AGROINDUSTRIAL TECHNOLOGY JOURNAL
ISSN : 2599-0799 (print) ISSN : 2598-9480 (online)
Accredited SINTA 3: No.225/E/KPT/2022

Effects of Maltodextrin on Characteristics of Calamansi Orange Peel (*Citrofortunella microcarpa*) as A Green Tea Flavor

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Article history:
Submitted: 10 January 2025
Revision: 3 March 2025
Accepted: 18 March 2025
Online: 31 May 2025
DOI : http://doi.org/10.21111/atj.v9i1.13663

ABSTRACT: *Calamansi orange peel contains bioactive compounds and essential oils but is often discarded as waste instead of being utilized. This research aims to determine the effect of adding maltodextrin during the drying process on the characteristics of calamansi orange peel and to assess panelists' acceptance of its use as a green tea flavoring. The study employed a Completely Randomized Design (CRD) with one factor, namely maltodextrin concentration (6%, 8%, 10%). Drying was carried out for 7 hours using an oven at 60 ºC. The organoleptic test was conducted by brewing 3 g of a mixture of green tea and calamansi peel powder in a 1:2 ratio in 220 ml of hot water at a temperature of 85 ºC for 5 minutes. The results showed that the calamansi peel powder had a moisture content of 1.41–3.41%, vitamin C content of 58.67–108.53 mg/100g, and volatile reducing substance (VRS) content of 6.5–12 meq. The highest level of panelists' preference for calamansi powder as a green tea flavoring was observed in the treatment with the addition of 10% maltodextrin, ranging from "liked" to "very liked."*

Keywords: *Calamansi orange peel; Flavor; Green tea; Maltodextrin*

1. INTRODUCTION

Calamansi lime (*Citrofortunella microcarpa*) is a hybrid between *Citrus* sp. and *Fortunella* sp. This fruit is a key horticultural commodity produced in Bengkulu Province Calamansi lime is small in size, with thin yellowish-green skin and a sour taste when ripe. It can grow up to 5 meters in height (Novita et al., 2017). A single calamansi lime contains 12 calories, 1.2 g of fiber, 37 mg of potassium, 7.3 mg of vitamin C, 57.4 IU of vitamin A, and 8.4 mg of calcium (Venkatachalam et al., 2023). One of the byproducts of calamansi lime syrup production is its discarded peels, which make up approximately 20% of the fruit's weight. Despite being treated as waste, these peels hold significant potential for further utilization.

Calamansi lime peel contains 0.15% ascorbic acid, 1.00% flavonoids, 0.51% pectin, 0.51% limonin, 5.98% reducing sugars, and 4.25% essential oil (Zou et al., 2020). The total volatile intensity of the calamansi lime peel was more than three times that of the juice. The dominant peel volatiles included limonene (10.53-27.85%), (Z)-3-hexenol (4.8512.51%), linalool (9.40-10.29%), 1-octanol (2.55-2.84%), α-terpineol (4.00-7.80%), iv isopiperitenone (1.91%), geraniol (0.79-1.06%), 8-hydroxylinalool (1.20-2.12%), (E)-ρ- mentha-2,8-dien-1-ol (0.39-1.61%), and hexadecanoic acid (0.81-1.31%) (Romero, 2020). Volatile compounds constitute approximately 99.26% of lime peel (Ayala et al., 2021). Additionally, alkaloids, flavonoids, saponins, terpenoids, and tannins have been identified in calamansi lime peel (Amiliah et al., 2021).

D-limonene, the primary component of calamansi lime essential oil, has been associated with numerous biological and pharmacological benefits, including antioxidant, antibacterial, anti-inflammatory, anti-hyperglycemic, anti-diabetic, anti-angiogenic, and anti-tumor properties (Venkatachalam et al., 2023). Further processing of calamansi lime peel can transform it into a marketable product, such as calamansi lime peel powder, which can serve as a natural flavoring in food products.

The increasing awareness of health benefits has driven extensive research on functional foods. Many studies focus on tea as a functional food product. The market has experienced a proliferation of various processed tea products. Researchers have explored different tea varieties, processing methods, and their respective benefits and characteristics. To optimize the health benefits and active compounds in tea while appealing to a broader audience and boosting sales, the development of more innovative tea varieties is necessary. Fragrant, organic, caffeine-free, herbal, and aromatic tea variants have become integral to the tea processing industry’s product lines. One potential product innovation is calamansi lime-flavored tea, which can serve as a form of product diversification.

The high moisture content of calamansi lime peel makes it susceptible to unpleasant odors and microbial growth. Therefore, drying is essential to enhance its usability. Sirait, (2018) processed calamansi lime peel into powder using an oven at 80°C for two hours. The resulting powder was utilized as a flavoring agent for green tea. Sensory panel evaluations indicated that the green tea infused with calamansi lime aroma was rated between "moderately liked" and "liked." This outcome was attributed to the loss of volatile compounds during the drying process.

Research conducted by (Widowati et al., 2022) investigated the addition of dried lemon peel as a flavor enhancer in herbal tea made from moringa leaves. The study found that dried lemon peel did not significantly mask the unpleasant aroma of moringa leaves, and the resulting flavor was not pronounced. This outcome was likely due to the absence of coating agents during the drying process.

Hidayatulloh et al., (2022) developed a beverage using a mixture of pomelo, young lime, and lemon peels. After boiling, the citrus peels were dried in a cabinet dryer at 55°C for approximately 24 hours. The resulting beverage had a pH of 6.77–6.84, indicating a near-neutral pH. Descriptive sensory analysis revealed that the beverage exhibited minimal sourness and sweetness.

Drying temperature and duration are critical factors in the preparation of lime peel powder. Volatile compounds in lime peel are highly susceptible to evaporation, while vitamin C is particularly prone to degradation during processing. Therefore, a coating material is required to protect the flavor components and vitamin C in calamansi lime peel, preventing deterioration during drying. One suitable coating material is maltodextrin, a safe and widely used food additive. Maltodextrin plays a crucial role in the drying process for several reasons: it accelerates drying, protects flavor components from heat, increases volume and total solids, and provides encapsulation.

Arifin, (2006) incorporated 8% maltodextrin into lemon peel before drying, and the resulting lemon peel powder was used as a flavoring agent for tea bags. Sensory panel evaluations indicated that the tea product was rated between "liked" and "strongly liked." Other researchers have also utilized maltodextrin as a coating agent in the production of fruit extract powders (Furayda & Khairi, 2023); (Gonardi et al., 2022); (Santana et al., 2023). Similarly, Erfianti et al., (2023) employed maltodextrin in the production of natural colorant powders derived from periwinkle flowers. These studies demonstrated that the properties of the resulting powders were influenced by the addition of maltodextrin. Maltodextrin has also been used by Cahyani & Widodo, (2024) in the encapsulated fermentation of noni fruit. The use of maltodextrin resulted in the lowest moisture content and the highest carbohydrate content compared to gelatin and xanthan gum. This study aims to examine the effect of maltodextrin addition during the drying process on the characteristics of calamansi lime peel powder and to evaluate sensory panel acceptance when used as a flavoring agent for green tea.

2. MATERIALS AND METHODS

2.1. Materials

The raw materials used are fresh calamansi lime peel, green tea powder, and maltodextrin. Chemicals required for analysis include distilled water (aquades), NaOH, $KMnO_4$, 20% KI, H_2SO_4, $Na_2S_2O_3 \cdot 5H_2O$, filter paper, phenolphthalein (PP) indicator, and starch indicator.

2.2. Equipment

The equipment used includes an air-flow oven (Memmert UN110), grinder (Philips), 35-mesh sieve (Endicotts), gas stove (Rinnai), VRS (Volatile Reducing Substance) aeration flask, porcelain dish, analytical balance (Sartorius ED224S), pH meter (009(I)A), desiccator, and various glassware.

2.3. Research Design

This study uses a Completely Randomized Design (CRD) with one factor, namely maltodextrin concentration, which consists of three levels (6%, 8%, and 10%). The experiment is repeated three times.

2.4. Research Procedure

2.4.1. Preparation of Calamansi Lime Peel Powder

Fresh greenish-yellow calamansi lime was obtained from the Agricultural Development Institute of the Baptist Mission (LPPB) in Pondok Kubang, Central Bengkulu. The lime peel was separated from the pulp and seeds, washed, and cut into slices with a thickness of approximately 3 mm. The peel was blanched by soaking it in water at 85°C for 3 minutes. Maltodextrin was then added according to the treatment levels (6%, 8%, and 10%). The peel was dried using an air-flow oven at 60°C for 7 hours. The dried calamansi lime peel was ground using a grinder and sieved with a 35-mesh sieve. The resulting calamansi lime peel powder was analyzed for moisture content, vitamin C content, and Volatile Reducing Substances (VRS).

2.4.2. Determination of Moisture Content

The moisture content was determined using the gravimetric method. A 5 g sample was dried in an oven at 105°C until a constant weight was achieved. The moisture content was calculated using the formula:

$$\text{Moisture content (\%)} = \frac{a-b}{a} \times 100\% \quad (1)$$

Where:

a = initial weight of the sample

b = final weight of the sample

2.4.3. Determination of Vitamin C Content

The vitamin C content was determined using the iodometric titration method (Sudarmadji et al., 1997). A 10 g sample was placed in a 100 mL volumetric flask and distilled water was added to reach the mark. The solution was filtered using filter paper. A 25 mL aliquot of the filtrate was placed in an Erlenmeyer flask and mixed with 1 mL of 1% starch solution. The mixture was then titrated with 0.01 N iodine solution until a blue color appeared. One milliliter of 0.01 N iodine solution is equivalent to 0.88 milligrams of ascorbic acid. The vitamin C content was calculated using the formula:

$$\frac{\text{mg ascorbic acid}}{\text{100 g sample}} = \frac{\text{mL Iod 0,01 N x 0,88 x dilution factor}}{\text{sample weight}} \text{X100} \quad (2)$$

2.4.4. Volatile Reducing Substances (VRS) Value

Using a VRS (Volatile Reducing Substances) apparatus, 1 g of calamansi lime peel powder was placed into a flask with 10 mL distilled water and 10 mL potassium hydroxide. After 40 minutes of setup, 5 mL of 6 N H_2SO_4 and 3 mL of 20% KI were added to the flask. The yellow solution was titrated with 0.02 N sodium thiosulfate in an Erlenmeyer flask. To eliminate the blue color, a starch indicator was added, and the titration was repeated. The titrant volume was recorded as **b** milliliters. A blank was also titrated, and its volume was recorded (a millliliters). The VRS value was calculated using the formula (Sailah & Miladulhaq, 2021):

$$VRS\ (mEq) = \frac{a-b\ x\ N\ Na\text{-}tiosulfat\ x\ 1000}{sample\ weight\ (g)} \quad (3)$$

2.4.5. Preparation of Calamansi-Flavored Green Tea

Calamansi-flavored green tea was prepared by mixing green tea powder with calamansi lime peel powder in a ratio of 2:1. The mixture was then packed into tea bags, with each bag weighing 3 g.

2.4.6. Organoleptic Test

An organoleptic sensory evaluation was conducted to assess panelists' preference levels for the color, aroma, and aftertaste of three samples of calamansi-flavored green tea infusions. Quantitative evaluations were expressed numerically based on the panelists' preferences. Twenty-five untrained panelists participated in the evaluation (Hastuti, 2017). Scores were assigned on a scale from 1 to 5, as shown in Table 1.

Table 1. Organoleptic scale

Hedonic Scale	Score
Dislike	1
Slightly like	2
Moderately Like	3
Like	4
Strongly Like	5

2.4.7. Sample Preparation for Organoleptic Test

The sample preparation for the organoleptic test was conducted by brewing one bag of calamansi-flavored green tea (3 g) with 220 mL of hot water at 85 °C for 5 minutes. Panelists were asked to evaluate the three provided samples, with the condition that after assessing one sample, they should drink plain water before proceeding to the next sample.

2.5. Data Analysis

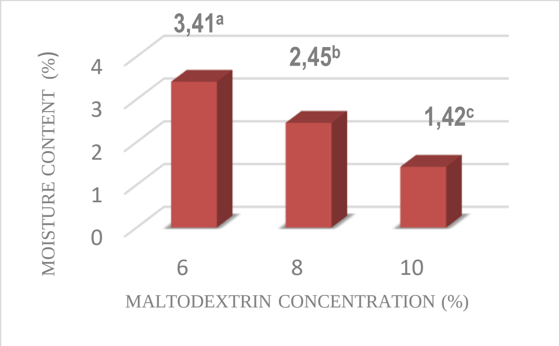
This study utilized ANOVA (Analysis of Variance) with a 5% significance level and DMRT (Duncan's Multiple Range Test) for additional testing to ensure data variability.

3. RESULTS AND DISCUSSION

3.1. Calamansi Peel Powder

3.1.1 Moisture Content

The percentage representation of a material's water content indicates the amount of water it contains. Since it affects the appearance, taste, and aroma of food, moisture content is an important quality parameter that must be considered in food products. However, if the moisture content is too high, mold, yeast, and bacteria may thrive, leading to food spoilage (Suriati et al., 2023). The results of the moisture content analysis of calamansi peel powder are presented in Figure 1.



Note: Numbers followed by the same letter indicate no significant difference.

Figure 1. Moisture Content (%) of Calamansi Peel Powder at Various Maltodextrin Concentrations (%)

Based on the ANOVA results, the moisture content of calamansi peel powder was significantly influenced by maltodextrin concentration ($p < 0.05$). Additional testing using DMRT at $\alpha = 5\%$ revealed significant variations in the moisture content of calamansi peel powder among all treatments. The average moisture content ranged from 1.42% to 3.41%.

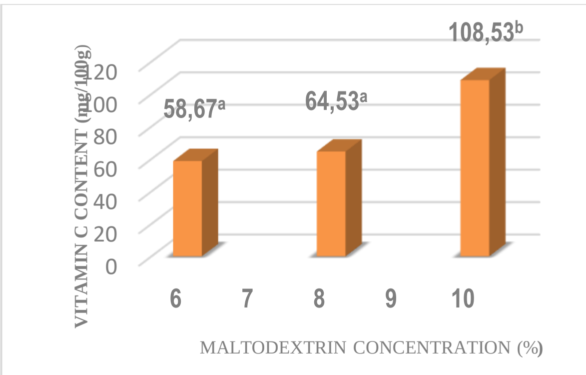
The moisture content of calamansi peel powder decreases as the concentration of maltodextrin increases, as shown in Figure 1. Since maltodextrin has the ability to absorb water, a higher maltodextrin concentration results in lower moisture content. The addition of 2% maltodextrin was able to reduce the moisture content of calamansi peel powder by approximately 1%. These findings align with the studies of Gonardi et al., (2022) on tomato powder production and Kusuma et al., (2023) on red watermelon powder production.

Maltodextrin, an incompletely hydrolyzed starch complex, contains a mixture of monosaccharides, short-chain oligosaccharides, and long-chain oligosaccharides in varying proportions. Maltodextrin has a wide range of dextrose equivalent (DE) values, ranging from 3 to 20, indicating the level of reducing sugar content. Although water binds weakly to maltodextrin, reducing sugars contain hydroxyl (-OH) groups that can bind free water. The ability of a mixture to bind free water in a material can be enhanced by adding more maltodextrin, which increases the amount of reducing sugars. Weak hydrogen bonds are formed when free water in the material interacts with maltodextrin (Kaixin et al., 2020). According to Tran & Nguyen, (2018), due to differences in binding strength between water within the material's matrix and water absorbed by maltodextrin, the water absorbed by maltodextrin evaporates more easily than the water bound within the material itself.

3.1.2 Vitamin C Content

Vitamin C plays a crucial role in various bodily functions. Its antioxidant properties help strengthen the immune system, minimize oxidative stress, and counteract free radicals (Makmun & Rusli, 2020). However, vitamin C is highly unstable and easily degraded during processing, including drying (Paramita, 2023). The vitamin C content of calamansi peel powder ranged from 58.67 mg/100 g to 108.53 mg/100 g. The test results for vitamin C content are shown in Figure 2.

ANOVA testing showed that the addition of maltodextrin significantly affected the vitamin C content of calamansi peel powder ($p < 0.05$). Further analysis using DMRT at $\alpha = 5\%$ revealed significant differences in vitamin C content between the 10% maltodextrin treatment and the 6% and 8% maltodextrin treatments.



Note: Numbers followed by the same letter indicate no significant difference.

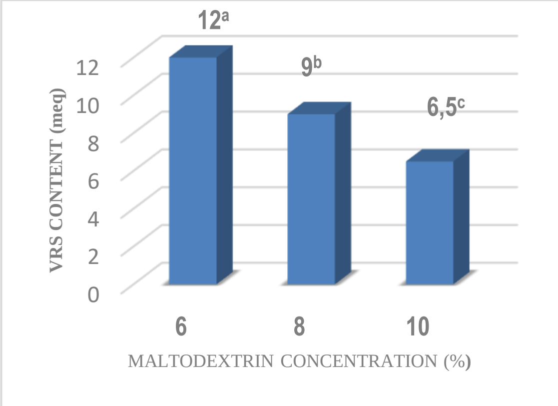
Figure 2. Vitamin C Content (mg/100 g) of Calamansi Peel Powder at Various Maltodextrin Concentrations (%)

As shown in Figure 2, increasing the amount of maltodextrin during the drying process enhances the retention of vitamin C in calamansi peel powder. The addition of 10% maltodextrin demonstrated a significantly greater ability to preserve vitamin C compared to the 6% and 8% concentrations. Maltodextrin can prevent vitamin C degradation due to its capability as an encapsulating agent that protects sensitive compounds from harmful environmental factors. Vitamin C (ascorbic acid) is highly susceptible to oxidation when exposed to air, light, and high temperatures. Maltodextrin forms a protective layer around vitamin C molecules, reducing direct contact with oxygen and slowing down the oxidation reaction. Suriati et al., (2023) et al. also used maltodextrin as a coating agent in the drying process of Aloe-bignay instant drink. The highest vitamin C content was obtained at a 10% maltodextrin concentration and a drying temperature of 40°C.

Maltodextrin possesses a high binding capacity, allowing it to encapsulate chemical compounds, particularly those with antioxidant activity. It effectively encapsulates nutrients, flavors, vitamins, and antioxidants, thereby preserving them in a stable form (Gabriela et al., 2020).

3.1.3 Volatile Reducing Substance (VRS) Content

Volatile Reducing Substance (VRS) refers to components present in a material or product that do not decompose, contributing to a unique aroma. A stronger aroma indicates a higher concentration of VRS. Calamansi peel contains 4.25% volatile compounds (Zou et al., 2020). These compounds are susceptible to loss or evaporation during heating processes, despite their significant role in aroma formation. To prevent the complete loss of volatile compounds during powder production, maltodextrin was added. The results of the VRS analysis are shown in Figure 3.



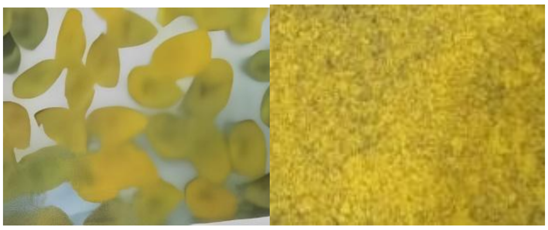
Note: Numbers followed by the same letter indicate no significant difference.

Figure 3. VRS Content (meq) of Calamansi Peel Powder at Various Maltodextrin Concentrations (%)

The ANOVA results indicated that the VRS content of calamansi peel powder was significantly influenced by maltodextrin concentration ($p < 0.05$). Additional testing using DMRT at $\alpha = 5\%$ confirmed significant differences among all treatments. The highest volatile compound evaporation occurred in the 6% maltodextrin treatment, reaching 12 meq, while the lowest was observed in the 10% maltodextrin treatment, at 6.5 meq. Maltodextrin can preserve volatile compounds during the drying process. Maltodextrin encapsulates the essential oil pockets in calamansi peel, reducing the risk of volatile compound evaporation during the drying process. A 10% concentration of maltodextrin provides stronger protection for volatile compounds in calamansi orange peel compared to concentrations of 6% and 8%, resulting in fewer volatile compounds being released during drying. A higher maltodextrin concentration resulted in less volatile compound evaporation during drying. The primary component of calamansi essential oil is D-limonene (Venkatachalam et al., 2023). These findings align with those of Arifin, (2006) in the production of lemon peel powder.

3.2. Organoleptic Testing of Calamansi-Flavored Green Tea

The calamansi peel powder produced (Figure 4) was applied as a flavoring in green tea, resulting in calamansi-flavored green tea. The ratio of green tea to calamansi peel powder was 2:1. The brewed tea was evaluated by 25 untrained panelists to determine preference levels based on color, aroma, and aftertaste. The results of the oraganoleptic test are shown in Table 2.



a b

Figure 4. (a) Dried Calamansi Peel; (b) Calamansi Peel Powder

Table 2. Organoleptic test results

Hedonic Parameter	Concentration Maltodextrin (%)		
	6	8	10
Color	3.56[a]	3.64[a]	4.28[b]
Aroma	3.72[a]	4.32[b]	4.60[b]
Aftertaste	3.48[b]	2.76[a]	2.64[a]

Note: Numbers followed by the same letter in the same row Indicate no significant difference (α = 0.05).

3.2.1 Organoleptic Test Results for Color

Color plays a crucial role in attracting consumers. If a food product tastes good but looks unappealing or has changed color, it may be considered inedible regardless of its flavor. Color is a key component to increase the ultimate appetizing value and consumer acceptance towards foods and beverages (Dey & Nagababu, 2022).

The 25 panelists gave color preference scores ranging from 3.56 to 4.28 (Table 2). The ANOVA results showed that panelists' approval of the color of calamansi-flavored green tea infusion was significantly influenced by maltodextrin concentration ($p < 0.05$). Additional testing using DMRT at α = 5% indicated that panelist approval dramatically increased when 10% maltodextrin was added, compared to the 6% and 8% treatments.

The color of green tea brewed water is influenced by the content of metabolite compounds. According to Kochman et al., (2021), green tea powder is high in catechins, caffeine, polyphenols, quercetin, vitamin C, tannins, and chlorophyll. The color of chlorophyll and carotenoid pigments in green tea powder is influenced by the type of clone (Mauliyah et al., 2023)

Meanwhile, calamansi peel powder appears yellow, as it contains 92.67% limonene (Venkatachalam et al., 2023). The addition of maltodextrin helps preserve these color components, ensuring that the calamansi-flavored green tea infusion retains a yellowish hue, similar to traditional tea. Panelist preference scores were significantly higher compared to those reported in a previous study by (Sirait, 2018).

3.2.2 Organoleptic Test Results for Aroma

Aroma is perceived through the sense of smell and, together with color, is a key determinant in consumers' final purchasing decisions. The aroma preference test results for the calamansi-flavored green tea infusion are shown in Table 2.

Panelist aroma acceptance scores ranged from 3.72 to 4.60 (like to strongly like). The ANOVA results showed that panelists' acceptance of the calamansi aroma in brewed green tea was significantly influenced by maltodextrin concentration ($p < 0.05$). Further DMRT analysis at α = 5% revealed a significant difference when 6% maltodextrin was added, compared to 8% and 10%.

The addition of maltodextrin helped preserve the volatile compounds in calamansi peel, allowing the aroma to remain noticeable when used as a flavoring in green tea. Calamansi has a strong, distinctive citrus fragrance, which aligns with the VRS analysis results, confirming that higher maltodextrin concentrations reduce volatile compound evaporation during drying.

3.2.3 Organoleptic Test Results for Aftertaste

The "aftertaste" refers to the lingering flavor sensation immediately after swallowing. The bitter and sour taste of the calamansi green tea brew is attributed to the bioactive compounds present in green tea and calamansi orange peel. Alkaloids, catechins, anthocyanins, phenolic acids, flavonol glycosides, and theaflavins importantly contribute to the bitter and astringent taste of tea infusion, the contents of which can be modulated during preharvest, processing, and post-processing (Ye et al., 2022). This statement is consistent with Nugraheni's findings, which indicate that the astringent and bitter taste of green tea is caused by tannin and catechin compounds (Wangiyana et al., 2021). Bitterness is also present in citrus peels. The bitter taste is caused primarily by its limonoids and flavonoids, particularly limonin and naringin (Konwar et al., 2024).

Panelist acceptance scores for aftertaste ranged from 2.64 to 3.48. ANOVA results showed that the aftertaste of calamansi-flavored green tea infusion was significantly affected by maltodextrin concentration ($p < 0.05$). Further DMRT analysis at $\alpha = 5\%$ indicated that panelist acceptance significantly differed when 6% maltodextrin was added, compared to 8% and 10%, with the highest score observed in the 6% maltodextrin treatment.

This result is consistent with the VRS analysis, showing that lower maltodextrin concentrations retain more volatile compounds, leading to a less intense bitter aftertaste. Conversely, higher maltodextrin concentrations result in greater volatile compound loss, enhancing the bitterness and astringency of the tea.

4. CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

The addition of maltodextrin during the drying process of calamansi peel significantly affects the moisture content, vitamin C content, and Volatile Reducing Substance (VRS) levels of calamansi peel powder. The higher the maltodextrin concentration, the lower the moisture content and VRS levels, while the vitamin C content increases. The addition of maltodextrin also significantly influences panelists' acceptance (color, aroma, and aftertaste) of the brewed calamansi-flavored green tea. As the maltodextrin concentration increases, the scores for color and aroma become higher, while the aftertaste score decreases. The results of this study have the potential to be applied to the manufacture of calamansi orange-flavored tea products.

RECOMMENDATIONS

Further research is needed to determine the optimal maltodextrin concentration for producing higher-quality calamansi-flavored green tea.

ACKNOWLEDGMENTS

Gratitude is extended to all parties who have contributed to the smooth progress of this research, in particular the Agricultural Technology Laboratory, Department of Agricultural Technology, Faculty of Agriculture, University of Bengkulu.

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