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Physicochemical and Sensory Analysis of Fruit Leather Made from Orange Peel and Dragon Fruit Peel with Isomalto-Oligosaccharides as Sucrose Substitute

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Abstract The nutritional content and bioactive compound offered by fruit peels that considered as food waste creates great opportunities for food industries which convert it into fruit leather product fortified with Isomalto-oligosaccharides (IMOs). This research aims to conduct analysis of IMO concentration elevation towards the physicochemical and sensory characteristic of products by five-different concentration (0%, 25%, 50%, 75%, 100%). The physicochemical analysis methods encompass measurement of color, texture, water activity, and syneresis percentage. While sensory analysis is conducted towards 62 untrained panelists which consists of hedonic test to measure the liking level and just-about-right (JAR) test to measure how each sensory attributes are perceived by the panelists. The research data result shows that the best sample formulation is the sample with 50% substitution of IMO with physicochemical characteristics which enhance hardness texture (1,836 ± 0,12), elasticity (0,1411 ± 0,0208), lower water activity (0,6696 ± 0,0006), lower syneresis (0,1926 ± 0,2724), and darker-red color. As well as sensory analysis which includes the hedonic test (5.33 ± 1.26) and JAR analysis which result in minimal penalty category for all attributes.

Keywords Fruit Leather, Orange Peel, Dragon Fruit Peel, Isomalto-Oligosaccharides

1. Introduction

Mandarin orange (*Citrus reticulata*) and dragon fruit (*Hylocereus polyrhizus*) are the types of fruit with high production amounts in Indonesia. The main reason these fruits are most favored is due to their sweet characteristics and offering a high number of micronutrients and bioactive compounds [1-2]. However, the increasing production of these fruit has led a significant contribution to the rising of food waste amount. This food waste poses environmental challenges, such as land usage and energy consumption for waste disposal, also contributing to greenhouse gas emissions [3]. Generally, the consumed part of the fruit is only the flesh, which contributes 60% of a mandarin orange's composition and 80% of a dragon fruit's composition. Meanwhile, other parts such as the seeds, fibers, and fruit peel are discarded and not consumed due to their unpleasant flavor and texture [1,4]. Currently, this food waste is still underutilized and only converted into a few products, such as essential oils, beauty products, and biofuels, which are not intended for re-consumption as food [5].

To address this issue, the proposed solution is to create a food product from the food waste itself which intended to increase the consumable fruit composition. Fruit leather is a type of food product made from dried and restructured fruits puree, consumed as a popular snack which is suitable to overcome the food waste problem. Fruit leather is a flexible thin sheet that has a sweet and fruity taste. It is capable of reducing the produced food waste by using orange and dragon fruit peels as its main ingredients. It is a healthy and nutritious alternative to other snacks, providing high levels of fiber, vitamins, minerals, and other bioactive compounds [6]. The production of fruit leather is relatively simple by mixing and drying methods which can be done at home or on a larger scale. Proper drying techniques can prolong the product's shelf life for several months at room temperature, due to reduced microbial activity [7].

Fruit leather products with a dominant sweet taste of sensory characteristics are desired by consumers and sucrose is commonly used as the main sweetening agent [6]. But excessive consumption of this natural sweetening component will increase the intake of large amounts of calories in the body which can lead to excess body weight (obesity) and in the long term the risk of diabetes type 2 [8]. Therefore, prebiotic sweeteners such as isomalto-oligosaccharides (IMOs) are used as sucrose substitutes to enhance the nutritional value of products. IMO is classified as a prebiotic due to its partial digestibility by the human gastrointestinal tract. It is also capable of selectively stimulating and supporting the activity of bacteria in the intestines, such as bifidobacteria and lactobacilli, which will ferment it. This fermentation process increases the microflora in the large intestine, leading to a healthier digestive system [9]. Furthermore, IMO has low calories (2.4 kcal/g) with the sweetness level about 60% of sucrose [10]. IMO has been shown to have a low glycemic index, for example the previous study shows the glycemic index of 34.66 ± 7.65 [11]. Study by Grubic et al. [12] exhibited that protein bar made using IMO elicited a low glycemic response than other sweetener.

The fruit leather made from orange and dragon fruit peel will be incorporated with IMO as sugar substitute at certain levels. This research aims to understand the physicochemical and sensory characteristics of fruit leather products to find the best formulation to create a high-nutrition and economically viable product.

2. Materials and Methods

2.1. Sample Preparation

Fruit leather is made using mandarin orange and dragon fruit obtained from a local supermarket. The fruits are washed, peeled (damaged or dirty peel would be trimmed), and the peel will be separated from the flesh. Subsequently, 10 g of mandarin orange peel and 100 g of dragon fruit peel are weighted and blended into a puree with 50 mL addition of water. The puree mixture is then heated at 100℃ for 10 minutes with varying ratio between IMO and sucrose, which are (0:100) as control, (25:75) as 25IMO, (50:50) as 50IMO, (75:25) as 75IMO, and (100:0) as 100IMO. The heating aims to dissolve sugar and eliminate pathogens. The resulting puree is spread on baking paper using a spatula, allowed to cool, and then dried in a food dehydrator at 55℃ for 6 hours, transforming the fruit purees into thin sheets of fruit leather which have a semi-solid chewy texture.

2.2. Color Analysis

Color analysis was conducted using the CIE (Commission Internationale de l'Eclairage) method, which employs two color representation spaces: CIE LAB and CIE LCH. These spaces are interrelated and are utilized for representing and measuring color. The Colorimeter (CS-10) device was utilized to evaluate various color attributes of the product, such as L* (brightness), a* (red-green), b* (blue-yellow), as well as C* (chroma/saturation), H* (hue), and ΔE (color change). To conduct the testing, the sample was positioned on a flat surface, and the colorimeter's receptor was placed on the sample's surface. The measurement process was initiated by pressing the target button, after which the device displayed the measured color values, including L*, a*, b*, C*, and H*. The recorded values were obtained by conducting three replications at different points on each sample.

2.3. Texture Analysis

Texture testing was performed using the Shimadzu EZ-SX texturometer, which can apply both pressure and movement to provide insights into the surface texture of fruit leather samples. The initial step involves placing the sample on the sample table. The Spherical probe is used and positioned on the probe's location. The distance between the probe and the sample table is adjusted, and the probe speed is set at 1mm/sec. Test parameters include test mode: texture, test type: compression, shape: plate, and quantity: 5. For elasticity testing, the Elongation Jig is used, and the sample is hooked onto the probe. The probe speed is set at 1mm/sec, with test mode: texture, test type: tensile, shape: plate, quantity: 5, and end test: break detection sensitivity selected. The entire target test area is chosen, and the general result section is populated by selecting all standard results. The analysis is then initiated by clicking "run test" on the texturometer. The measurements are conducted with three replications for each sample, and the results are displayed on the computer screen.

2.4. Water Activity

Water activity (Aw) analysis is achieved through direct measurement of vapor pressure using an Aw meter (Aqualab 4TE). The process of measuring water activity begins with placing representative samples in cup containers. These containers are then positioned within an Aw meter chamber, and the lever is shifted to the left to initiate water activity reading for the samples. The samples need enough time to reach equilibrium, allowing water migration to occur. The time required for equilibrium varies, and samples with lower moisture content might take several hours to achieve accurate water activity values. The measurements are conducted with three replications for each sample, then the results are displayed on the Aw meter's screen.

2.5. Syneresis Analysis

Syneresis analysis on fruit leather samples aims to gather information about the amount of free water components that exudates from the sample. The test is simply performed using the gravimetric method, where the measurement of exudation water content is based on the difference in sample mass influenced by a specific condition. In this case, the condition is low-temperature storage (4℃) within a refrigerator. At predefined time intervals (0, 24, 48, and 72 hours), samples are taken out of the refrigerator to measure their weight with three replications for each sample. The results are obtained by comparing the weight differences from each time interval which is expressed as percentage. Additionally, measurements of fruit leather thickness are also taken to understand the volume changes.

2.6. Hedonic and Just-About Right (JAR) Test

The hedonic and JAR analyses were conducted involving 62 untrained panelists, who were given five different fruit leather samples. They were then asked to provide feedback on their individual liking levels for each sample based on the level of IMO substitution for sucrose, which evaluate for each sensory attribute (color, taste, texture, aroma, and overall). Panelists are given cutleries with the fruit leather samples in separate labelled cups with randomized numbers. The hedonic rating level used a 7-point hedonic scale for evaluation, ranging from 1-very much dislike, 2-dislike, 3-somewhat dislike, 4-neutral, 5-somewhat like, 6-like, to 7-very much like. While the JAR analysis was conducted by using the same panelists to evaluate the intensity appropriateness of various sensory attributes of each fruit leather sample, based on their subjective opinions. The perceived intensity levels are rated by panelists using a 5-point JAR scale: 1-too weak, 2-slightly weak, 3-just-about-right, 4-slightly strong, and 5-too strong. The six different attributes assessed are sweetness level, citrusy aroma, dragon fruit aroma, chewiness, stickiness, and stretchability. The panelists responses are collected through a questionnaire.

2.7. Penalty Analysis

The score result obtained from the hedonic overall attribute and JAR test calculated for the mean drop and the percentage of total respondent which responding too weak or too strong on each attribute. Note that the average results of the JAR test from the 5 levels will be grouped into 3 categories: too weak, JAR, and too strong. Slightly weak results will be included in the 'too weak' category, while slightly strong results will be included in the 'too strong' category. The score was plotted on scatter graph of mean drop versus total percentage of respondents.

2.8. Statistical Analysis

The results were shown as mean ± standard deviation (STD) for three replications of each sample. Then the resulting data from this analysis will be processed statistically by IBM SPSS Statistics 25 software to conduct one-way analysis of variance (ANOVA) and using Tukey Honestly Significance Difference (HSD) as the post hoc test to observe whether there is a significant difference between the group samples at $P<0.05$.

3. Results and Discussion

3.1. Color Analysis

Color has become one of the crucial parameters that determine the sensory quality of a food product, where color will be the first characteristic to be perceived by consumers [13]. In general, the produced fruit leather product has a visually apparent red color perceived by the eye, which is reflected in the a* (red) value and the h* value indicating the degree of red (around 360^o) [14]. The addition of IMO concentration to the sample resulting on a significant effect to the color characteristics especially affects the lightness, red chromaticity, chroma, and delta E value. According to [15] the study conducted to observe physicochemical characteristics by different IMO concentrations, the IMO addition to the sample is decreasing its lightness, increasing the red chromaticity, and decreasing the yellow chromaticity. This is in accordance with the results of the color analysis shown in Table 1, which it has been proven by the sample color are darken (decreasing of lightness L*) as the concentration of IMO increases, with a significant difference occurring at an IMO concentration of 50% compared to control group. The b* value of the sample is also decreasing which in accordance with the reference but with no significance effect between sample groups [15]. Meanwhile, the red chromaticity (a*) are increasing as the IMO concentration is increased with sample of 100IMO resulting on out of orderly data (slightly decreasing from the previous sample) due to zero content of sucrose which facilitates caramelization and the red color of the sample [16]. The overall results of L*, a*, and b* are affected by the chemical reaction of Maillard reaction which occurs under acidic and high temperature treatment on the fruit leathers. This reaction will produce a product in the form of a melanoidin compound which has a dark brown color. On the other hand, the higher sucrose concentration, the more Maillard reaction inhibition because sucrose is not directly involved in the Maillard reaction [17].

Table 1. Color analysis results of fruit leather with differentiation of IMO concentrations

Formulation	Color Characteristics					
	L*	a*	b*	C*	h*	ΔE*
Control	13.69 ± 0.04[a]	3.94 ± 1.12[d]	-0.47 ± 0.01[a]	6.51 ± 0.01[bc]	356.53 ± 1.27[a]	-
25IMO	13.39 ± 0.21[a]	5.07 ± 0.42[cd]	-0.53 ± 0.04[a]	9.22 ± 0.40[a]	355.63 ± 2.99[a]	2.716 ± 0.37[b]
50IMO	11.86 ± 0.07[b]	7.18 ± 0.57[b]	-0.65 ± 0.47[a]	7.23 ± 0.61[b]	354.53 ± 4.09[a]	2.048 ± 0.09[b]
75IMO	11.50 ± 0.07[b]	9.18 ± 0.39[a]	-0.70 ± 0.48[a]	5.13 ± 0.44[cd]	352.70 ± 5.23[a]	2.660 ± 0.28[b]
100IMO	10.14 ± 0.21[c]	6.50 ± 0.01[bc]	-2.03 ± 1.45[a]	4.56 ± 1.30[d]	334.71 ± 17.79[a]	4.855 ± 0.59[a]

[1]Different letters indicate significant differences (Tukey HSD) between sample groups (P<0.05).

Subsequently, the chroma C* value shows a significant decrease as the IMO concentrations are increased. The tendency of the sample C* value to decrease was affected by the darker sample color as the IMO concentration of sucrose increased. This is consistent with the brightness L* values pattern decreasing with increasing IMO. But overall, the sample shows a dark color with low chroma [14]. Then the hue value is a critical color characteristic in color testing to eliminate bias in color. As seen in Table 1, the h* values ranged from 334.71 to 356.53 degrees, representing reddish-purple hues on the color circle. This is attributed to the significant ratio of dragon fruit to mandarin orange in the samples, where reddish-purple pigments like betacyanin and anthocyanins influence the obtained h* values [18]. The delta ΔE* are also crucial on this research which aim to measure the magnitude of color difference between samples to understand whether the color difference between sample is visible or not. The samples 25IMO, 50IMO, and 75IMO exhibit ΔE* values ranging from 2.048 to 2.716, falling into the category of 2 – 3.5 according to delta E interpretation principle which indicates that untrained observers can perceive slight differences. However, the sample 100IMO, with a ΔE* value of 4.855, falls into the category of 3.5 – 5, indicating clear differences between the sample and the standard [19].

3.2. Texture Analysis

Texture can be defined as a quality attribute closely linked to the structure and mechanical properties of a food substance, in this case, fruit leather samples. This aspect is crucial in understanding how the mechanical texture properties of a food substance can influence the sensory quality and perception of a specific product [20]. A good fruit leather product exhibits low water activity and features a soft (semi-solid) texture, with a surface appearance resembling thin sheets of leather. The ideal sensory characteristics of the fruit leather include being chewy, sweet-tasting, aromatic, delicious, lightweight, and easily storable due to its thinness. According to the data shown in Table 2, the sample with the highest hardness value is the 100IMO sample with a value of 5.2708N, while the sample with the lowest hardness value is the 25IMO sample with a value of 1.2674N. Generally, the hardness values for all samples except the 100IMO sample are similar to literature findings for fruit leather from various tropical fruits, ranging from 60-491gf or 0.59-4.8N [6].

There is a trend of increasing hardness with higher IMO concentration in the fruit leather samples. The increase in hardness is attributed to the higher hydrogen bonding in IMO, leading to a more structured texture [21]. Another factor contributing to the texture hardening is the retrogradation process that occurs during the storage of fruit leather samples. Retrogradation is a process where gelatinized starch molecules reassociate and form a denser structure, leading to material compaction and hardening. In this context, IMO, being a derivative of starch, also tends to undergo retrogradation to some extent. The degree of retrogradation in IMO depends on factors like chain length, concentration, temperature, water content, and storage duration. Additionally, the obtained results indicate a decrease in elasticity with increasing IMO concentration [22-23].

Table 2. Hardness and elasticity result on fruit leather sample with different IMO concentrations

Formulation	Hardness Force (N)	Elasticity (Pa)
Control	3.674 ± 0.258[b]	0.563 ± 0.051[a]
25IMO	1.267 ± 0.084[d]	0.458 ± 0.080[a]
50IMO	1.836 ± 0.120[cd]	0.141 ± 0.020[b]
75IMO	3.134 ± 0.259[bc]	0.051 ± 0.011[b]
100IMO	5.270 ± 0.544[a]	0.079 ± 0.022[b]

[1]Different letters indicate significant differences (Tukey HSD) between sample groups (P<0.05).

3.3. Water Activity Analysis

The value of water activity (Aw) significantly affects the stability, quality, and safety of a food product. This is because microorganisms such as bacteria and yeast require water to support their growth and survival [24]. Several other studies have indicated that a good fruit leather product has low moisture content (10-20%) and a moderate water activity (below 0.7). A low Aw value indicates that there is less water available for microorganisms to grow on the food sample, effectively extending the shelf life of the product. It has been reported that an Aw value close to 0.62 can stabilize fruit leather products, preventing deterioration caused by microorganisms for up to 6 months without the need for preservatives [6,25]. In general, the overall results of the water activity analysis have shown compliance with the standards, as they fall below the Aw value of 0.85, where microorganisms can grow optimally. In other words, the drying process carried out at 55°C for 6 hours for the fruit leather samples has yielded positive outcomes.

According to the definition of water activity stating that Aw measures the degree of free water available in food, the addition of IMO as a prebiotic sugar is also intended to act as a humectant, which will bind and retain water, thereby lowering water activity. The best-performing samples showing the lowest water activity values in Table 3 are those with 75% IMO and 100% IMO. The effective water-binding capability of IMO is based on its chemical structure, which includes numerous hydroxyl (-OH) groups that make it more soluble in water. This is due to an uneven distribution of electrons that causes oxygen to bond with negative atoms and hydrogen to bond with positive atoms, forming hydrogen bonds. It is these hydrogen bonds that enable IMO to absorb and retain water to a greater extent than sucrose [21,26].

Table 3. Water activity result on fruit leather samples with different IMO concentrations.

Formulation	Water Activity
Control	0.712 ± 0.003[a]
25IMO	0.675 ± 0.002[b]
50IMO	0.669 ± 0.000[bc]
75IMO	0.658 ± 0.006[d]
100IMO	0.660 ± 0.020[cd]

[1]Different letters indicate significant differences (Tukey HSD) between sample groups (P<0.05).

3.4. Syneresis Analysis

Sineresis refers to the phenomenon in which a certain amount of liquid or dissolved components is expelled (exuded) from the gel matrix of a food material due to unstable conditions and restructuring of the structure. This causes the volume of the fruit leather sample to decrease and become wrinkled as a result of the release of free water [27]. The sineresis test results on fruit leather samples which are shown in Table 4, indicate a significant decrease in the percentage of sineresis with the increase in IMO concentration relative to sucrose. The decreased percentage of syneresis is the result of an increase of IMO concentration which is considered to have a positive effect on binding water molecules in a sample of fruit leather. The amount of IMO increase will be proportional to its ability to bind more water so that water molecules are trapped in the fruit leather gel matrix [28]. The main reason for this water-binding ability is the different chemical structure between IMO and sucrose. The referred chemical structure pertains to the degree of polymerization (DP), a measure of monomers in the polymer chain of a compound chemical structure. In this context, IMO exhibits a higher degree of polymerization of 6 compared to sucrose which only 2. Each of the monomers which linked to each other through these glycosidic bonds will contribute to the formation of a wider and interconnected gel formation, thus providing better structural integrity and stability. In simpler terms, a higher degree of polymerization with more polymer chains composing a compound supports the retention of more water within the gel matrix or enhances its water-holding capacity. This results in lower levels of syneresis, where water is released from the matrix [21].

Table 4. Syneresis percentage of fruit leather based on weight between samples

Formulation	Syneresis Percentage (%)
Control	1.093 ± 0.288[a]
25IMO	0.288 ± 0.235[b]
50IMO	0.192 ± 0.272[b]
75IMO	0.122 ± 0.173[b]
100IMO	0.116 ± 0.165[b]

[1]Different letters indicate significant differences (Tukey HSD) between sample groups (P<0.05).

3.5. Hedonic Test

Hedonic testing is a sensory evaluation method based on the liking level of panelists towards a sample using a scale of preference. In essence, panelists are asked to assess their liking for each sample based on their preferences. Evaluation involves assigning scores to sensory attributes including color, aroma, texture, taste, and overall liking, using a 7-point scale: 1-very much dislike, 2-dislike, 3-somewhat dislike, 4-neutral, 5-somewhat like, 6-like, to 7-very much like. The analysis of the hedonic test results in Table 5 reveals significant differences for certain attributes such as color, texture, taste, and overall liking as the concentration of IMO to sucrose increases [29].

According to Table 5, the sample with the lowest score (least preferred) is the control sample with no addition of IMO, while the sample with the highest score (most preferred) is the 25IMO sample. This indicates that increasing the concentration of IMO has led to more preferred product samples, as evident in the 50IMO and 75IMO samples. Overall, the analysis of panelists liking the fruit leather samples has not shown optimal results. The average scores for each sample range from 3.37

(somewhat dislike) to 5.96 (somewhat like), and no attribute has an average score reaching the scale of 6 (like) or nearing the scale of 7 (very much like). In other words, the fruit leather formulation still needs improvement to create products that are more preferred by consumers.

In terms of visual attribute, the color aspect is generally well-liked by the panelists, evidenced by the lowest color preference score in the control sample (5.24 ± 1.44) and the highest color preference score in the 100IMO sample (5.96 ± 0.99). The color is influenced by the Maillard reaction when heated at high temperatures, aiding the formation of melanoidin compounds and caramelization reactions, resulting in a darker and reddish color of the samples [21]. While the aroma attribute does not show any significant differences between samples, both IMO and sucrose do not pose a strong aroma. Then the flavor attribute received diverse acceptance but generally yielded favorable results. This is evident from the lowest taste preference score in the 100IMO sample (4.19 ± 1.45) and the highest taste preference score in both the 25IMO (5.45 ± 1.33) and 50IMO (5.45 ± 1.32) samples. This is due to the fact that IMO has only a 60% sweetness level of sucrose, which tends to lead the panelists to prefer samples with a lower level of sweetness up to a certain extent [12, 30]. Overall, the samples were received diversely but still resulted in positive outcomes. This is evident from the equal lowest overall preference scores in the control (4.29 ± 1.44) and 100IMO (4.29 ± 1.58) samples, and the highest overall preference score in the 25IMO sample (5.41 ± 1.30).

The Just-about-right (JAR) test is a sensory analysis method used to determine the optimal level or intensity of a specific sensory attribute in a product that is preferred by consumers. This method aims to gather information about the sensory attribute characteristics that are perceived as too weak, too strong, or just right (just-about-right). Essentially, panelists are asked to evaluate six specific sensory attributes of fruit leather samples, including sweetness level, citrus aroma, dragon fruit aroma, chewiness, stickiness, and stretchability using a 5-point JAR scale: 1 = too weak, 2 = slightly weak, 3 = just-about-right, 4 = slightly strong, and 5 = too strong [31]. From the JAR data obtained, the sensory attributes of fruit leather sample made from mandarin orange and dragon fruit peels has a medium to low percentage of JAR, therefore there are still much sensory attributes must be improved especially on the six sensory attributes being tested. Based on the results of the JAR test on the fruit leather samples in Figure 1, it can be observed that the number of respondents indicating JAR for the control sample is less than 65%. As a result, each sensory attribute in that sample is considered not yet an optimal formulation according to panelist preferences, requiring further penalty analysis. The sample with the lowest JAR responses is the control sample, it can be seen that all the sensory attributes including sweetness, citrusy aroma, dragon fruit aroma, stretchability, stickiness, and chewiness are not yet optimal for the consumers which means it have the most points to be improved on their sensory characteristics [33].

Table 5. Hedonic test result of fruit leather with differentiation of IMO concentrations

Formulation	**Sensory Attributes**				
	Color	**Aroma**	**Texture**	**Flavor**	**Overall**
Control	5.24 ± 1.44[b]	4.46 ± 1.31[a]	3.37 ± 1.76[b]	4.87 ± 1.33[a]	4.29 ± 1.44[b]
25IMO	5.35 ± 1.38[b]	4.98 ± 1.15[a]	5.20 ± 1.57[a]	5.45 ± 1.33[a]	5.41 ± 1.30[a]
50IMO	5.77 ± 1.01[ab]	4.83 ± 1.17[a]	5.04 ± 1.59[a]	5.45 ± 1.32[a]	5.33 ± 1.26[a]
75IMO	5.80 ± 1.09[ab]	4.77 ± 1.20[a]	4.80 ± 1.46[a]	5.29 ± 1.06[a]	5.19 ± 1.18[a]
100IMO	5.96 ± 0.99[a]	4.69 ± 1.08[a]	3.83 ± 1.64[b]	4.19 ± 1.45[b]	4.29 ± 1.58[b]

[1]Different letters indicate significant differences (Tukey HSD) between sample groups (P<0.05).

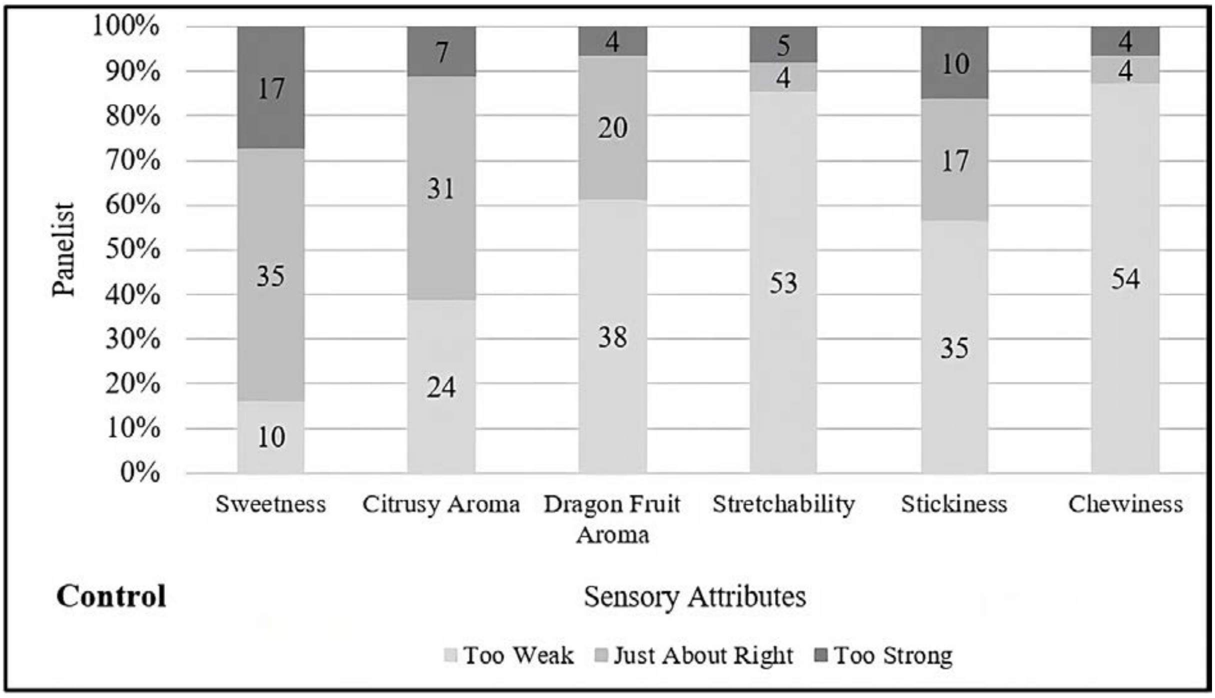

Figure 1. JAR data from fruit leather control sample

Table 6. Hedonic test result of fruit leather with differentiation of IMO concentrations (TS = Too Strong, TW = Too Weak).

Control	25 IMO	50 IMO	75 IMO	100 IMO
Minimal penalty: • Citrusy aroma (TW) • Dragon fruit aroma (TW) • Stickiness (TW) • Chewiness (TW) • Sweetness (TS) Severe penalty: • Stretchability (TW)	Minimal penalty: • Citrusy aroma (TW) • Dragon fruit aroma (TW) • Stickiness (TW) • Stretchability (TW) • Chewiness (TW) Severe penalty: • Sweetness (TS)	Minimal penalty: • Citrusy aroma (TW) • Stretchability (TW) • Chewiness (TW) • Sweetness (TS) • Stretchability (TS) • Stickiness (TS)	Minimal penalty: • Citrusy aroma (TW) • Dragon fruit aroma (TW) • Chewiness (TS) • Stickiness (TS) Moderate penalty: • Sweetness (TW) • Stretchability (TW)	Minimal penalty: • Stickiness (TS) • Chewiness (TS) Severe penalty: • Citrusy aroma (TW) • Dragon fruit aroma (TW) • Chewiness (TW) • Sweetness (TW) • Stretchability (TW)

After conducting the Hedonic and JAR tests, the next step involves performing a penalty test that combines both methods. The goal is to obtain information and identify which sensory attributes of the given samples deviate significantly from the optimal level. There are three penalty categories, including: minimal penalty: involves a 20-100% reduction in respondents and a 0-1 mean drop; moderate penalty: includes a 20-40% reduction in respondents and a 1-3 mean drop; and severe penalty: encompasses a 40%-100% reduction in respondents and a 1-3 mean drop [32]. Each panelist who conducted the JAR test, their responses to the overall liking average from the hedonic test for each sample will be examined. These responses will then be plotted against the percentage of panelists providing the response, and mean drop calculations will be performed for the "too weak" and "too strong" levels. Thus, the plotted results on the graph will be used to evaluate which attributes of the samples fall critically into the quadrant with a high risk, referred to as the critical corner [33]. Based on the penalty analysis results of fruit leather samples in Table 6, the sample that has the most penalty is 100IMO which consists of two minimal penalties and five severe penalties. It can be observed that several attributes indicating "too weak" (citrusy aroma, sweetness, dragon fruit aroma, stretchability, chewiness) and "too strong" (chewiness, stickiness) fall into the critical corner area (more than 20% of respondents). In other words, the overall penalties show a significant mean drop. The sensory attributes rated as "too strong" fall into the critical corner area with the category of minimal penalty due to the high number of respondents with a low mean drop (less than 1). On the other hand, the sensory attributes rated as "too weak" fall into the severe penalty category due to the high number of respondents with a high mean drop (more than 1). This indicates that these sensory attributes have a significant impact on the decrease in panelists' liking for the 100IMO sample, thus requiring immediate improvement [32-33].

4. Conclusions

From five samples with different IMO concentrations, the sensory test results showed that samples with a concentration of 25% isomalto-oligosaccharides were the most preferred by consumers and control samples were the least preferred treatment. While based on the physicochemical and sensory tests conducted, it can be concluded that the fruit leather sample with 50% IMO addition is the best formulation. The color analysis results for this sample are as follows: L* value of 11.86 ± 0.07, a* value of 7.18 ± 0.57, b* value of -0.65 ± 0.47, C* value of 7.23 ± 0.61, h* value of 354.53 ± 4.09, and ΔE* value of 2.048 ± 0.09. Furthermore, the physicochemical analysis results include an activity water of 0.6696 ± 0.0006, a percentage of syneresis of 0.1926 ± 0.2724, a hardness of 1.8368 ± 0.1200, and an elasticity of 0.1411 ± 0.0208. The sensory analysis results encompass hedonic testing (5.33 ± 1.26), JAR analysis, and penalties that do not fall into the severe penalty category for all attributes. Therefore, based on these comprehensive analyses, it can be concluded that the formulation with 50% IMO addition yields the best fruit leather sample formulation.

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