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Physicochemical properties of carrot (*Daucus carota* L.) milk produce from rotary extraction

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Abstract

The objective of this study was to evaluate how the concentration ratio of trehalose and Carrot Extract affected the features of carrot milk powder. The experiment utilized a random block design with repeated 3 x 3 factorials, followed by Duncan's test. Trehalose concentrations (5%, 7.5%, and 10%) and Carrot Extract concentrations (10%, 15%, and 20%) comprised the experimental variables. This study's results include water content, total carotenoids, antioxidant activity, yield, viscosity after rehydration, solubility, dissolving time, color intensity, as well as hygroscopic and hedonic tests on color, flavor, and aroma. The results demonstrated that the concentrations of trehalose and Carrot Extract influenced the water content, yield, viscosity after rehydration, solubility, dissolving time, color measurement, and hygroscopic and hedonic tests on color, flavor, and scent. The relationship between trehalose content and Carrot Extract had an effect on yield, viscosity after rehydration, solubility level, solubility time, color intensity, and hygroscopic and hedonic tests. The t1w1 sample (trehalose 5% and Carrot Extract 10%) produced the best organoleptic findings.

Keywords: carrot extract; carrot milk powder; Trehalose; rotary drying.

Practical Application: Concentration of natural dyes used in the manufacture of carrot milk powder.

1 Introduction

According to Agricultural Statistics (Statistik Konsumsi Pangan, 2018), the annual carrot production rises. The average carrot production increase in Indonesia was 0.56%. β-carotene is one of the many elements that carrots have that are beneficial to the body. The β-carotene concentration of carrots is 8,285 g per 100 grams (United States Department of Agriculture, 2019).

β-carotene is a carotenoid, which is a pigment found naturally in plants and is orange in color. β-carotene has antioxidant properties. Compared to other forms of carotenoids, β-carotene inhibits free radicals most effectively (Mangunsong et al., 2019; Wahyuni et al., 2020). Carrots' high β-carotene content can be turned into functional powder drinks as an added benefit.

Drying is the process of removing the water content contained in a material. The drying process is carried out to produce solid and dry food, so that the volume of the material is more compact, easy and space-saving in transportation, besides that it can reduce costs and reduce difficulties in packaging, handling, transporting and storing. Drying according to Atuonwu et al. (2011) is basically a process of reducing the water content of a material or a relatively small separation of the material using heat energy. The result of the drying process is a dry material that has a lower moisture content.

Trehalose is a non-reducing disaccharide consisting of two glucose molecule. Trehalose is naturally found in mushrooms, shellfish and algae. Trehalose is considered to have better stability than other types of disaccharides. Trehalose is not sensitive to changes in temperature and pH. Trehalose is also a non-reducing sugar so it is not easy to digest hydrolyzed by acid (Sedijani, 2014).

Milk powder quality is complex because it is dependent on a complex combination of physical and functional properties of milk powder (Sharma et al., 2012). For example, the dissolution behaviour of the milk powder is driven by its physical properties, such as particle size distribution and bulk density, and functional properties such as dispersibility (Oldfield & Singh, 2005).

2 Materials and methods

2.1 Carrot extract production

Carrots of the chantenay variety are chopped into 1 cm 1 cm cubes and then pulverized in a blender with water at a ratio of 1:1. After that, a filter cloth is used to separate the particulates from the liquid in order to obtain Carrot Extract.

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2.2 Carrot milk powder making

The fresh milk, Carrot Extract, and trehalose are weighed in accordance with the formula. The components are then combined and placed in the rotary dryer machine. At a temperature of 70 °C, drying is carried out. After the drying process is complete, the resulting milk powder will be grinded and sifted through an 80-mesh screen.

2.3 Establishment of selected samples

The selection of chosen samples is based on the highest number of organoleptic findings scores. Then, on selected samples, total carotenoid analysis, antioxidant activity, PSA and SEM testing were conducted.

2.4 Design and statistical analysis of experiments

The experimental design was a 3x3 factorial block design that was replicated twice. Trehalose concentrations (5%, 7.5%, and 10%) and Carrot Extract concentrations (10%, 15%, and 20%) comprised the experimental variables. The data were evaluated using analysis of variance (ANOVA), followed by Duncan's test to identify changes that were statistically significant (P 0.05). P value less than or equal to 0.05 was considered significant.

3 Results and discussion

3.1 Moisture content

Moisture content decrease with the increase in the concentration of trehalose but increase with the increase in the concentration of Carrot Extract (Table 1).

Moisture content is one of the most essential milk powder properties. Foods with a high moisture content will perish rapidly, especially microbiologically. According to SNI 01-2970-2006, the maximum amount of moisture in milk powder is 5% (Badan Standardisasi Nasional, 2006). This demonstrates that the final product is compliant with SNI.

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Moreover, as the concentration of trehalose rises, the moisture content of carrot milk powder tends to fall. Moisture content is one of the most essential milk powder properties. Foods with a high moisture content will perish rapidly, especially microbiologically. According to SNI 01-2970-2006 (Badan Standardisasi Nasional, 2006), the maximum amount of moisture in milk powder is 5%. This demonstrates that the final product is compliant with SNI.

3.2 Viscosity after rehydration

Viscosity increase with the increase in the concentration of trehalose and Carrot Extract (Table 2).

Fresh milk viscosity ranges between 1.5 and 2.0 cP. This indicates that the addition of trehalose and Carrot Extract increases the viscosity (Qullana, 2021).

Increased trehalose concentration will increase the viscosity of carrot milk powder. The viscosity of a solution increases as the additional sugar concentration rises. The mechanism of increased viscosity is due to the presence of a hydroxyl group in the structure of trehalose, which binds to water molecules via hydrogen bonds, hence decreasing the amount of water in meals (Kim, 2010; Fitri, 2017).

Similarly, the addition of more Carrot Extract tends to improve the viscosity of rehydrated carrot milk powder. This is due to the fact that the higher the concentration of a solution, the more particles of the substance will be dissolved, so increasing the friction between particles and thus the viscosity of the solution (Lumbantoruan, 2016).

3.3 Yield

Yield decrease with the increase in the concentration of Carrot Extract but increase with the increase in the concentration of trehalose (Table 3).

Carrot milk powder output tends to diminish with increasing carrot content. This is because the higher the carrot content, the more liquid is produced, resulting in more water evaporating during the drying process. Therefore, it causes the material's weight to decrease and its yield value to fall (Andriani, 2013).

Table 1. The results of Moisture Content on Carrot Milk Powder.

Treatment	Moisture Content (%)
t1w1	3.43 ± 0.01[a]
t1w2	3.66 ± 0.23[a]
t1w3	3.76 ± 0.07[a]
t2w1	3.27 ± 0.01[a]
t2w2	3.39 ± 0.04[a]
t2w3	3.63 ± 0.02[a]
t3w1	3.23 ± 0.04[a]
t3w2	3.34 ± 0.13[a]
t3w3	3.58 ± 0.13[a]

Different letters in the same column mean that the data are statistically different from the least significant difference (p < 0.05).

Table 2. The results of Rehydration on Carrot Milk Powder Viscosity.

Treatment	Viscosity After Rehydration (cP)
t1w1	4.64 ± 0.11[a]
t1w2	4.87 ± 0.04[b]
t1w3	5.25 ± 0.21[de]
t2w1	4.81 ± 0.01[ab]
t2w2	5.13 ± 0.04[cd]
t2w3	5.22 ± 0.01[d]
t3w1	5.47 ± 0.16[e]
t3w2	5.44 ± 0.05[e]
t3w3	5.43 ± 0.12[e]

Different letters in the same column mean that the data are statistically different from the least significant difference (p < 0.05).

Table 3. The results of Yield on Carrot Milk Powder.

Treatment	Yield (%)
t1w1	12.15 ± 0.12[d]
t1w2	11.07 ± 0.14[bc]
t1w3	11.10 ± 0.28[c]
t2w1	14.90 ± 0.19[g]
t2w2	10.93 ± 0.14[a]
t2w3	11.03 ± 0.14[ab]
t3w1	14.50 ± 0.14[f]
t3w2	13.88 ± 0.12[e]
t3w3	13.62 ± 0.07[e]

Different letters in the same column mean that the data are statistically different from the least significant difference ($p < 0.05$).

Table 4. The results of Solubility on Carrot Milk Powder.

Treatment	Solubility (%)
t1w1	79.04 ± 0.55[f]
t1w2	72.54 ± 0.14[b]
t1w3	70.57 ± 0.64[a]
t2w1	77.49 ± 0.64[e]
t2w2	75.59 ± 0.43[d]
t2w3	73.97 ± 0.08[c]
t3w1	80.54 ± 0.16[g]
t3w2	74.77 ± 0.18[cd]
t3w3	74.39 ± 0.49[cd]

Different letters in the same column mean that the data are statistically different from the least significant difference ($p < 0.05$).

As the content of trehalose rises, the yield value of carrot milk powder tends to increase. This is due to milk powder's greater carbohydrate content. Unlike free water, solids such as carbs do not evaporate during the drying process, hence the higher the carbohydrate content, the higher the yield value will be.

3.4 Solubility

Solubility decrease with the increase in the concentration of Carrot Extract but increase with the increase in the concentration of trehalose (Table 4).

The higher the solubility value, the higher the created product quality. The more a product's solubility, the quicker it will dissolve in water since it may be served more conveniently (Alfonsius & Purwijantiningsih, 2015).

The higher the concentration of trehalose, the more solubility carrot milk powder will have. Due of sugar's high solubility in water, higher trehalose concentrations will be utilized, which will improve solubility. According to previous research, increasing the concentration of trehalose will increase the solubility of royal jelly powder (Haryanto, 2017; Li et al., 2022).

Moisture content is one of the elements that determine solubility. The greater a product's moisture content, the lesser its solubility. The greater the Carrot Extract content, the lower the solubility of carrot milk powder.

3.5 Dissolving time

Dissolving time increase with the increase in the concentration of Carrot Extract but decrease with the increase in the concentration of trehalose (Table 5).

Table 5. The results of Dissolving Time on Carrot Milk Powder.

Treatment	Dissolving Time (Secon)
t1w1	16.80 ± 0.42[a]
t1w2	36.51 ± 0.62[h]
t1w3	41.03 ± 0.13[i]
t2w1	21.02 ± 0.30[b]
t2w2	24.08 ± 0.44[d]
t2w3	33.50 ± 0.54[g]
t3w1	22.97 ± 0.26[c]
t3w2	27.69 ± 0.36[f]
t3w3	26.20 ± 0.60[e]

Different letters in the same column mean that the data are statistically different from the least significant difference ($p < 0.05$).

The higher the concentration of trehalose utilized, the faster carrot milk powder tends to dissolve. This is because a higher sugar concentration will boost a powdered product's solubility (Haryanto, 2017). Similar to solubility, the water content factor also influences the soluble time. The higher the moisture level of a food item, the more clots it will form and the longer it will take to break down the bindings between particles (Kaljannah, 2018). It is worth mentioning that this Physical and functional properties of milk powder varies with characteristic changes raw materials (i.e. milk) and milk powder processing conditions such as temperature, which has an impact on the end use of milk powder (Crowley et al., 2015).

3.6 Hygroscopicity

Dissolving time increase with the increase in the concentration of Carrot Extract but decrease with the increase in the concentration of trehalose (Table 6).

Hygroscopicity is the capacity of a solid to absorb moisture near its surface microscopically, A product is classified as non-hygroscopic if its hygroscopic value falls below 10% (Schuck et al., 2012).

3.55-5.3% is the average hygroscopic value of carrot milk powder. An increase in trehalose concentration tends to decrease the hygroscopicity of carrot milk powder. This is consistent with the hypothesis that trehalose has a water replacement feature, which permits water absorbed by foodstuffs to be replaced by hydrogen bonds generated by trehalose, so inhibiting the absorption of water into the material's surface (Zhang et al., 2021).

Hygroscopic properties are integrated with the water content component. The lower the moisture content, the more hygroscopic a substance is likely to be. However, as the water content of carrots increases, the hygroscopic properties tend to rise. This may arise as a result of inadequate product storage conditions. Temperature and humidity have an effect on hygroscopic properties. To prevent the product from being

Table 6. The results of Hygroscopicity on Carrot Milk Powder.

Treatment	Hygroscopicity (%)
t1w1	5.05 ± 0.07^{d}
t1w2	5.25 ± 0.07^{d}
t1w3	4.10 ± 0.14^{b}
t2w1	4.05 ± 0.07^{b}
t2w2	4.40 ± 0.14^{b}
t2w3	5.30 ± 0.14^{d}
t3w1	3.55 ± 0.21^{a}
t3w2	4.45 ± 0.21^{bc}
t3w3	4.60 ± 0.28^{c}

Different letters in the same column mean that the data are statistically different from the least significant difference ($p < 0.05$).

Table 7. The results of Colour Intensity on Carrot Milk Powder.

Treatment	L*	a*	b*
t1w1	67.98 ± 0.47^{b}	3.32 ± 0.14^{c}	25.40 ± 0.26^{cd}
t1w2	76.03 ± 0.61^{de}	6.00 ± 0.24^{g}	33.90 ± 0.09^{fg}
t1w3	62.74 ± 0.48^{a}	10.22 ± 0.09^{g}	36.98 ± 0.08^{g}
t2w1	76.85 ± 0.35^{e}	1.46 ± 0.05^{a}	24.30 ± 0.50^{b}
t2w2	84.05 ± 0.30^{h}	2.51 ± 0.12^{b}	22.36 ± 0.25^{a}
t2w3	67.44 ± 0.07^{b}	3.53 ± 0.08^{e}	26.47 ± 0.60^{e}
t3w1	79.88 ± 0.35^{f}	1.13 ± 0.08^{a}	25.77 ± 0.45^{de}
t3w2	75.78 ± 0.34^{c}	2.60 ± 0.48^{b}	21.99 ± 0.06^{a}
t3w3	83.84 ± 0.62^{gh}	3.51 ± 0.56^{de}	24.94 ± 0.08^{b}

Different letters in the same column mean that the data are statistically different from the least significant difference ($p < 0.05$).

hygroscopic, it must be kept at a low temperature and relative humidity (Ansar et al., 2006).

3.7 Colour intensity

L* value decrease but a* and b* value increase with the increase in the concentration of Carrot Extract however L* increase but a* and b* value decrease with the increase in the concentration of trehalose (Table 7).

Colorimetry measurement of carrot milk powder's color intensity (L*, lightness; a*, redness; and b*, yellowness). As the concentration of trehalose increases, the value of L* increases, whereas the values of a* and b* drop. This is because trehalose is a white powder that, when added, produces a bright color; the more trehalose is added, the brighter the carrot milk powder becomes, hence increasing the lightness value. However, as the brightness of carrot milk powder increases, the orange hue of carrot milk powder tends to diminish (Kaljannah, 2018).

In contrast, when carrot concentration is added, the L* value tends to decrease, while the a* and b* values grow more. This finding is owing to the presence of the orange pigment carotene in carrots. Carrot milk powder's lightness will diminish, but its a* and b* values will increase due to the inclusion of a carrot concentrate with a greater orange hue. This demonstrates that the link between Lightness and Carotenoids is inversely proportional, although the values of a* and b* are directly proportionate (Andhika, 2011).

3.8 Organoleptic responses

Organoleptic exposure is carried out against the attributes of color, aroma and taste. The increase of the concentration of trehalose and Carrot Extract tends to decrease the panellist's level of preference (Table 8).

Table 8. The results of Hedonic Test on Carrot Milk Powder.

Treatment	Color	Aroma	Flavor
t1w1	6.05 ± 0.03^{g}	5.87 ± 0.05^{h}	6.42 ± 0.07^{c}
t1w2	6.09 ± 0.02^{g}	5.47 ± 0.05^{d}	5.67 ± 0.19^{b}
t1w3	5.28 ± 0.21^{d}	5.60 ± 0.10^{e}	5.74 ± 0.09^{b}
t2w1	5.20 ± 0.10^{c}	5.77 ± 0.09^{f}	6.32 ± 0.16^{c}
t2w2	4.52 ± 0.16^{a}	4.60 ± 0.04^{a}	5.55 ± 0.11^{b}
t2w3	5.65 ± 0.21^{f}	5.27 ± 0.09^{b}	5.17 ± 0.05^{a}
t3w1	5.20 ± 0.04^{c}	5.82 ± 0.02^{g}	5.57 ± 0.05^{b}
t3w2	5.12 ± 0.12^{b}	5.34 ± 0.05^{c}	5.55 ± 0.11^{b}
t3w3	5.45 ± 0.07^{e}	5.44 ± 0.05^{c}	5.27 ± 0.09^{a}

Different letters in the same column mean that the data are statistically different from the least significant difference ($p < 0.05$).

The change in hue is observable due to the different concentrations of Carrot Extract and trehalose employed. The orangeness of the resulting milk powder will increase proportionately to the carrot content. Because carotene is an orange pigment, this is the case. As the concentration of Carrot Extract rises, so do the degrees of favorability. In the meantime, as the quantity of trehalose increases, the color of the milk powder lightens and the orange hue tends to disappear. This is because trehalose is a white powder that, when applied, produces a vibrant hue. Thus, as trehalose concentration increases, the amount of favorability falls (Mangunsong et al., 2019; Kaljannah, 2018).

The higher the concentration of carrots, the lower the value of the scent characteristic. Due of the carrots' langu scent, this is the case. The smell scent is disliked by certain users due to its high terpenoid volatile component content (Chodijah et al., 2019). However, the higher the concentration of trehalose, the greater the tendency for the fragrance attribute's value to grow. This is because trehalose can mask a material's off-notes.

Along with an increase in carrot concentration, the degree of desirability will decrease. This is because the natural flavor of carrots is both sweet and bitter. Due to the inclusion of carbohydrates such as glucose, fructose, and sucrose, the flavor is sweet.

3.9 Carotenoid content

On the basis of the organoleptic data, it is possible to determine that the selected sample is a t1w1 sample. The t1w1 treatment had 88 ppm total carotenoids (Table 9).

Total carotenoids of t1w1 treatment is 88 ppm. According to previous research 10% Carrot Extract added to yogurt has a total carotenoid concentration of 131 ppm (Febrihantama, 2014). This substantial drop is the result of the drying process.

Table 9. The results of Total Carotenoid Content on Carrot Milk Powder (t1w1).

Treatment	Total Carotenoid (ppm)
t1w1	88

Table 10. The results of Antioxidant Activity on Carrot Milk Powder (t1w1).

Treatment	Antioxidant Activity (ppm)
t1w1	2204.61

Carotenoids are typically destroyed by heat, light, and oxidation. Carotenoids' double bonds make them susceptible to oxidation. Drying and freezing might result in oxidation reactions (Karabacak & Karabacak, 2019).

3.10 Antioxidant activity

The t1w1 treatment had 2204.61 antioxidant activity (Table 10).

If a substance has an antioxidant value between 200 and 1,000 ppm, it is less effective as an antioxidant but still has the ability to inhibit oxidative damage (Molyneux, 2004).

According to previous research, the antioxidant activity in kefir eskrim with 5% Carrot Extract has a concentration of 930 ppm (Mahdiana, 2015). This large discrepancy is due to the drying process involved in the production of carrot milk powder. Antioxidant activity decreases when drying temperatures are too high. Due to the high heating temperature, secondary metabolite molecules (carotene) that can act as antioxidants would be destroyed (Dewi et al., 2017). Carotenoids deteriorated at a temperature of 120 °C, however in this investigation, antioxidant activity was no longer present at a temperature of 70 °C; another factor may be the drying time (Anggreini et al., 2018). When exposed to high temperatures over an extended period of time, antioxidant chemicals breakdown quickly. This is due to the inability of antioxidant molecules to donate electrons to neutralize radical chemicals (Patras et al., 2010). In a previous study, the antioxidant activity of herbal teabags dried at a temperature of 60 °C for four hours was diminished. During the course of the trial, drying times varied between 4 and 6 hours (Nadia Nathaniel et al., 2020).

3.11 SEM

The t1w1 treatment had a smooth surface because of trehalose (Figure 1).

Scanning Electron Microscope (SEM) is an electron microscope that allows direct observation of the surface of solid objects. SEM operates on the basis of the principle of electron reflection (Hamriani, 2016). The surface morphology of carbon particles can be observed based on the findings of SEM testing at a magnification of 1000x and a scale of 50 m. The typical particle form has an imperfect spherical smoothness. In addition, there is a small clumping of a few particles.

3.12 PSA

The t1w1 treatment's particle size range of 6.37 μm to 24.93 μm (Figure 2).

The Particle Size Analyzer (PSA) is used to measure particle size distribution. The PSA test yielded a particle size range of 6.37 m to 24.93 m, resulting in an average particle size of 16.66 m. the smaller size of particle milk powder will accelerate the dissolving time.

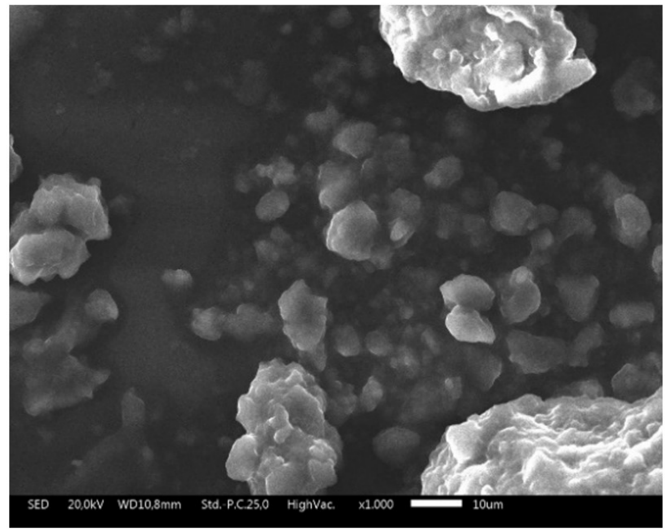

Figure 1. Test SEM Results 1000x Magnification.

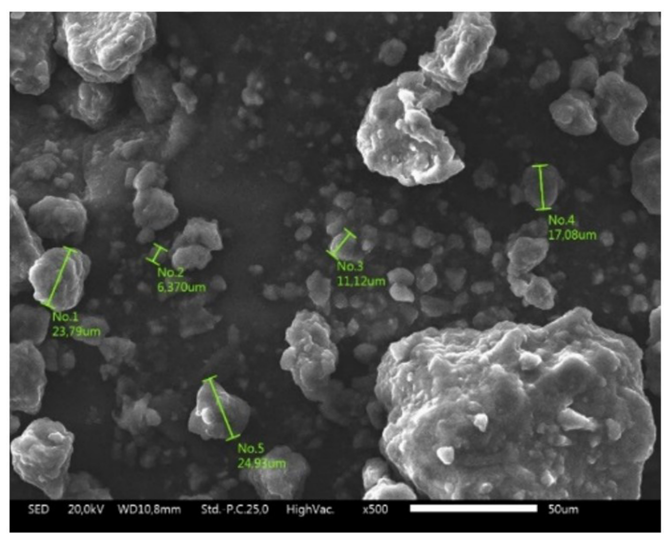

Figure 2. PSA Test Results.

4 Conclusion

The addition of trehalose and carrot extract exerts a markedly different influence on moisture content, viscosity, hygroscopicity, color intensity (L*, a* and b* values), yield, solubility, and solubility time, as well as organoleptic characteristics of carrot milk. The best treatment based on organoleptic results is a t1w1 sample (containing 5%

trehalosa and 10% carrot extract). The selected sample was then carried out further analysis consisting of 88.5 ppm of total carotenoids and 2,204.61 ppm of antioxidant activity, 3.43% water, viscosity of 4.64 cP, yield of 12.15%, solubility of 79.04%, dissolving time of 16.8 seconds, hygroscopicity of 5.05%, L* 67.98, a* 3.32, and b* 25.40. This research can be proposed as an alternative to adding nutritional value of milk powder which is not only rich in protein but rich in anthocyanins, carotenoids and vitamins, which can potentially be implemented in production units.

Conflict of interest

The authors declare no conflict of interest.

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