***Original Research Article***

**Development and Characterization of Bigel Based on Corn Oil and Beeswax with Gelatin Hydrogel as a Fat Replacer**

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**ABSTRACT**

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| The aim of this study was to determine the optimal ratio of bigel based on beeswax-corn oil oleogel and gelatin hydrogel as a fat replacer. The study employed a completely randomized design (CRD). Data obtained were processed using Microsoft Excel and analyzed using analysis of variance (ANOVA). If significant or highly significant differences were found, Duncan’s Multiple Range Test (DMRT) was applied. The study was conducted at the Laboratory of Animal Product Technology, Faculty of Animal Science, and the Food Technology Laboratory, Universitas Brawijaya, from February 3 to March 25, 2025. The research investigated bigel formulations made from beeswax-corn oil oleogel and gelatin hydrogel at various ratios as a fat substitute. The variables observed included moisture content, fat content, texture, color, oil binding capacity (OBC), weight loss, antioxidant activity, FTIR, and microstructure. The results showed highly significant differences (*P*<0.01) in moisture content (18.51%–42.53%), fat content (81.87%–50.53%), texture (0.49 N–0.91 N), weight loss (0.81%–1.92%), and antioxidant activity (26.08 µg/ml – 61.48 µg/ml). However, OBC and color did not show significant differences (*P*>0.05), with OBC ranging from 97.98%–98.22% and color values of L\* (87.13–88.98), a\* (0.25–0.22), and b\* (15.29–15.03). The study concluded that bigel based on beeswax-corn oil oleogel and gelatin hydrogel had a significant effect on moisture, fat content, texture, weight loss, and antioxidant activity, but did not significantly affect OBC and color. The best oleogel-to-hydrogel ratio was found in treatment P1 with a ratio of 80:20. |

*Keywords: Bigel; Oleogel; Hydrogel; Beeswax; Corn Oil; Gelatine.*

**1. INTRODUCTION**

Bigel is an innovative semi-solid system consisting of a combination of hydrogel and oleogel that combines two phases to produce a material with superior stability, encapsulation capabilities and mechanical properties (Shakeel et al., 2022). Bigel is a gel form of vegetable fats and gelatin that can be used to replace some saturated fats as a healthier alternative technique with the potential to reduce saturated fat levels and increase the profile of unsaturated fatty acids (Jing et al., 2015). Beeswax is able to form dense tissue that can maintain the physical integrity of the bigel, slow the migration of active substances and provide rheological characteristics suitable for topical and food applications (Meng et al., 2018). Oleogels are generally rich in unsaturated fatty acids that acquire a solid texture while trapped in three-dimensional crystalline tissue formed by regulatory agents (oleogelators) at certain concentrations. The characteristics of each gel such as viscosity, hardness and melting point may vary depending on the regulatory agent allowing the development of different products (Floter et al., 2021). The use of oleogel not only to replace fat can act as a carrier of water-insoluble bioactive substances, a stabilizer for products that do not use emulsifiers, oil binders or provide heat resistance to food products (Puscas et al., 2020).

Corn oil is used as an oil phase in the development of bigels because it contains polyunsaturated fatty acids, especially linoleic acid and vitamin E, which function as natural antioxidants (Dwiputra et al., 2015). The combination of beeswax and corn oil in oleogel formation is able to produce a matrix that is stable and flexible in regulating its textural and functional properties. Hydrogels derived from natural polymers such as gelatin have a good ability to absorb water and form stable hydrophilic networks through the interaction of hydrogen bonds and three-dimensional structures. (Chen et al., 2011). Combining beeswax and corn oil oleogels with gelatin hydrogels in a bigel system is expected to be able to form a stable multiphase structure. The main focus in this formulation is evaluating the role of beeswax in shaping and strengthening oleogel tissue, which has a direct impact on the overall physicochemical characteristics of the bigel. Thus, the development of bigels based on beeswax, corn oil and gelatin is expected to contribute to producing food or pharmaceutical products that are healthier, more stable and have good sensory qualities.

**2. material and methods**

**2.1 Sampling of Raw Materials**

The materials used in this study were beeswax oleogel-based bigel (Beeswax) with corn oil (*Zea mays L*.) and gelatin hydrogel. Ingredients used in this study included beeswax (Kembang Joyo), corn oil (Tropicana Slim), GMS (Glycerol monostearate), bovine gelatin (Haqiqi) and aquades. Tools used include glass beaker (Pyrex), glass stirrer, magnetic hotplate stirrer SH-2, electric stove, handblender (Bosch) knife, 200ml plastic container.

**2.2 Preparation of Oleogel, Hidrogel and Bigel**

The hydrogel manufacturing procedure refers to a method developed by Noman and Neetu (2023) with some modifications. Making hydrogel is carried out in several stages, namely preparing 20 grams of gelatin powder, then dissolving it in 180 ml of aquades in a beker glass. The solution is heated and homogenized to a temperature of 40˚C for 15 minutes. Put in a container for 2.5 hours until hardened.

The procedure for making oleogel refers to the method proposed by Zulfiqar et al. (2024) with some modifications. The stages of making oleogel begin by heating beeswax to 6% of the 500 ml amount of corn oil. Next, add 5.1grams of GMS (Glycerol monostearate) and corn oil. The mixture is then heated on an electric stove under the supervision of a thermometer until it reaches a temperature of 70˚C, while being homogenized until the beeswax dissolves completely. After that, the solution was poured into a storage container and left at room temperature of 27.5 ˚C for 1.5 hours until hardened.

The procedure for making bigel refers to the modified method of Prasad et al. (2023). Corn oil oleogel (*Zea mays L*.) and gelatin hydrogel were prepared in ratios of 80:20, 70:30, 60:40, and 50:50. The mixture was then homogenized using a handblender (Bosch). After mixing evenly, the bigel is stored in a container and ready for testing.

**2.3 Water Content**

The water content testing procedure uses the gravimetric method Sakul, et al. (2019) with modifications. The cup is placed in the oven for 24 hours at a temperature of 105˚C, then placed in a desiccator for 30 minutes and left to cool and then weighed (A). A sample of 3 grams is put into a weighing bottle then weighed (B), the cup is placed in the oven at a temperature of 105˚C for 24 hours. After completion, the sample is put into a desiccator and then left to cool and then weighed (C).

Water Content = $\frac{B-C}{B-A} x$ 100

**2.4 Fat Content**

The fat content testing procedure uses the Soxhlet AOAC method (2005) with modifications: filter paper and cotton dioven at a temperature of 105°C for 12 hours. Put in a desiccator for 15 minutes then weighted as (BS). Weighing the sample by 1 gram and wrapped in filter paper and cotton to form a cylinder then weighing it as (BSK). A solution of Petroleum Ether (PE) of 60 ml was added above the cylinder and 150 ml below the cylinder. Samples were extracted for 6 hours. Samples wrapped in filter paper were taken. Cooled and placed in an oven at 105°C (24 hours). Put in a desiccator for 15 minutes then weighted as (BK).

Fat Content (%) = $\frac{BS – (BSK – BK)}{BK}$ X 100%

Dry Fat Content %

= $\frac{ \left(100 –\%water content\right) \%fat content}{100}$

**2.5 Texture**

The texture testing procedure uses the texture analyzer Kaimal and Shinghal (2012) as follows: a sample of 50 grams is prepared in the cup which will be measured and placed under the probe, installed and positioned the sample well. Turn on the device and make sure that the value displayed on the monitor is at zero. Select the "*start test*" menu and pull the handle down so that the probe moves through the sample. The assay is considered complete when the probe returns to its initial position. The test results will be displayed in Newton units (N) on the monitor.

**2.6 Color**

Test procedure Color L\*a\*b\* using colorimeter refers to Phatarhe et al. (2013) is as follows: Color reader is turned on by pressing the power button. Color measurements use color reader scales L\* (white), a\* (red), and b\* (yellow). A sample of 10 grams is inserted and flattened into a 7x10 plastic clip, then placed on the lens on the tool. First time chromameter with white as standard. The measurement results are in the form of L\*, a\*, and b\* values.

**2.7 Weight Loss**

The modified Calligaris et al. (2021) weight shrink testing procedure is as follows: 2 grams of bigel is weighed and then placed in a petri dish, then Bigel is left for 2 weeks at room temperature 25. The final weight of the bigel is obtained by weighing the bigel. After that, calculate the weight loss using the following formula:

Weight Loss (%) = $\frac{early weight-final weight)}{early weight}$ x 100%

**2.8 *Oil Binding Capacity* (OBC)**

The oil binding capacity test procedure refers to Li et al. (2024) with the following modifications: a blank centrifuge tube was weighed as (m1), then a sample of 6 grams was prepared and placed in a 15 ml centrifuge tube and then weighed as (m3), centrifuged at 4500 rpm for 15 minutes. Inverted the tube for 5 minutes until all the oil came out and weighed as (m3). The OBC formula is as follows:

OBC (%) = 100% - $\frac{m2-m3}{m2-m1}$

**2.9 Microstructur**

Microstructural testing using *Confocal Laser Scanning Microscopy* (LEICA) as follows: 6 grams of bigel was stained with 40 µL of Rhodamine B dye (0.2%, w/v), then the sample was diluted with 100 µL of aquades. After that, samples were taken and 10 µL of type G emergent oil was dripped on the slide and covered with a glass cover. Observed samples with Confocal Laser Scanning Microscopy. Images are taken using 40x objectives

**2.10 Antioksidant Activity**

Procedure for testing antioxidant activity based on AOAC (2005). The principle of testing antioxidant activity uses the DPPH method and continues with the use of IC₅₀ as follows: dilute a sample of 0.1 grams with 10 ml of methanol in a centrifuge tube, then leave for 24 hours. Subsequently, three concentrations were prepared, namely 100%, 50% and 25% and 1 ml of DPPH was added to these concentrations. Homogenized and masrated for 30 minutes. Next, it was placed in a cuvette and absorbance was measured with a wavelength of 517 nm with a methanol blank. The absorbance value was measured using a 517 nm wavelength spectrophotometer. The IC₅₀ value is determined by entering the sample concentration and % inhibition into the linear regression equation. The x value is intended for sample concentration and the y value is directed to the y axis Determination of the IC₅₀ value is included in the equation Y = ax + b, y is 50 and x is the expected IC₅₀ value.

**2.11 *Fourier Transform Infrared* (FTIR)**

The FTIR test procedure refers to Martins et al. (2023) using Shimadzhu IRSprint as follows: turn on the Shimadzu IRSpirit FTIR instrument and wait until the system is ready. Heated tool about 15–30 minutes. Sample drops and measurements were carried out in a vacuum atmosphere, in the wave number range of 400 to 4000 cm⁻¹.

**2.12 Statistical Analysis**

The research method applied was an experimental method using a Complete Randomized Design (RAL) consisting of 4 treatments and 4 replicates. The data obtained were analyzed using variance analysis (ANOVA) by applying the Complete Randomized Design (RAL) and repeated four times. If there is a significant (*P*<0.05) or very significant (*P*<0.01) difference in the analysis results, the Duncan Multiple Distance Test (UJBD) is performed.

**3. results and discussion**

The results of this study are presented in tables summarizing the proximate analysis and physical quality of with varying ratios of oleogel to hydrogel. Table 1 shows data on water content, fat content, and antioxidant activity. Table 2 presents sensory and physical quality parameters of the bigel, including color values (L, a\*, b\*), oil binding capacity (OBC), weight loss, and texture.

**Tabel 1. Proximate Analysis**

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| --- | --- | --- | --- |
| Parameters | Water Content (%) | Fat Content (%) | Antioksidant (µg/ml) |
| P1 (80:20) | 18,33 ± 2,04ª | 81,87 ± 4,69ª | 26,08 ± 8,08ª |
| P2 (70:30) | 24,90 ± 1,05ᵇ | 71,68 ± 0,72ᵇ | 32,38 ± 0,93ªᵇ |
| P3 (60:40) | 35,05 ± 0,90ᶜ | 60,65 ± 1,93ᶜ | 51,28 ± 4,59ᵇ |
| P4 (50:50) | 42,53 ± 2,42ᵈ | 50,53 ± 2,27ᵈ | 61,48 ± 12,70ᶜ |

*Values are presented as mean ± Standard Deviation from four replications. Means in the same column with different superscripts are significantly different at p<0.05.*

**Table 2. Sensory Analysis**

|  |  |
| --- | --- |
| Parameters | Variables |
| L | a\* | b\* | OBC (%) | Weight Loss(%) | Texture (N) |
| P1 (80:20) | 18,33 ± 2,04ª | 81,87 ± 4,69ª | 1,96 ± 0,49ª | 97,98 ± 0,12 | 0,81 ± 0,11ª | 1,96 ± 0,49ª |
| P2 (70:30) | 24,90 ± 1,05ᵇ | 71,68 ± 0,72ᵇ | 2,67 ± 0,67ª | 97,99 ± 0,06 | 0,86 ± 0,07ªᵇ | 2,67 ± 0,67ª |
| P3 (60:40) | 35,05 ± 0,90ᶜ | 60,65 ± 1,93ᶜ | 2,80 ± 0,70ªᵇ | 98,00 ± 0,05 | 1,64 ± 0,73ᵇ | 2,80 ± 0,70ªᵇ |
| P4 (50:50) | 42,53 ± 2,42ᵈ | 50,53 ± 2,27ᵈ | 2,74 ± 0,91ᵇ | 98,22 ± 0,44 | 2,18 ± 0,95ᵇ | 2,74 ± 0,91ᵇ |

*Values are presented as mean ± Standard Deviation from four replications. Means in the same column with different superscripts are significantly different at p<0.05*

* 1. **Water Content**

The results of the variance analysis showed that the ratio of beeswax and gelatin-based oleogel and hydrogel exerted a very significant effect (*P*<0.01) on the mean moisture content values in the bigel. The lowest moisture content value was obtained in sample P1 at 18.33% with an oleogel to hydrogel ratio of 80:20, followed by sample P2 at 24.90%, sample P3 at 35.05% and the highest value was found in sample P4 at 42.53% with a ratio of 50:50. The increase in moisture content as the proportion of hydrogel increases indicates that the higher the hydrogel composition in the bigel, the greater the moisture content absorbed.

According to Table 1, the moisture content makes a very significant difference to the characteristics of the bigel, with a value range between 18.33% and 42.53%. These results are not much different from studies conducted by Gulsac et al. (2024), who reported moisture content in plant-based bigels from protein hydrogels of chickpeas and oleogel glyceryl monostearate ranging from 49.81% to 56.54%. This difference can be explained through the properties of each bigel-forming component. The use of gelatin as a hydrogel material allows the formation of three dimensional networks of hydrophilic polymer structures capable of absorbing and retaining large amounts of water. (Firdaus et al., 2024). In addition, based on research conducted by Kaimal and Rekha (2023), bigels with a hydrogel to oleogel ratio of 75:25, 50.55 and 25:75 have consecutive water content values of 73.84%, 49.14% and 23.41%. This suggests that the increase in hydrogel fraction significantly contributes to the increase in moisture content in the bigel system.

* 1. **Fat Content**

The results of the variegation analysis showed that the ratio of oleogel to hydrogel in beeswax and gelatin based bigels made very significant differences in fat content. The highest mean value was found in sample P1 at 81.87%, while the lowest mean value was found in sample P4 at 50.53%. The average value of P1-P4 has decreased because the proportion of oleogel has decreased. Oleogel is the fat phase in bigel which is composed of corn oil and beeswax, so an increase in the proportion of oleogel contributes to the high fat content in bigel. In contrast, the addition of a large proportion of gelatin-based hydrogels containing water tends to significantly decrease fat levels. Overall, the bigel fat content in this study was in the range of 81.87%–50.53%. This is not in accordance with the study by Gulsac et al (2024), the fat content in hydrogel-based bigels of chickpea protein and oleogel glyceryl monostereate was 12.10%-28.65%. This difference is due to the type of base used because beeswax and corn oil have a much higher fat content than glyceryl monostearate.

* 1. **Antioksidant Activity**

The results of the variegation analysis showed that the ratio of oleogel to hydrogel made a very significant difference (*P*<0.01) to the antioxidant activity in the bigel. The IC₅₀ mean value of antioxidant activity of P1 sample was 26.08 µg/ml, P2 sample was 32.38 µg/ml, P3 sample was 51.28 µg/ml and the sample with the highest value in P4 sample was 61.48 µg/ml. The highest mean value was found in the P1 sample at 26.08 µg/ml with an oleogel and hydrogel proportion of 80:20. This is not much different from research conducted by Firdaus and Sunita (2024), the IC₅₀ value for bigel antioxidant activity based on beeswax oleogel and coconut oil is 26.13 µg/ml. P1 samples had quite high antioxidant activity values because the proportion of oleogel containing corn oil was greater. Research is not much different from Khelifi, et al (2019), a 5,8-dihydroxy-1,4-naphthoquinone based bigel with DPPH methofe has a value of 19 × $10^{-3}$ mg/mL dan 35× $10^{-3}$ mg/ml. According to Kholifah et al. (2023), an IC₅₀ value (µg/ml) between <50 indicates very strong antioxidant activity, a value of 50–100 indicates strong antioxidant activity and a value above 100 indicates weak antioxidant activity. According to Table 1 it can be observed that beeswax and corn oil based bigels show strong antioxidant activity as corn oil is a good source of antioxidants.

* 1. **Color**

The results of the variance analysis showed that the ratio of oleogel to hydrogel in the bigel did not make a significant difference (*P*>0.05) to the L\*, a\* or b\* values. The average value in the L\* parameter (brightness) ranges from 87.13-88.98. The average value in the a\* (redness) parameter ranges from 1.00-0.86, while for the b\* (yellowish) parameter it has a value of 15.29-15.03. This can be explained because beeswax-based oleogels and corn oil have a natural brownish yellow color, so a decrease in the number of oleogels causes a reduction in the intensity of redness and yellowishness in the bigel. This research is similar to Lee, et al. (2024), the color value in the oleogel based bigel of kadelila wax with guar gum hydrogel has an L\* value of 32.59-35.57, an a\* value of 14.35-11.59 and a b\* value of 30.50-28.76 shows that bigel also has quite dominant yellowish color characteristics. In addition, research conducted by Shaikh et al (2022), a kandelila wax oleogel-based bigel and sesame oil with a guar gum hydrogel color value L\* of 97.76-98.81, the a\* parameter is -5.74 to -7.05, while for the b\* parameter it is 19.06-23.92.

* 1. ***Oil Binding Capacity* (OBC)**

The results of the variance analysis showed that the ratio of oleogel to hydrogel in the bigel presented a very significant difference (*P*<0.01) to OBC. The average OBC value has an increase in each sample. Sample P1 had the lowest value at 97.98%, sample P2 at 97.99%, sample P3 at 98.00% and sample P4 had the highest value at 98.22% at around 97%-98.22% as the proportion of hydrogel increased. Increased proportion of hydrogels in bigel formulations that contribute significantly to increased OBC. The ability of hydrogels to form stable and organized hydrophilic networks. The three-dimensional structure produced by the hydrogel is supported by its high water absorption capacity so that it is able to maintain elasticity. This is in accordance with Shakouri, et al (2025), increasing the hydrogel phase limits the movement of oil in the bigel and increases the OBC thereby acting as a surfactant to effectively reduce interfacial tension and inhibit phase separation. Based on Table 3. The highest OBC mean value was found in the P4 sample at 98.22%. This is in agreement with Liu et al (2025), the highest OBC value in soybean oil and insect wax based bigels was 99.8%. Meanwhile, research conducted by Samui et al (2021), bigels with long homogenization treatments of 1,3.5 and 7 minutes was valued at 85%, 99%, 99% and 91%.

* 1. **Weight Loss**

The results of the variance analysis showed that the ratio of oleogel to hydrogel in the bigel presented a very significant difference (*P*<0.01) with respect to weight shrinkage. The mean value of the shrinkage of the P1 sample weight was 0.81%, the P2 sample was 0.86%, the P3 sample was 1.64% and the P4 sample had a value of 2.18%. The highest value was found in the P4 sample, namely 2.18% and the lowest value, namely 0.81%. Weight loss increases as the proportion of hydrogel in the bigel formulation increases. This is because hydrogels have a high water content so that during the evaporation or storage process mass loss occurs due to evaporation of water from the system. The greater the proportion of hydrogel, the greater the amount of water available to evaporate and causes the weight loss value to be higher. Based on Table 4. the average value of weight loss in the bigel sample during two weeks of observation ranged from 0.81%-2.18%. This weight loss value is relatively low when compared with the results of research by Silva et al (2022), who reported that weight loss in their bigels ranged from 13.20% to 23.90% after a 28 day observation period.

* 1. **Texture**

Variety anailis results showed that the ratio of beeswax and gelatin-based oleogel to hydrogel gave very significant differences (*P*<0.01) in the texture in the bigel. The lowest texture average value was found in sample P1 having a mean value of 1.96 N followed by sample P2 of 2.67 N, sample P3 with the highest value of 2.80 N and sample P4 of 42.53%. Based on the measurement results of the average value of the bigel texture ranging from 1.96 N to 2.80 N, the bigel has an increase in hardness as the proportion of hydrogel in the bigel formulation increases. This is in line with Martins et al (2023), the ratio of oleogel to hydrogel 50:50 to 99:1 has decreased hardness values in bigel when the proportion of oleogel is increased. This is due to the ability of hydrogels, especially gelatin, to form three-dimensional polymer networks that are hydrophilic. This tissue is able to hold water well and provides a stable mechanical structure, thereby strengthening the overall physical integrity of the bigel. The results of this study are in line with the findings of Shakouri et al. (2024), the value of bigel texture decreases as the proportion of gelatin decreases and the proportion of CMC increases with a range of 2.62 N to 1.72 N. Bigel samples with higher gelatin content showed a more robust texture, indicating that gelatin plays an important role in forming a strong and dense gel network compared to CMC which produces a softer gel structure. According to Samui et al (2021), bigel studies with differences in homogenization duration of 1, 3, 5 and 7 minutes were 0.35 N, 0.35 N, 0.30 N and 0.20 N.

* 1. **FTIR**

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**Fig 1.** FTIR graph of bigels

The FTIR analysis of Figure 1 shows several absorption bands illustrating changes in the chemical composition of the sample. The absorption band area of 3100-3500 cm⁻¹ is related to the OH strain (stretching) of the alcohol or hydroxyl group, experiencing an increase in intensity in the P4 sample. This suggests a high water or hydrogel content of gelatin in accordance with the findings of Mallamace et al. (2015), the wide band in this range is closely related to the vibrations of O–H and N–H, both in free and bound form commonly found in hydrogel-based systems. In contrast, the absorption band area of 2800-3000 cm⁻¹ shows aliphatic CH strain of the lipid or oleogel components of beeswax and corn oil, experiencing a decrease in intensity from P1 to P4. This is in accordance with Sagiri et al. (2015), C–H peaks in 2920 and 2850 cm⁻¹ decreased with reduction in lipid fraction in the bigel system. The absorption band region of 1600-1750 cm⁻¹, derived from the C=O strain of ester or carbonyl groups (from triglycerides or beeswax esters), is most intense at P1, indicating oleogel dominance. This is in accordance with Martins et al. (2023), the presence of absorption bands around 1745 and 1160 cm⁻¹ indicates an increase in oleogel fraction associated with C=O and C–O strain vibrations of triglycerides. In sample P4, the intensity of this band is reduced due to a decrease in the proportion of oleogel. The band around 1630 cm⁻¹ comes from a C=O strain of amide I (gelatin protein) or –OH of structured water and is more prominent in samples with a high hydrogel ratio (P4) indicating an increased content of gelatin hydrogel or structured water. This is in accordance with Hashemi et al, (2017), a band around 1620 cm⁻¹ associating with the characteristics of gelatin proteins in the protein-polyphenol gel system. The absorption band of the region 1000-1200 cm⁻¹ associated with ether or polysaccharide groups in the hydrogel material shows a decrease in intensity as the ratio of gelatin hydrogel in the sample (P4) increases. This was conveyed by Cakman and Arslan (2022), the reduction in the fraction of polysaccharides sourced from oleogels or interactions between components that influence their existence and strengthens the idea that structural changes in bigels are physical.

* 1. **Microstructur**

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| --- | --- | --- | --- |
| a. | b.  | c.  | d. |
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**Fig 2**. *Confocal Laser Scanning Microscopy* (CLSM) bigel image based on beeswax and gelatin with rhodamine. The top row shows the oil phase distribution (red) and the bottom row shows the image of the gray scale. a) 80:20, b.) 70:30, c.) 60:40 and d.) 50:50. Bar scale = 25 µm.

Based on Figure 2. The results of bigel observations using *Confocal Laser Scanning Microscopy* (CLSM) with rhodamine B staining which shows the difference in oil phase distribution in bigels with variations in oleogel and hydrogel ratios. Large oil droplets were seen in samples with higher oleogel ratios. The droplets are dispersed in an uneven manner (Figure a). As the proportion of hydrogels increases (Figure b, c, d) the droplet distribution becomes more homogeneous with smaller, evenly dispersed droplet sizes. The network structure formed becomes denser and more continuous, indicating increased interaction between phases. This pattern suggests that hydrogels play a role in stabilizing the bigel system by forming a stable three-dimensional network that is able to limit the movement of the oil phase and inhibit phase separation.

According to research by Silva et al (2022), the protein-based bigel structure of chickpeas along with oleogel glyceryl monostearate shows that increasing the proportion of hydrogels increases the homogeneity of oil droplet distribution along with the stability of the bigel structure. This finding is in line with the research of Zhang et al. (2021), the increase in hydrogel fraction in oleogel monoglyceride-based bigels and gellan gum hydrogels led to a decrease in oil droplet size as well as an increase in homogeneity of distribution. Similarly, a study by Li et al. (2024), the addition of hydrogels increases the stability of the internal structure of the bigel and reduces the agglomeration of the oil phase and strengthens the interactions between the phases. In addition, these results are also consistent with the research of Kavya et al. (2024), emphasizing the importance of comparisons in determining the microstructure and stability of bigels.

**4. Conclusion**

The results showed that beeswax oleogel and corn oil based bigels with gelatin hydrogel exerted a very significant effect on moisture content, fat content, texture, weight loss and antioxidant activity, while not providing significant differences on OBC and color. A good ratio of oleogel to hydrogel was present in the P1 treatment at a ratio of 80:20.

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