Journal of Applied Agricultural Science and Technology *E-ISSN: 2621-2528*
JAAST 8(2): 144-158 (2024) *ISSN: 2621-4709*

SUCROSE OSMOTIC TREATMENT EFFECT ON MOISTURE, ANTIOXIDANT, TEXTURE, AND SENSORY PROPERTIES OF GINGER EXTRACT-IMERSED COCONUT CHIPS

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Abstract*. In this study, ginger extract was used to impart a distinctive, popular flavor and functional properties (antioxidants) to coconut chips. Sucrose was added to the extract as an osmotic agent to facilitate the migration of antioxidant and flavor compounds from the ginger extract into the fresh coconut flesh during immersion. This study aimed to determine the effects of immersion in ginger extract with the addition of various concentrations of sucrose on the antioxidant, moisture, texture, and sensory characteristics of green coconut chips. The antioxidant activity was analyzed by 2,2-diphenyl-1-picrylhydrazyl scavenging assay. Instrumental texture analysis included Fmax, hardness, and deformation parameters. The results showed that higher concentrations of sucrose added to the ginger extract resulted in increasing antioxidant activity, Fmax, hardness, and panelist preference for color, taste, and overall, and decreasing moisture and deformation. Based on the antioxidant activity parameter, adding sucrose to ginger extract enhanced the effectiveness of immersion, thereby reducing the immersion duration to achieve greater antioxidant activity.*
Keywords: *ginger extract; osmotic; coconut chips; antioxidant; texture.*

1. Introduction

Indonesia, renowned as one of the largest coconut producers in the world, possesses significant potential for coconut production. In 2020, coconut production reached approximately 2.858 million tons, experiencing a slight increase compared to the previous year. The coconut plantations cover an expanding area of approximately 3.392 million hectares. The coconuts produced from these plantations fulfill domestic market demands and serve as a crucial export commodity, with an export volume of around 2.1 million tons in 2020 (Gartina & Sukriya, 2021). The growth in coconut production in Indonesia positively impacts farmer incomes and regional economic development and strengthens Indonesia's role as a significant player in the coconut market.

Green coconut is a coconut variety commonly used for refreshing coconut water. However, the potential of coconut flesh as a food ingredient has yet to be optimally utilized (Santana *et al.*, 2011). Despite the numerous benefits of coconut flesh, such as its high calorie, protein, fat, carbohydrate content, and other components, its use is still limited as an addition to dishes. However, coconut flesh has been processed into various important products (Towaha *et al.*, 2008). These potentials highlight significant opportunities for developing a sustainable food industry and

Received November 9, 2023; Accepted February 8, 2024; Published May 27, 2024
https://doi.org/10.55043/jaast.v8i2.246.

adding value to the agricultural sector.

Coconut milk is a common product used in traditional dishes and snacks, while coconut flesh is processed into grated coconut used in cakes, bread, and desserts. Products such as coconut oil, coconut milk, and coconut flour are also produced through further processing. Coconut flesh can also be used for high-protein snacks, fresh coconut beverages, coconut ice, and coconut chips (Victor, 2013). Coconut chips are chosen as the research object due to their potential as an innovative product that combines deliciousness, nutrition, and functional properties, such as a source of fiber (Kamsiati, 2010). This research aims to enhance the functional value and consumer appeal of coconut chips and to open opportunities for the development of a more diverse coconut-based food industry. Processing coconut flesh into coconut chips also helps maintain the quality and shelf life of coconuts, which have high moisture content (Divekar *et al.*, 2010).

Previous studies have successfully used immersion in green tea extract, pumpkin seeds, and hibiscus flowers to prevent color changes in fresh-cut potatoes and apples, relying on the high antioxidant properties of the extracts (Bobo *et al.*, 2022; Wessels *et al.*, 2014). In this study, however, coconut flesh is immersed in ginger extract before being dried to make coconut chips in an oven. The objective is to impart functional properties derived from the antioxidant compounds of the ginger and provide the distinctive aroma and flavor of ginger to the coconut chips. The Indonesian population widely recognizes and favors ginger's unique flavor in various food preparations. Emprit ginger (*Zingiber officinale* var. Amarum) was chosen in this study due to its higher active compound content than red ginger and elephant ginger, particularly gingerol and shogaol. Both phenolic compounds, along with zingiberene, possess strong antioxidant effects and contribute to the distinct flavor of ginger (Febriyanti & Yunianta, 2015). Thus, the ginger extract also provides additional characteristics, such as a distinctive aroma and flavor (Fathonah, 2011). The ginger extract usage as the immersion medium in this study is expected to enhance the value and appeal of these processed green coconut products.

In the production of coconut chips, sucrose is added during the immersion stage of coconut flesh to provide the preferred sweet taste for consumers. Furthermore, sugar, particularly sucrose, is known as a natural preservative that inhibits microbial activity in food ingredients due to its impact on lowering water activity. Sucrose application in immersion solution also creates an osmotic dehydration effect, resulting in the migration of sucrose into the coconut flesh and the initial release of some water from the flesh, which facilitates the drying process. This osmotic treatment also influences the physical properties and texture of the coconut flesh. Moreover, sugar molecules can retain the flavor in the ingredients (Yadav & Singh, 2014). The migration of sucrose molecules into the coconut flesh is also expected to carry phenolic compounds from the ginger extract into the coconut tissue since sugar molecules can interact with phenolic compounds (Shalaby *et al.*, 2016). Sucrose is chosen to provide the osmotic effect in this study because the use of sucrose yields better product in terms of texture, color structure, and sensory acceptance compared to other sugars (honey, fructose, and glucose) in previous research (Chauhan *et al.*, 2011).

Therefore, this study aims to determine the effect of adding sucrose to ginger extract on the antioxidant activity, texture, and sensory characteristic of ginger chips produced from immersion in the extract. This study is expected to provide information on the use of sucrose in ginger extract, which can aid the migration of phenolic compounds that act as antioxidants into the coconut flesh, thus enhancing the effectiveness of the immersion process. This effectiveness can reduce the required immersion time to achieve high antioxidant activity.

2. Methods

2.1. Material

The primary ingredients used in the production of these coconut chips are green coconuts (*Cocos nucifera* L. var. Viridis) aged 11-12 months, cultivated in Kulon Progo, Yogyakarta, and emprit ginger (*Zingiber officinale* var. Amarum) rhizome, cultivated by local farmers in Tawangmangu, Karanganyar. The coconut husk was removed using a husking spike. Subsequently, the shell was cracked open with a machete and split in half to discharge the coconut water. The coconut flesh was separated from the shell by using a thick and strong blade.

2.2. Ginger extract preparation

The ginger extract preparation was conducted following the method used by previous research (Chasparinda *et al.*, 2014). The preparation of ginger extract began by thoroughly washing the ginger rhizomes. Then, the ginger rhizomes were air-dried for approximately 10 minutes to remove moisture gained from the washing process. Subsequently, the ginger was dried for 70 minutes at 100 °C to enhance its antioxidant activity (Borde, 2011). After being dried, the ginger rhizomes were allowed to cool for 10 minutes before peeling. Once peeled, the ginger rhizomes were cut into approximately 1 cm long pieces to reduce their size and facilitate extraction. The cut ginger rhizomes were then extracted using hot water (95 °C) for 45 minutes with a ginger-to-hot water ratio 1:2 (% w/v). The resulting mixture was then filtered and settled, and the clear portion was collected as a ginger extract. The ginger extract was subsequently combined with sucrose at three different concentrations: 25%, 50%, and 75% (w/v).

2.3. Sample preparation

The process of making coconut chips was conducted following the previous research (Sivasakthi & Sangeetha, 2012). Initially, the coconut flesh was sliced to a thickness of 0.8 mm.

The coconut slices were then immersed in ginger extract supplemented with sucrose (0, 25, 50, and 75% w/v). The immersion was carried out for different durations (1, 2, and 3 hours). After the immersion process, the coconut slices were dried using a cabinet dryer for 6 hours at a temperature of 60 ºC. Subsequently, the coconut slices were roasted in an oven for 3 minutes at a temperature of 150 ºC until they became coconut chips (Divekar *et al.*, 2010). The antioxidant activity of the coconut chips was then analyzed to select the best immersion duration based on the highest antioxidant activity. The coconut chips from the chosen immersion method were further analyzed for their physical and sensory characteristic.

2.4. Antioxidant activity

The antioxidant activity analysis was conducted using the DPPH (2,2-Diphenyl-1-picrylhydrazyl) radical scavenging assay, following the previous research method (Herald *et al.*, 2012). A total of 0.1 g of the sample was ground into powder, mixed with 5 ml of methanol in an Erlenmeyer flask, then incubated for approximately 12 hours. The mixture was then centrifuged at 5,000 rpm for 10 minutes to obtain the filtrate. Subsequently, 25 µl of the filtrate was mixed with 200 µl of 150 µM DPPH reagent and incubated in the dark for 30 minutes at room temperature. The absorbance was then measured at a wavelength of 517 nm. A control experiment was conducted using the same procedure, but the sample was replaced with absolute methanol. The antioxidant activity was calculated as the percentage difference between the blank absorbance and the sample absorbance divided by the blank absorbance.

2.5. Moisture

The moisture content analysis was conducted following the AOAC 2005 method. Crushed coconut chip samples (2 g) were weighed in a pre-dried weighing bottle at a temperature of 105 °C for 1 hour, and the weight was recorded. The weighing bottle containing the sample was then placed in an oven at a temperature of 105 °C for 4-6 hours until the weight of the sample and weighing bottle reached a constant value with a difference of 0.2 mg. The moisture content was calculated as a percentage of the difference between the weight of the sample before and after drying, divided by the weight before drying.

2.6. Texture

The texture analysis was performed using the Brookfield CT3 Texture Analyzer with a TA-18 probe. The testing involved compressing the coconut chip samples using the probe at a test speed of 0.5 mm/s, a trigger point of 50 g, and a target value of 2.5 mm. The physical parameters observed were Fmax (N), hardness (N/mm), and deformation (mm).

2.7. Sensory analysis

The sensory analysis used in this research was a hedonic test using a scoring method. The hedonic test was conducted with 25 untrained panelists. The panelists were presented with three different types of samples (coconut chips produced by immersion in a ginger extract with the addition of three different concentrations of sucrose: 25, 50, and 75% w/v). The testing was conducted with parameters such as taste, aroma, texture, color, and overall preference. Subsequently, the panelists completed a questionnaire based on their level of preference, using a rating scale of 1=dislike very much, 2=dislike, 3=neutral, 4=like, and 5=like very much.

2.8. Experimental design

This study consisted of two phases. The first phase employed a Completely Randomized Design (CRD) with two factors: sucrose concentration (three treatment levels) and immersion duration (three treatment levels). This phase aimed to investigate the effect of sucrose concentration on the antioxidant activity of coconut chips and determine the best immersion duration that provides higher antioxidant activity in coconut chips. The coconut chips from the best immersion duration were used for the next phase of the study. The second phase employed a CRD with a single factor: sucrose concentration (four treatment levels). This phase aimed to examine the influence of sucrose concentration on coconut chips' physical and sensory characteristics. Each treatment in this study was replicated three times. The obtained results were analyzed using Analysis of Variance (ANOVA) to determine the significance of the treatments. If significant effects were observed, Duncan Multiple Range Test (DMRT) was conducted to identify significant differences between treatments.

3. Results and Discussion

3.1. Antioxidant activity

The antioxidant activity (DPPH scavenging) of coconut chips in this study ranged from low to moderate (5.88 - 52.44%). According to previous research, the antioxidant activity of fresh coconut flesh can reach up to 52% (Phonphoem *et al.*, 2022), depending on the variety, while coconut chips immersed in sucrose solution alone exhibited an antioxidant activity of 19.77% (Pravitha *et al.*, 2022). The use of high temperature (150 °C) during the roasting stage may result in the degradation of naturally occurring antioxidant compounds in the coconut flesh, especially unstable flavonoids and vitamin E during thermal processing (Phonphoem *et al.*, 2022; Zhang *et al.*, 2019; Pignitter *et al.*, 2019).

Although immersion duration significantly affected the antioxidant activity of coconut chips ($F_{calculated}$ 68.9 > $F_{0.05}$ 4.74), its effect was less effective than the influence of sucrose concentration on the antioxidant activity of coconut chips. Figure 1 shows that immersion duration only increased the antioxidant activity of coconut chips in the treatment with the lowest sucrose concentration (25% w/v). The increase in antioxidant activity was relatively low compared to the effect of sucrose concentration on antioxidant activity. An immersion duration of 3 hours only resulted in a twofold increase in antioxidant activity compared to a 1-hour immersion duration at the same sucrose concentration (25% w/v). Increasing the immersion duration at higher sucrose concentrations (50% and 75% w/v) decreased the antioxidant activity of coconut chips to nearly one-third of the initial antioxidant activity.

Previous research also reported that immersion in osmotic solutions, such as sucrose solutions, for a specific duration can induce water movement out of the coconut flesh cells due to the concentration gradient, creating voids within the cells. Conversely, sucrose and other molecules in the osmotic solution move into these empty spaces through the coconut flesh cell walls, which act as a permeable membrane (Rodrigues *et al*., 2009). However, prolonged immersion in the osmotic solution not only creates empty spaces within the coconut flesh cells but also leads to cell damage and cell wall rupture, resulting in a decrease in the integrity of the cells and tissues to retain their components (Prinzivalli *et al*., 2006). The reduction in cell integrity probably caused the release of antioxidant and ginger's distinct flavor compounds that had previously migrated into the coconut flesh cells during a 1-hour immersion. Therefore, as the immersion duration increases (2 or 3 hours) in ginger extract, the antioxidant activity of coconut chips decreases.

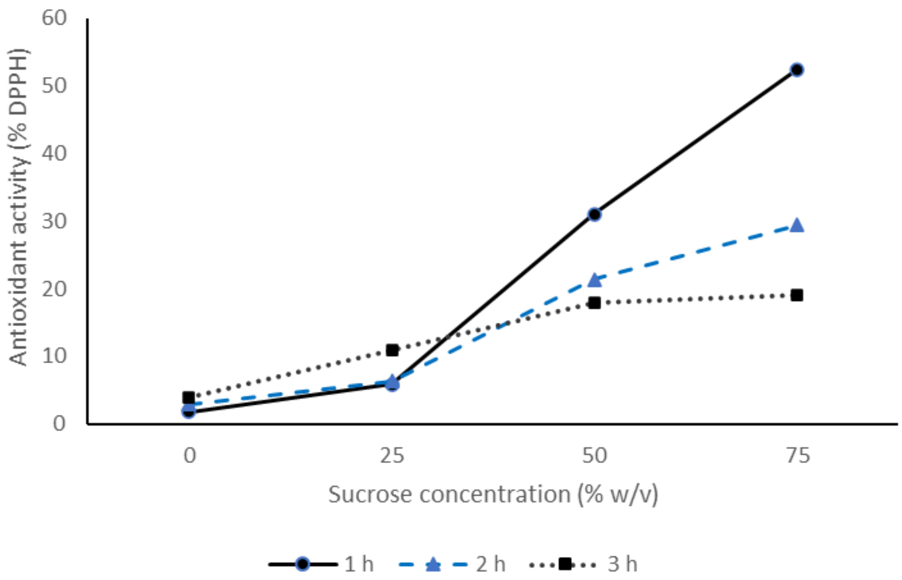

Figure 1. Effect of sucrose concentration on antioxidant activity of coconut chips

Considering that the increase in antioxidant activity is related to the migration of antioxidant compounds of ginger into the coconut flesh cells, modifying the treatment to enhance the transfer of functional compounds from ginger extract into the coconut flesh cells by increasing the sucrose concentration in the ginger extract is more effective compared to prolonging the immersion duration. The results of this study indicate that the shortest immersion duration (1 hour) in ginger extract is the most effective duration for enhancing the antioxidant activity of coconut chips. Therefore, in the subsequent research phase, the samples will be processed with a 1-hour immersion duration and ginger extract with 25, 50, and 75% w/v sucrose concentrations.

3.2. Moisture

Based on the analysis of variance, the concentration of sucrose in the ginger extract significantly affected the moisture content of coconut chips ($F_{calculated}$ 114.78 > $F_{0.05}$ 4.07). Table 1 shows that the immersion treatment in ginger extract with the addition of sucrose at concentrations of 25, 50, and 75% w/v resulted in a reduction in the moisture content of coconut chips compared to the control chips. This reduction in moisture content reached up to one-third of the moisture content of the control coconut chips. However, an increase in the moisture content of coconut chips was observed with increasing sucrose concentration from 25 to 75% w/v.

During immersion, the concentration gradient created by the osmotic solution, such as sucrose solution, drives water molecules out of the cells and tissues of the fruit flesh to equalize the concentration inside and outside the fruit tissue. This process leads to the formation of empty pockets and microscopic channels within the fruit tissue, thereby enhancing the effective diffusivity of water (Rodrigues *et al*., 2009). The formation of these microscopic channels can also increase drying effectiveness (Gallego-Juarez *et al*., 1999). However, the sucrose in the fruit tissue can reabsorb water during drying and conditioning before packaging due to its hygroscopic nature, thus acting as a humectant (Caballero-Cerón *et al*., 2018). The interaction between sugar and water can often pose a significant challenge, especially in fruits with high sugar content, such as dates (Hasan *et al*., 2022). The ability of sucrose molecules to interact with water probably contributes to a slight increase in the moisture content of coconut chips with increasing concentration of the sucrose solution used. However, the use of sucrose has been shown to help reduce the moisture content of coconut chips compared to the control.

Table 1. Moisture and texture of coconut chips produced from 1-hour immersion in ginger extract

Sucrose concentration (% w/v)	Moisture (%)	Fmax (N)	Hardness (N/mm)	Deformation (mm)
0	3.09^{d} ±0.13	1.19^{a} ±0.27	0.39^{a} ±0.07	2.62^{c} ±0.04
25	1.11^{a} ±0.03	2.59^{b} ±0.06	2.12^{b} ±0.25	1.26^{a} ±0.15
50	1.24^{b} ±0.07	3.34^{c} ±0.18	3.51^{c} ±0.46	0.97^{a} ±0.13
75	1.63^{c} ±0.19	2.23^{b} ±0.55	1.42^{b} ±0.17	1.87^{b} ±0.26

The average with the same alphabet in the same column indicates no significant difference at α 5% significance level according to the Duncan Multiple Range Test (DMRT)

3.3. Texture

The sucrose concentration used in the immersion significantly influenced the Fmax of coconut chips ($F_{calculated}$ 49.93 > $F_{0.05}$ 4.07). Table 1 shows an increase in the Fmax of coconut chips due to the immersion treatment in the ginger extract at all concentrations of sucrose (25, 50, and 75% w/v) compared to the control. This increase reached two to three times the Fmax of the control. Although there was an increase in Fmax due to the osmotic treatment with sucrose, this increase was followed by a decrease in deformation (Table 1), indicating that applying force up to Fmax required less time or resulted in less shape change before the sample broke.

The moisture of a material significantly affects its Fmax value. The lower the moisture content of a material, the higher its Fmax value (Oyedeji *et al.*, 2017). Similar results were obtained in this study (Table 1). The sucrose addition at any concentration to ginger extract produced coconut chips with lower moisture content and higher Fmax than the control (without sucrose). According to the previous research (Jia *et al.*, 2019), in addition to moisture content, changes in the texture of dried food products are influenced by rehydration ratio and hygroscopicity.

In addition, the migration of sucrose into the fruit tissue contributes to the formation of sucrose crystal structures that help maintain density and hardness after drying. The crystallization of sucrose around the dried fruit cells can form a solid matrix that provides structural support to the fruit tissue, particularly through interactions with cellulose, pectin compounds, and other polysaccharides, ultimately thickening the cell walls and resulting in a harder texture (Prothon *et al.*, 2001; Tran & Chen, 2013). Table 1 shows that as the concentration of sucrose in the ginger extract increases up to 50% w/v, the Fmax of the resulting coconut chips also increases. However, at a concentration of 75% w/v, the Fmax of the coconut chips decreases, although it is still significantly higher than the control. At this highest concentration of sucrose, it is presumed that there is excessive osmotic pressure, leading to massive water loss from the coconut fruit cells, which can disrupt cell structure and result in a softer texture (Chauhan *et al.*, 2011).

Hardness (N/mm) represents the ratio between the maximum force applied to the sample and the maximum deformation just before the sample breaks or fractures (Shirvani *et al.*, 2014; Tran & Chen, 2013). Table 1 shows that the hardness of the coconut chips increases with the addition of sucrose in the ginger extract used for the immersion ($F_{calculated}$ 21.74 > $F_{0.05}$ 4.07). This increase reaches three to nine times the hardness of the coconut chips without sucrose addition (control). The peak increase in coconut chip hardness is observed at 50% w/v, and then it decreases again at a 75% w/v sucrose concentration. This fluctuation in hardness aligns with the Fmax of the coconut chips, which increases along with the increasing concentration of sucrose (peak at 50% w/v) and then decreases at a concentration of 75% w/v sucrose.

The increase in Fmax (N) followed by an increase in hardness (N/mm) of the coconut chips indicates a change in the texture of the coconut chips to a firmer consistency. From Table 1, it can be observed that the coconut chips resulted by immersion with sucrose addition in ginger extract are harder compared to the control (without sucrose addition). However, this hardness is also necessary to maintain the integrity of the chips during storage or product distribution before reaching the consumers. Coconut chips with lower hardness are reported to be more prone to breakage or crumbling during packaging and handling (Pravitha *et al.*, 2022).

The change in hardness of the coconut chips is presumed to be related to the moisture content of the chips (Table 1). Coconut chips resulting from all concentrations of sucrose have lower moisture content and higher hardness compared to the coconut chips without sucrose addition (control). These results align with previous research (Kingcam *et al.*, 2008), which reported that a faster rate of moisture reduction leads to faster structural changes in the material, resulting in increased hardness and firmness of dried potato chips. Additionally, other research (Barret *et al.*, 2010) reported that the integrity of the material determines its toughness. The higher the integrity of the material, the higher its toughness. In this study, the structural integrity within the coconut chips is formed by sucrose migrating into the coconut fruit tissue during immersion. The sucrose molecules crystallize during the drying process. These sugar crystals contribute to Fmax and hardness in the coconut chips. Therefore, it is presumed that a higher concentration of sucrose would increase the amount of sucrose within the coconut fruit tissue, ultimately increasing Fmax and hardness of the coconut chips. However, the decrease in hardness at the highest sucrose concentration treatment is likely due to the beginning of structural disruption and cell wall damage caused by excessive osmotic pressure.

Deformation, in the context of this study, refers to the maximum change in shape (measured in mm) caused by the maximum force just before a sample breaks or fractures during compression testing (Tran & Chen, 2013). The deformation parameter can be used to determine the flexibility or brittleness of the chips. Materials with the same Fmax can exhibit higher hardness or lower deformation, indicating that the material is more brittle or less flexible (Şimşek & Palazoğlu, 2017). From previous research on coconut chips with various osmotic agents, a decrease in deformation also provides a positive sensory impression by increasing crispness, although the acceptability level may decrease due to a perception of easy breakage or decreased hardness (Pravitha *et al.*, 2022). In this study, the increase in Fmax is also accompanied by a decrease in deformation (Table 1), enhancing crispness and compensating for the increased hardness in terms of sensory perception. The decrease in deformation is presumed to be caused by the separation of fibers within the coconut fruit tissue, which has a higher moisture content. As reported by previous research (Mayor *et al.*, 2007), water molecules fill the spaces between these fibers.

The importance of deformation in texture measurements is also supported by the other research (Triawan *et al.*, 2021), who reported that crispness, which can be indicated by the strain energy value, is influenced not only by the Fmax value but also by deformation. The smaller the deformation while maintaining the same Fmax, the smaller the strain energy, indicating an increase in crispness. The effect of deformation on crispness will be further discussed in the analysis of the sensory texture evaluation.

3.3. Sensory characteristics

The concentration of sucrose added to the ginger extract significantly affected the preference of the panelists toward the color, taste, and overall parameters. According to Table 2, as the sucrose concentration increases, the panelists' preference toward the color, taste, and overall quality of the coconut chips also increases.

Table 2. Sensory characteristics of coconut chips produced from 1-hour immersion in ginger extract

Sucrose concentration (% w/v)	Color	Aroma	Taste	Texture	Overall
25	$3.0^{a} \pm 0.3$	$3.0^{a} \pm 0.2$	$2.6^{a} \pm 0.3$	$3.1^{a} \pm 0.4$	$2.8^{a} \pm 0.1$
50	$2.9^{ab} \pm 0.9$	$3.1^{a} \pm 0.4$	$3.0^{ab} \pm 0.7$	$3.2^{a} \pm 0.5$	$2.9^{ab} \pm 0.7$
75	$3.5^{b} \pm 0.1$	$3.4^{a} \pm 0.6$	$3.6^{b} \pm 0.4$	$3.3^{a} \pm 0.3$	$3.5^{b} \pm 0.3$

The average with the same alphabet in the same column indicates no significant difference at α 5% significance level according to the Duncan Multiple Range Test (DMRT)

The increase in panelists' preference toward the color is presumed to be related to the change in the chip's color chips to a yellow-brown with increasing sucrose concentration. This finding is also reported by other research (Pravitha *et al.*, 2022), which stated that panelists do not prefer plain white coconut chips but prefer coconut chips with a golden-yellow and reddish-yellow color. Previous research (Iijima & Joh, 2014) reported the presence of pigment compounds in ginger that contribute to a pale-yellow color, such as curcumin, demethoxycurcumin, and 6-dehydrogingerdione. Among these compounds, 6-dehydrogingerdione is the most stable. This pigment compound is presumed to contribute to the yellow color of the coconut chips. The facilitation of compound migration from the ginger extract by the sucrose concentration gradient enables the migration of these pigment compounds into the coconut flesh during immersion. Additionally, based on the other research report (Quintas *et al.*, 2007), thermal processes below 160 °C allow the sucrose caramelization reaction, resulting in the formation of dark brown-colored pigment compounds, even though the reaction may not be in the logarithmic or maximal phase as at 160 °C. As the sucrose concentration in the material increases, the amount of sucrose degradation products contributing to the dark brown color also increases.

The increased preference toward the taste is related to the migration of taste-contributing compounds from ginger extract (especially gingerol and shogaol) into the coconut flesh. It is indicated by the increase of antioxidant activity (Figure 1) as the increase in sucrose concentration. The antioxidant activity is also contributed by the flavor-contributing compounds of ginger, particularly gingerol and shogaol. Another important finding is that although sucrose concentration affects the taste, it does not affect the aroma. The aroma-contributing compounds such as zingiberene, curcumene, and phellandrene are volatile (Nakamnanu *et al.*, 2019), leading them to evaporate during the thermal process, while shogaol is a thermal degradation product of gingerol (Ghasemzadeh *et al.*, 2018). Shogaols were accumulated more during the drying and roasting stages. Shogaol is reported to produce a distinctive spicy and hot sensation, which is stronger than gingerol. Therefore, the osmotic treatment with sucrose has a more significant impact on ginger's distinctive taste than ginger's distinctive aroma.

The preference of the panelists for the texture of coconut chips was not affected (Table 2), even though instrumental texture analysis showed a significant effect of sucrose concentration on the texture of coconut chips (Table 1). This finding indicates that the observed changes in texture through instrumental analysis still fall within the acceptance range of the panelists. Based on the findings of previous research (Pravitha *et al.*, 2022), instrumental texture analysis is closely related to sensory texture analysis. Lower values of hardness and rupture time (equivalent to deformation) from instrumental texture analysis are followed by higher sensory acceptance of crispness, although overall sensory acceptance may decrease because panelists perceive that the product is more prone to damage during packaging and distribution. Based on Table 1, this study shows that a decrease in deformation compensates for the increase in hardness. Deformation in the instrumental analysis also indicates the time required for a force (including Fmax) to cause the tested sample to rupture under compression, as the analysis is performed at a constant speed. Thus, deformation can explain how long a panelist must bite down with a certain force before the sample ruptures. Lower deformation means a shorter time for a panelist to exert force by biting, although the greater force required. This shorter time affects the panelists' perception of the acceptance of the texture of coconut chips. The panelists perceive that the three samples are similar regarding crispness because they only need to bite down for a shorter period, even though a higher force is required for biting. The significance of deformation is also evident in the other study (Pravitha *et al.*, 2022), reporting that samples with higher acceptance had low hardness and deformation (equivalent to deformation time) as well. These results provide insights into the importance of deformation as a key parameter in texture analysis to provide a comprehensive discussion on the texture of food products, particularly coconut chips.

The increased preference of the panelists toward the color and taste of coconut chips, along with the increase in sucrose concentration, contributes to the overall preference for coconut chips. Although there was an increase in preference compared to using 25% w/v sucrose, the preference scores for color, taste, and overall coconut chips with 75% w/v sucrose treatment did not significantly differ from the 50% w/v treatment.

4. Conclusions

The addition of sucrose in ginger extract used for immersion of coconut flesh increased antioxidant activity, Fmax, hardness, and panelists' preference toward color, taste, and overall parameters. However, it reduced the deformation of the coconut chips. The significant changes in texture assessed instrumentally had no influence on the panelist's preference. These findings highlight the potential of osmotic treatment with sucrose in enhancing the quality and functional properties of coconut chips obtained from immersion in ginger extract. Based on the antioxidant activity parameter, using sucrose to induce osmotic dehydration enhanced the effectiveness of immersion, thus a reduction in the immersion time can be achieved. Furthermore, the utilization of osmotic treatment to accelerate the migration of other functional compounds into various food materials could potentially be further developed.

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