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Formulation of Chewable Gummy Tablet of *Moringa oleifera* L. Leaf Extract Using Combination Kappa Carrageenan and Iota Carrageenan

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Keywords

Chewable gummy tablets; Moringa oleifera; Kappa Carrageenan; Iota Carrageenan

ABSTRACT

Moringa leaves were the most commonly used part of the Moringa plant because they were rich in nutrients. Moringa leaves extract was developed into a chewable gummy tablet to improve its acceptability. The main component of the chewable gummy tablet was a gelling agent. This study aims to determine the effect of gelling agent ratio (kappa-carrageenan and iota-carrageenan) on the physical characteristics of the chewable gummy tablet. Furthermore, this study was also conducted to determine the optimum formula for a chewable gummy tablet and analyze the physical stability of the prepared formula during storage. In this study, the concentration of gelling agents was 2%. The formulas were developed in this study using the various ratio of kappa-carrageenan and iota-carrageenan 1:0 (control formula), 1:1 (formula 1), 2:1 (formula 2), and 3:1 (formula 3). The results showed that the ratio of kappa-carrageenan and iota-carrageenan determined the texture, disintegration time, swelling ratio, and syneresis. The most optimum formula was Formula 1 (1:1). The characteristics of this formula were a yellow color, melon odor, sweet taste, square shape, chewy texture, the average weight was 2.86 g ± 0.02, the disintegration time was 7.47 min ± 0.02, the swelling ratio was 1.21% ± 0.20, and the syneresis percentage was 0.93 ± 0.11%. The result of physical stability evaluation during 14 days of storage also revealed that formula 1 was the most stable.

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ABSTRACT
Moringa leaves were the most commonly used part of the Moringa plant because they were rich in nutrients. Moringa leaves extract was developed into a chewable gummy tablet to improve its acceptability. The main component of the chewable gummy tablet was a gelling agent. This study aims to determine the effect of gelling agent ratio (kappa-carrageenan and iota-carrageenan) on the physical characteristics of the chewable gummy tablet. Furthermore, this study was also conducted to determine the optimum formula for a chewable gummy tablet and analyze the physical stability of the prepared formula during storage. In this study, the concentration of gelling agents was 2%. The formulas were developed in this study using the various ratio of kappa-carrageenan and iota-carrageenan 1:0 (control formula), 1:1 (formula 1), 2:1 (formula 2), and 3:1 (formula 3). The results showed that the ratio of kappa-carrageenan and iota-carrageenan determined the texture, disintegration time, swelling ratio, and syneresis. The most optimum formula was Formula 1 (1:1). The characteristics of this formula were a yellow color, melon odor, sweet taste, square shape, chewy texture, the average weight was 2.86 g ± 0.02, the disintegration time was 7.47 min ± 0.02, the swelling ratio was 1.21% ± 0.20, and the syneresis percentage was 0.93 ± 0.11 %. The result of physical stability evaluation during 14 days of storage also revealed that formula 1 was the most stable.

Keywords: *Chewable gummy tablets, Moringa oleifera, Kappa Carrageenan, Iota Carrageenan*

1. INTRODUCTION

Moringa plant (*Moringa oleifera* L.), is known as the "miracle tree" (miracle tree) because almost every part of it contains potential as a source of nutrition and has various health benefits [1,2]. The most commonly used part of the Moringa plant is the leaves. Moringa leaves are rich in minerals, vitamins, amino acids, fiber, protein, fat, and other important phytochemicals [3]. Moringa leaves have not been widely consumed because the characteristics of Moringa leaves have a distinctive odor and are not preferred by the consumer, so there is a need for innovation in processing Moringa leaves so that their nutritional content can be utilized by the body [4]. In this study, Moringa leaf extract was formulated into a nutraceutical product in the form of chewable gummy tablets to increase consumer acceptance. Nutraceutical is a type of food derived from natural ingredients, where the components are useful in improving health, preventing and treating disease as well as potential health benefits for the body [5,6].

Chewable gummy tablets are formulated from concentrated sugar solutions, gelling agents, and other ingredients. Chewable gummy is a product with a firm, soft and chewy structure made with gelling agent based on gelatine, starch, or pectin [7–9]. This dosage form has various advantages including sweet taste, unique texture, attractive shape and color, distinctive aroma, and ease of consumption so that it will be preferred by all age groups, especially children and the elderly who have difficulty swallowing [4,10]. –12]. The gelling agent is one of the important factors in the formulation of this product. Gelatine is the most commonly used gelling agent in pharmaceutical preparations [12]. However, gelatine is hygroscopic and can quickly increase the moisture content of products [13]. In addition, the halal status of

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gelatine is still in doubt for Muslims because of the alleged content of pork elements [14]. Research on replacing gelatine as a gelling agent has been carried out, one of which is carrageenan [14].

Carrageenan is a sulphated linear polysaccharide of D-galactose and 3,6-anhydro-D-galactose extracted from red algae namely Chondrus, Eucheuma, Gigartina, and Hypnea. Carrageenan has three main types, namely kappa, iota, and lambda carrageenan [15]. Each type of carrageenan has different properties which are influenced by the number and position of sulphate ester groups and the content of 3,6-anhydro-galactose. Each type of carrageenan has various unique characteristics including gel strength, viscosity, temperature stability, elasticity, and solubility [16]. Kappa and iota are gel-type carrageenan's, while lambda is not a gelling agent [15,17]. Kappa carrageenan produces a brittle gel that is hard and has very poor freeze-thaw stability. In contrast, iota carrageenan forms a highly elastic thixotropic solution or gel that has good freeze-thaw stability. The gel produced by kappa carrageenan has a high syneresis level, while the gel from iota carrageenan does not show syneresis [15].

The use of kappa-carrageenan as the sole gelling agent in chewable gummy tablets results in a preparation that tends to syneresis [18,19]. Control of gel strength properties is very important because it can affect the level of public acceptance, while high syneresis can cause the preparation to shrink and dry during storage [20]. The use of a combination of kappa-carrageenan and iota carrageenan can increase the stability of the gel formed against changes in temperature and prevent syneresis [15]. The addition of iota carrageenan can improve the brittle nature of kappa-carrageenan gel by increasing its elasticity because iota carrageenan has a gel with a soft texture and high elasticity so that it can reduce gel strength and does not trigger syneresis [21,22].

In this study, there were 4 formulas developed with a total gelling agent concentration of 2%. The difference between the four formulas lies in the ratio of kappa-carrageenan and iota carrageenan used. The formulas are F0 (1:0), F1 (1:1), F2 (2:1), and F3 (3:1). This study aims to analyze the effect of differences in the ratio of kappa-carrageenan and iota carrageenan as a gelling agent for the preparation of chewable gummy tablets of Moringa leaf extract. The prepared chewable gummy tablet of Moringa leaf extract was then evaluated for physical characteristics including physical observation tests (color, smell, taste, shape, and texture), weight variation, tablet dimension, disintegration time test, swelling ratio, and syneresis. The data obtained will then be analyzed descriptively and inferential statistics using the one-way ANOVA method. Furthermore, this study was also conducted to determine the optimum formula for a chewable gummy tablet and analyze the physical stability of the prepared formula during storage. The results of the stability test during storage were also analyzed using the one-way ANOVA to find out whether there is any alteration in physical stability.

2. METHOD

2.1 Material

The ingredients used in the formulation of chewable gummy tablets include ethanolic extract of *Moringa oleifera* leaves (Materia Medica Batu). Other excipients used are pharmaceutical grade (p.g) or food-grade (f.g) excipients, including kappa-carrageenan (Planet Kimia, Indonesia), iota-carrageenan (Planet Kimia, Indonesia), mannitol (Planet Kimia, Indonesia), sucrose (Planet Kimia, Indonesia). PT. Sugar Group Companies, Indonesia), citric acid (Planet Kimia, Indonesia), sodium benzoate (Planet Kimia, Indonesia), propylene glycol (Planet Kimia, Indonesia), Na_3-Citrate (Planet Kimia, Indonesia), melon flavor (PT. Anggana Catur Prima, Indonesia), yellow dye (PT. Anggana Catur Prima, Indonesia) and purified water.

2.2 Preparation of Chewable Gummy Tablets

The formulas developed in this study consist of four formulas, including the control formula (formula 0) which used kappa carrageenan with 2% concentration, and 3 other formulas using a combination gelling agent consisting of kappa-carrageenan and iota carrageenan with 2% concentration. The formula was developed with a successive ratio, these are 1:1 (formula 1), 2:1 (formula 2), and 3:1 (formula 3). Chewable-gummy tablet weight per unit is 3 g. The method of making chewable gummy tablets in this study used the pour molding method. This process was conducted by pouring the chewable gummy tablet mass when it was still hot into the mold [10]. This method was chosen because it is a relatively easy method, the equipment used is also simple, and the costs required are not too large.

Sucrose, mannitol, and Na_3Citrate were dissolved in purified water while stirring and heated at a temperature of 70-80°C. Kappa carrageenan and iota carrageenan were added to the mixture, then stirred until homogeneous. Propylene glycol, sodium benzoate, and citric acid were added to the mixture while stirring until homogeneous. The melon flavor and coloring agent are then added slowly to the mixture and stirred until homogeneous. After the temperature of the mixture was around 60°C, ethanol extract of Moringa leaves was added and stirred until homogeneous. The mixture mass of chewable gummy tablets is then poured into the mold slowly and allowed to store at room temperature. After reaching room temperature, the preparation was put in an airtight container and stored at room temperature (25-30°C) covered with plastic wrap for 24 hours. After being

stored for 24 hours, the chewable gummy tablets were slowly removed from the mold. The chewable gummy tablet formula can be seen in Table 1 below:

of 10 tablets individually. The results of each dimension variation from 10 tablets must be within ± 5%.

Table 1. Formula of *Chewable Gummy* Tablet based *Moringa oleifera* leaves extract

No	Component	Function	Control formula (%)	Formula 1 (%)	Formula 2 (%)	Formula 3 (%)
1	*Moringa oleifera* leaves extract	Active ingredient	2	2	2	2
2	Kappa Karagenan	Gelling Agent	2	1	1.33	1.5
3	Iota Karagenan	Gelling Agent	0	1	0.67	0.5
4	Manitol	Sweeteening agent	10	10	10	10
5	Sucrose	Filler and sweetening agent	30	30	30	30
6	Citric acid	Acidulant	1.7	1.7	1.7	1.7
7	Sodium benzoate	Preservative	0.5	0.5	0.5	0.5
8	Propilen Glycol	Plasticizer	4	4	4	4
9	Melon flavor	Flavor	2	2	2	2
10	Yellow color	Coloring agent	0.01	0.01	0.01	0.01
11	Na_3Sitrat	pH adjuster	0.9	0.9	0.9	0.9
12	Purified water	Solvent	46.89	46.89	46.89	46.89

2.3. Physical Characteristics Evaluation

2.3.1 Physical Characteristics Evaluation

Physical characteristics evaluation has been conducted to evaluate the physical characteristics of the gummy tablet including shape, elasticity, color, taste, and odor. The results will be evaluated to predict the acceptance of consumers.

2.3.2 Weight Variation Test

The weight variation test was carried out by weighing 20 tablets individually, then the average weight was calculated. Chewable gummy tablets fulfil the requirement if the weight of each tablet unit does not deviate from the average weight of more than 7.5%. If there is 1 tablet that is outside the range, then the test is carried out again with an additional 20 tablets. Chewable gummy tablets are declared uniform in weight if there is not a single tablet unit that exceeds the average weight of more than 10% [24]

2.3.3 Tablet Dimension Test

Tablets dimension test was carried out to ensure the uniformity of chewable gummy tablet size. Tablet dimension is an essential parameter that affects not only consumer acceptance but also the accuracy of the active ingredient dosage. The tablet dimension test was conducted by measuring the length, width, and thickness

2.3.4 Swelling Ratio

The swelling ratio test aims to see the swelling ability of the carrier. The greater and faster the swelling capacity of the carrier, the faster the dissolving time, hence the release of the active ingredient from the dosage form is also faster [28]. The swelling ratio test was carried out by weighing the dry chewable gummy tablet, the preparation was then immersed in 100 ml ± 10 seconds of water to obtain the wet weight. The analysis can be obtained by using this equation [28]:

$$\textit{Swelling ratio}\ (\%) = \frac{(\text{Wet weight} - \text{Dry weight})}{\text{Dry weight}} \text{x } 100\%$$

2.3.5 Disintegration Time

The disintegration time test is an initial approach to predict the disintegration process and the release process of the active ingredient from the dosage form. The dispersion time was carried out by placing the preparation in a glass beaker containing 100 mL of distilled water at 37°C, then observing the time until the preparation was not observed anymore. Experiments were carried out with three replications [29]. The test results are presented as mean ± standard deviation.

2.3.6 Syneresis

Syneresis is the elimination of water from a gel structure when the gel structure tightens and contracts

[15]. The syneresis test was carried out by weighing the initial weight of the chewable gummy tablet, then the preparation was placed on filter paper and weighed again. To determine the occurrence of syneresis, it is calculated by comparing the weight after being placed on the absorbent paper (final weight) with the initial weight of the preparation. Calculations can be done with the following equation [30,31]:

$$\text{Syneresis percentage} = \frac{(\text{Final weight} - \text{Initial weight})}{\text{Initial weight}} \text{ x } 100\%$$

2.3.7 Physical Stability Evaluation during Storage

Evaluation of the physical stability of chewable gummy tablets during storage was carried out by observing physical characteristics including physical appearance, weight variation, tablet dimensions, dispersion time, swelling index, and tablet syneresis. Observation of the physical characteristics of the chewable gummy product of Moringa leaf extract was carried out on days 1st, 7th, and 14th.

2.4 Data Analysis

The data obtained from the evaluation of the physical characteristics of the chewable gummy tablet preparation will be analyzed using descriptive analysis and inferential statistics. Descriptive analysis was used in the physical observation test (color, smell, taste, shape, and texture), weight variation test, and tablet dimension test. Meanwhile, inferential statistics were used in the dispersion time test, swelling ratio, and syneresis test. Statistical tests were performed using SPSS parametric analysis using the One-way ANOVA method. If in the analysis it is observed that there is a significant difference between the treatment groups indicated by a p value <0.05, then it is continued with the Post Hoc Tukey HSD test. Analysis of the physical stability of the chewable gummy preparation of Moringa leaf extract during storage for up to 14 days was also carried out using the One-Way ANOVA method and continued with Post-hoc Tukey HSD whether there is any significant difference.

3. RESULTS AND DISCUSSION

The chewable gummy formula of Moringa leaf extract in this study was designed with four ratios of kappa-carrageenan and iota-carrageenan. The combination of kappa-carrageenan and iota carrageenan was chosen because it increases the stability of the chewable gummy, is not easily affected by temperature changes, and minimizes syneresis tendency [32]. The use of kappa-carrageenan as the sole gelling agent in the chewable gummy formulation resulted in a chewable gummy texture with a stiff texture. The addition of iota carrageenan as a combination gelling agent with kappa carrageenan can increase the elasticity of the gel structure formed [33]. The results of the physical observation evaluation of the four formulas showed that the chewable gummy preparations of Moringa leaf extract were rectangular in shape, yellow in color, with a chewy texture, sweet taste, and melon aroma. Control formula and formula 3 physically showed a stiffer texture than formula 1 and formula 2. The higher ratio of kappa-carrageenan to the total amount of gelling agent caused the gel texture to be stiffer and less elastic. The rigid and less elastic structure is due to the lower sulphate content of kappa carrageenan than iota carrageenan [34]. This condition causes the 3,6-anhydro-D-galactose bonds in kappa carrageenan to form intramolecular cation bonds, so that the gel formed becomes denser and stiffer [32]. The physical description of the chewable gummy of Moringa leaf extract is shown in Figure 1.

Physical characteristics evaluation carried out on chewable gummy Moringa leaf extract in addition to physical observations included weight variation, tablet

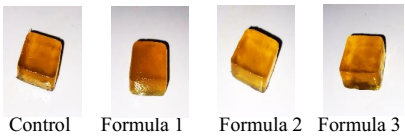

Figure 1. Physical characteristics of *Moringa oleifera* leaf extract chewable gummy tablet

dimensions, swelling index, dispersion time, and syneresis. The results of the evaluation of the physical characteristics of the chewable gummy of Moringa leaf extract are shown in Table 2. The test of the weight variation of the Moringa leaf extracts chewable gummy was carried out to ensure the suitability of the weight of the preparation and analyze the variation of the weight. The weight variation test can provide information about the uniformity of the content of Moringa leaf extract in each dosage unit [35]. The weight variation is determined based on the deviation of the weight of each dosage form against the average weight in accordance with predetermined specifications [36]. The results of the weight variance test show that the four formulas meet the specifications if there is no unit of each formula that deviates from the average weight of more than 7.5%. This condition indirectly indicates that the content of Moringa leaf extract is evenly distributed in all units of the chewable gummy preparation.

The uniformity of the dimensions of the chewable gummy tablets of Moringa leaf extract was determined by measuring the length, width, and thickness of each dosage unit. The test results show that the four formulas meet the specifications because the standard deviation of each dimension is not more than 5% [37]. The results of determining the uniformity of chewable gummy dimensions correlated with the diversity of weights,

dimensions of primary packaging materials, and patient acceptance of the prepared products.

Evaluation of the swelling ratio of the chewable gummy preparation of Moringa leaf extract was carried out to see the ability of the chewable gummy matrix to absorb water caused the gel structure expanded [38]. The process of water molecules entering the gel structure will enhance the diffusion of the active ingredients from the chewable gummy. The larger and faster the ability of the matrix to expand, the faster the release of Moringa leaf extract from the preparation occurred [39]. The results of statistical analysis of the swelling ratio parameters showed that there were significant differences between the four formulas ($p<0.05$). Analysis by Post-hoc Tukey showed that the swelling ratio of the control formula (Formula 0) which only used kappa carrageenan as a gelling agent was significantly different from the other three formulas that used the combination of kappa carrageenan-iota carrageenan. In addition, the swelling ratio of formula 1 was significantly different compared to formula 3. This indicates that the increase in the proportion of kappa-carrageenan in the gelling agent combination of kappa-iota carrageenan has a direct impact on increasing the swelling ability of chewable gummy tablets. The largest swelling ratio was shown by the control formula (formula 0), formula 3, formula 2, and formula 1 respectively. These results are in line with previous research, that increasing the concentration of kappa-carrageenan in the combination of kappa-carrageenan and iota carrageenan can increase the swelling ratio index [40].

The disintegration time of the chewable gummy tablets with Moringa leaf extract was also correlated to the swelling ability of the chewable gummy gel structure. The disintegration time is the result of the hydrogel's ability to absorb water and the diffusion capacity of water molecules entering the hydrogel structure, causing the volume expansion of the hydrogel [43]. The evaluation of the disintegration time was carried out to obtain an overview of the disintegration process and the release of the extract from the chewable gummy product. The faster the disintegration time of the chewable gummy preparation, the faster the process of releasing Moringa leaf extract and then dissolving it into the media [35]. The results showed that the disintegration time of the four chewable gummy formulas met the requirements (not more than 15 minutes). The results of statistical analysis showed that there were differences in the disintegration time of the four chewable gummy formulas of Moringa

Table 2. Physical characteristics of the prepared *chewable-gummy* tablets of *Moringa oleifera* extract

Parameters		Formula			
		Control formula (F0)	**Formula 1 (1:1)**	**Formula 2 (2:1)**	**Formula 3 (3:1)**
Organoleptic	Scent	Melon	Melon	Melon	Melon
	Color	Yellow	Yellow	Yellow	Yellow
	Flavor	Sweet	Sweet	Sweet	Sweet
	Shape	Square	Square	Square	Square
	Texture	Non-sticky, elastic	Non-sticky, elastic	Non-sticky, less elastic	Non-sticky, less elastic
Swelling ratio (%)		1.91±0.20	1.21 ± 0.20	1.45 ± 0,14	1.60 ± 0,19
Dispersion Time (minutes)		6.07 ± 0.03	7.47 ± 0.02	7.35 ± 0.02	7.23 ± 0.03
Syneresis (%)		2.22 ± 0,11	0.93 ± 0,11	1.34 ± 0.19	1.60 ± 0.16
Average weight (g)		2.86 ± 0.02	2.86 ± 0.02	2.86 ± 0.02	2.86 ± 0.02
Tablet dimension	Length (cm)	1.49 ± 0.01	1.49 ± 0.01	1.49 ± 0.01	1.49 ± 0.01
	Width (cm)	1.49 ± 0.01	1.49 ± 0.01	1.49 ± 0.01	1.49 ± 0.01
	Thickness (cm)	1.00 ± 0.02	1.00 ± 0.01	1.00 ± 0.01	1.00 ± 0.01

Kappa-carrageenan hydrogels consist of polymer chains containing charged groups, namely sulphate groups. The sulphate group can be deprotonated at neutral pH conditions to produce an ionic group OSO_3- in the hydrogel structure. The charged sulphate groups on the other chains will induce electrostatic repulsion, hence the distance between the polymer chains is stretched. This condition pursues the space between the polymer networks to become wider and water molecules more easily penetrate into the space [41]. Kappa carrageenan consists of polymer chains that have a higher water absorption capacity, resulting in rapid electrostatic repulsion and volume expansion [42]. This resulted in the escalation swelling ratio of chewable gummy with a higher proportion of kappa-carrageenan than the formula with a higher proportion of iota carrageenan.

leaf extract ($p<0.05$). Continued analysis with Tukey's Post Hoc shows that there are differences between the

formulas analyzed in this research. The results of the evaluation showed a correlation between the swelling index and the disintegration time of the Moringa leaf extract chewable gummy. The control formula with the largest swelling ratio had the fastest disintegration time, followed by formula 3 (3:1), formula 2 (2:1), and formula 1 (1:1). Based on these results, it is known that a larger proportion of kappa-carrageenan in the formula causes a larger swelling ratio value, hence the chewable gummy disintegration time is faster. This phenomenon is supported by the characteristics of Kappa carrageenan gel which tend to be brittle and easy to exhibit syneresis compared to iota carrageenan [44].

Syneresis evaluation was carried out to observe the leakage of water molecules from the chewable gummy preparation of Moringa leaf extract. The release of water molecules from the chewable gummy structure is due to the lack of strong bonding of water molecules to the gel structure. Chewable gummy tablets with a high percentage of syneresis indicate the chewable gummy texture softens quickly causing the quality of the preparation decreases [30]. The results of the syneresis evaluation showed that there was a difference in the percent syneresis of the four formulas ($p<0.05$). The largest percentage of syneresis was indicated by the control formula followed by formula 3, formula 2, and formula 1. The higher the proportion of kappa-carrageenan in the gelling agent combination, the higher the syneresis percentage of the preparation. On the contrary, the higher the proportion of iota carrageenan, the lower the syneresis percentage of the preparation. This condition is caused by differences in the polymer network structure between kappa and iota-carrageenan. The network structure of kappa-carrageenan is denser than iota-carrageenan because the double helix formation in kappa-carrageenan is more extensive. The stronger polymer network causes the gel structure to become denser and harder. This causes the empty space between the polymer networks to become narrower, so that trapped water molecule is more easily pushed out [45].

Evaluation of the physical stability of the chewable gummy was conducted on the 7th and 14th days of storage including physical observation parameters, weight variation, tablet dimensions, swelling ratio, dispersion time, and syneresis. The results of the disintegration time, swelling ratio, and syneresis during storage are shown in Figure 2, Figure 3, and Figure 4. Physical observation of the chewable gummy showed that there was no change in terms of shape, color, odor, taste, and texture compared to the initial conditions. A white layer which is the crystallization of sucrose was observed in all four formulas on the 14th day. This phenomenon is caused by changes in the balance of water content in chewable gummy during storage, which caused sucrose crystallizes. The addition of sorbitol and glycerol as plasticizers can hold water molecules in the chewable gummy structure so that the formation of crystals on the chewable gummy surface can be inhibited [35]. A decrease in tablet weight was also observed in the four formulas on the 7th and 14th days compared to the initial conditions. The trend of greater weight loss occurred in the formula with a larger proportion of kappa-carrageenan. During storage, the network structure of the kappa carrageenan polymer becomes denser. The number of double helix and polymer network bonds becomes more complex so that the water molecules are pushed out of the chewable gummy structure. This condition causes the chewable gummy to shrink and dry, resulting in a decrease in weight [46]. This condition also has an impact on the uniformity of the dimensions of the chewable gummy preparation.

The results of stability analysis of disintegration time showed that the disintegration time of the preparations became faster on the 7th and 14th days of the four formulas. Statistical analysis showed that there were significant differences in the disintegration time parameters of the four formulas compared to the initial conditions ($p<0.05$). The observed decrease in disintegration time was due to the syneresis phenomenon and the ability of the hygroscopic chewable gummy ingredients to absorb moisture from the environment. This condition causes changes in the equilibrium of surface water molecules; hence the preparation becomes wet and soft [35]. The impact of these conditions is a decrease in the integrity of the polymer network, so the disintegration time of the preparation becomes faster than the initial conditions. The decreasing trend of disintegration time of the four formulas during storage is shown in Figure 2.

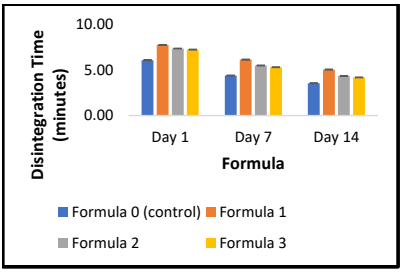

Figure 2. The disintegration time of *Moringa oleifera* leaf extract chewable gummy tablet during storage

The changes of swelling ratio are also observed during storage. The results of statistical analysis using one-way ANOVA showed that there were differences in the swelling ratio of each formula compared to the initial conditions ($p <0.05$). The swelling ratio of the chewable gummy preparation of Moringa leaf extract increased significantly on the 7th and 14th days. The increase in the swelling ratio occurred due to changes in the pH of the

chewable gummy during storage, enhanced by the environmental condition. When the pH changes, the negatively charged sulphate groups on different chains induce electrostatic repulsion, hence the voids between the chains widen and become more permeable. This condition causes the amount of water that enters the tissue abundant, caused the swelling ratio of the chewable

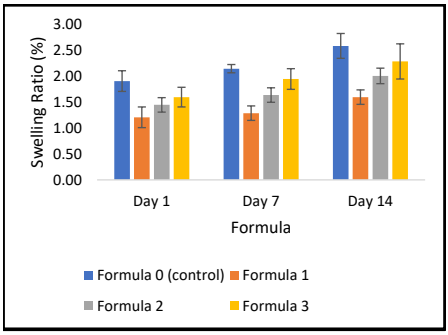

Figure 3. The swelling ratio of *Moringa oleifera* leaf extract chewable gummy tablet during storage

gummy tablet becomes larger [41]. The results of the chewable gummy of Moringa leaf extract swelling ratio during storage is tabulated in Figure 3.

The alteration in syneresis percentages was also observed from the four formulas during storage on the 7th and 14th days. The results of statistical analysis showed a significant change in the syneresis percentage during storage ($p<0.05$). The highest syneresis percentage was indicated by the control formula (formula 0) with single kappa carrageenan as a gelling agent, followed by

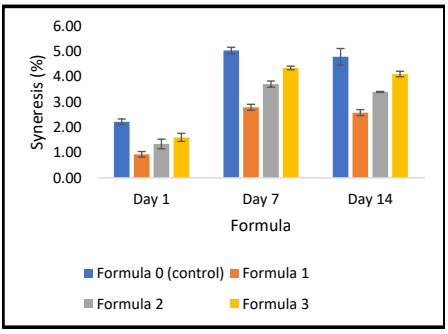

Figure 4. The syneresis percentage of *Moringa oleifera* leaf extract chewable gummy tablet during storage

formula 3, formula 2, and formula 1. The increase in syneresis observed from the four chewable gummy formulas of Moringa leaf extract is shown in Figure 4. Chewable gummy with a higher proportion of kappa-carrageenan showed a higher percentage of syneresis because during storage there was a rigid network formation observed due to cross-linking of the double helix polymer. This conformation pulled out the water molecules from the gel structure.

Based on the evaluation of the physical stability of the chewable gummy of Moringa leaf extract in this study, it was found that there were changes in tablet dimensions, weight, disintegration time, and syneresis percentage for 14 days of storage. The control formula, formula 3, and formula 2 with a larger proportion of kappa-carrageenan than iota carrageenan showed an increase in the swelling ratio and syneresis, as well as significant changes in weight and dimensions compared to formula 1.

4. CONCLUSION

The ratio of kappa-carrageenan and iota-carrageenan affect the physical characteristics of the chewable gummy of Moringa leaf extract. The greater the ratio of kappa-carrageenan in the gelling agent, the chewable gummy texture becomes stiffer, and the disintegration time becomes longer. The swelling ratio and syneresis percentage are also increased. The optimum ratio of gelling agent combination kappa-carrageenan and iota carrageenan in the chewable gummy formulation of Moringa leaf extract is 1:1 (formula 1). Chewable gummy Moringa leaf extract in this formula has a chewy texture, uniform weight and dimensions, disintegration time less than 15 minutes, and the lowest syneresis percentage. Evaluation of the physical stability of the chewable gummy extract of Moringa leaves also showed that there was an alteration in the physical characteristics of the chewable gummy preparation. Chewable gummy with the proportion of kappa-carrageenan – iota carrageenan 1:1 (formula 1) showed better stability than other formulas.

AUTHOR'S CONTRIBUTIONS

Karina Citra Rani contributes to the conceptualization and writing original article, Nabilaberty Prisma Gemilang contributes to conduct research and prepare the data, Nikmatul Ikhrom Eka Jayani contributes to the writing process and review the article.

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