelmoschus manihot* L. Medik) asal Sulawesi Utara sebagai emulgator pada sediaan emulsi. *Jurnal Tumbuhan Obat Indonesia,* 10(1), 17–24. http://dx.doi.org/10.22435/toi.v10i1.7125.17-24

Marganingsih, N. D., Mustofa, A., & Widanti, Y. A. (2018). Aktivitas antioksidan minuman fungsional daun katuk-rosella (*Sauropus androgynous* (L) Merr.- *Hibiscus sabdariffa Linn*) dengan penambahan ekstrak jahe (*Zingiber officinale* Rosc.). *Jurnal Teknologi dan Industri Pangan*, 3(2), 144–151. https://doi.org/10.33061/jitipari.v3i2.2697

Miyagawa, Y., Ogawa, T., Nakagawa, K., & Adachi, S. (2016). Destabilization of mayonnaise induced by lipid crystallization upon freezing. *Bioscience, Biotechnology and Biochemistry*, 80(4), 786–790. https://doi.org/10.1080/09168451.2015.1123611

Mustafa, I., & Chin, N. L. (2023). Antioxidant properties of dried ginger (*Zingiber officinale* Roscoe) var. Bentong. *Foods*, 12(1), 1–18. https://doi.org/10.3390/foods12010178

Nurlaela, L., Yundra, E., & Romadhoni, I. F. (2020). The effect of the addition of turmeric and temulawak on the hedonic value of starfruit syrup. *International Joint Conference on Science and Engineering*, 196(1), 292–297. https://doi.org/10.2991/aer.k.201124.053

Nusa, M. I., Masyhura, M. D., & Hakim, F. A. (2019). Identifikasi mutu fisik kimia dan organoleptik penambahan ekstrak jahe (*Zingiber officinale*) pada pembuatan es krim sari kacang hijau (*Phaseolus Radiatus* L.). *Jurnal Teknologi Pangan dan Hasil Pertanian, 2*(2), 47–51. https://doi.org/10.30596/agrintech.v2i2.3433

Paputungan, M. (2021). Optimasi penggunaan starter dengan metode pancingan dan fermentasi berbantuan bakteri *Saccharomyces cerevisiae* untuk optimalisasi pemisahan lemak, protein dan air pada pembuatan VCO. *Journal of Chemistry*, 3(1), 57–68. https://doi.org/https://doi.org/10.34312/jambchem.v3i1.10467

Parumpa, N. H. D., Mutsyahidan, A. M. A., & Une, S. (2024). Pengaruh konsentrasi ekstrak jahe merah (*Zingiber officinale var. Rubrum*) terhadap uji zona hambat bakteri *Streptococcus* mutans, organoleptik, dan karakteristik fisik permen lembaran. *Journal of Agritech Science*, 8(1), 38–49. https://doi.org/10.30869/jasc.v8i1.1329

Perdani, C. G., Wijana, S., & Nurmaysta Sari, F. (2017). Pemanfaatan bubur kelapa gading (*C. Nucifera* var eburnea) dalam pembuatan es krim. *Jurnal Teknologi dan Manajemen Agroindustri*, 6(1), 22–30. https://doi.org/https://doi.org/10.21776/ub.industria.2017.006.01.4

Pratama, E. W., Iswoyo, & Fitriana, I. (2020). Pengaruh penambahan ekstrak jahe terhadap sifat fisikokimia dan sensori es krim. *Jurnal Teknologi Pangan dan Hasil Pertanian*, 15(1), 1–9.

Rachmawati, Y., Ramdany, R., Rumoning, S. H., Kesehatan, P & Sorong, K. (2023). Mutu hedonik mie kering berbahan labu kuning modifikasi ikan gabus sebagai makanan darurat. *Jurnal Gizi dan Kesehatan*, *3*(2), 117–128.

Rahman, M. H., Suarti, B., Saiful, E., & Bin, B. (2023). Karakteristik fisik dan sensori minuman jahe (*Zingiber officinale*) dengan penambahan jenis pemanis di Kuala Lumpur. *Jurnal Ilmu Pangan dan Hasil Pertanian*, 7(2), 181–195. https://doi.org/10.26877/jiphp.v7vi2i.17437

Ramadhan, G. R., Subardjo, Y. P., & Dwiyanti, H. (2022). Aktivitas antioksidan minuman fungsional berbasis nira kelapa dengan penambahan ekstrak secang, kayu manis, jahe dan beras hitam. *Jurnal Gizi dan Pangan Soedirman*, 6(2), 71–85. https://doi.org/10.20884/1.jgipas.2022.6.2.6971

Rizal, S., Suharyono, S., Nurainy, F., & Merliyanisa, M. (2020). Pengaruh glukosa dan jahe merah terhadap karakteristik minuman probiotik dari kulit nanas madu. *Jurnal Teknologi Industri & Hasil Pertanian*, 25(2), 110–119. http://dx.doi.org/10.23960/jtihp.v25i2.110-119

Rusmalina, S. (2018). Penentuan kualitas minyak goreng berdasarkan pada nilai asam lemak bebas. *Jurnal Ilmu Pengetahuan dan Teknologi*, 32(1), 51–57. https://doi.org/10.31941/jurnalpena.v32i1.969

Sari, D., & Nasuha, A. (2021). Kandungan zat gizi, fitokimia, dan aktivitas farmakologis pada jahe (*Zingiber officinale* Rosc.). *Journal of Biological Science*, 1(2), 11–18.

Sasmitaloka, K. S., Widowati, S., & Sukasih, E. (2020). Karakterisasi sifat fisikokimia, sensori, dan fungsional nasi instan dari beras amilosa rendah. *Jurnal Penelitian Pascapanen Pertanian*, 17(1), 1–14. https://doi.org/http://dx.doi.org/10.21082/jpasca.v17n1.2020.1-14

Septiani, N. K. A., Parwata, I. M. O. A., & Putra, A. A. B. (2018). Penentuan kadar total fenol, kadar total flavonoid dan skrining fitokimia ekstrak etanol daun gaharu (*Gyrinops versteegii*). *Jurnal Matematika, Sains, dan Pembelajarannya*, 12(1), 78–89. https://doi.org/https://doi.org/10.23887/wms.v12i1.13868

Setyopratiwi, A., & Fitrianasari, P. N. (2021). Formulasi krim antioksidan berbahan v*irgin coconut oil* (VCO) dan *red palm oil* (RPO) dengan variasi konsentrasi trietanolamin. *Bencoolen Journal of Pharmacy*, 1(1), 26–37. https://doi.org/https://doi.org/10.33369/bjp.v1i1.15592

Srikandi, S., Humaeroh, M., & Sutamihardja, R. (2020). Kandungan gingerol dan shogaol dari ekstrak jahe merah (*Zingiber Officinale Roscoe*) dengan metode maserasi bertingkat. *Al-Kimiya*, 7(2), 75–81. https://doi.org/10.15575/ak.v7i2.6545

Su'i, M., Sumaryati, E., & Sucahyono, D. D. (2016). Pemanfaatan fraksi kaya asam laurat hasil hidrolisis dari endosperm kelapa menggunakan lipase endogeneus sebagai pengawet susu kedelai kemasan. *AGRITECH*, 36(2), 154–159. https://doi.org/https://doi.org/10.22146/agritech.12859

Su'i, M., Sumaryati, E., Anggraeni, F. D., & Wijayanti. (2022). Uji kualitas minuman kesehatan santan kelapa dan kecambah kedelai (kajian dari pengaruh perbandingan santan kelapa dengan ekstrak kecambah kedelai dan lama inkubasi). *Jurnal Buana Sains*, 22(2), 33–42. https://doi.org/https://doi.org/10.33366/bs.v22i2.3769

Surahman, D. N., Ekafitri, R., Desnilasari, D., Ratnawati, L., Miranda, J., Cahyadi, W., & Indriati, A. (2020). Pendugaan umur simpan *snack bar* pisang dengan metode *arrhenius* pada suhu penyimpanan yang berbeda. *Biopropal Industri*, 11(2), 127–137. https://doi.org/10.36974/jbi.v11i2.5898

Szmejda, K., Duliński, R., Byczyński, Ł., Karbowski, A., Tomasz, F., & Żyła, K. (2018). Biotechnology and food science analysis of the selected antioxidant compounds in ice cream supplemented with spirulina (*Arthrospira platensis*) extract. *Biotechnology and Food Science*, 82(1), 41–48. http://www.bfs.p.lodz.pl

Tambun, R., Sijabat, G. J. J., Sidebang, T. J., & Tambun, B. (2023). Kombinasi persamaan rosin-rammler dan metode pengapungan Batang (*Buoyancy Weighing-Bar Method*) pada penentuan distribusi ukuran gelembung air dalam kerosin. *Jurnal Teknik Kimia USU*, 12(1), 24–30. https://doi.org/10.32734/jtk.v12i1.11269

Tarmizi, A., & Ulyah, U. (2017). Pengaruh tanggal kadaluarsa dan label halal pada kemasan produk makanan terhadap keputusan pembelian masyarakat Sungai Terap Muaro Jambi. *Journal for Religious Innovation Studies*, 17(1)., 45-54 https://doi.org/https://doi.org/10.30631/innovatio.v17i1.15

Tatontos, S. J., Harikedua, S. D., Mongi, E. L., Wonggo, D., Montolalu, L. A. D. Y., Makapedua, D. M., & Dotulong, V. (2019). Efek pembekuan-pelelehan berulang terhadap mutu sensori ikan cakalang (*Katsuwonus pelamis* L). *Jurnal Media Teknologi Hasil Perikanan*, 7(2), 32–35. https://doi.org/https://doi.org/10.35800/mthp.7.2.2019.23611

Tenda, P. E., Kapitan, L. A. V., Indrawati, M. I. M., & Soeharto, F. R. (2023). Quality and antioxidant activity of faloak (*Sterculia quardifida* R.Br) extract syrup with variations in addition of ginger (*Zingiber officinale* Roscoe). *Jurnal Ilmiah Farmasi*, 19(1), 15–30. https://doi.org/10.20885/jif.vol19.iss1.art2

Yang, Z., Guo, Z., Yan, J., & Xie, J. (2024). Nutritional components, phytochemical compositions, biological properties, and potential food applications of ginger (*Zingiber officinale*): A comprehensive review. *Journal of Food Composition and Analysis*, 128(1), 106057. https://doi.org/10.1016/j.jfca.2024.106057