Journal of Food Science and Technology (Iran)

Homepage:www.fsct.modares.ir

Scientific Research

Preparation of Gel-filled Emulsion Based on Canola Oil-Different Hydrogelators (Gelatin, Agar-agar and Xanthan) as Butter Substitute

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ARTICLE INFO

Article History:

Received:2024/9/7

Accepted:2025/7/1

Keywords:

Canola oil,

Emulsion,

Gel,

Gelatin,

Agar-agar,

Xanthan

DOI: **10.22034/FSCT.22.165.86.**

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ABSTRACT

This study was investigated the production and evaluation of gel-filled emulsions based on canola oil, water, and hydrogelators as commercial butter substitutes. Given the growing need, this research attempted to create emulsions that are similar or even superior to commercially available butter samples in terms of functional and nutritional value, by utilizing aqueous phase structuring with the help of various hydrogelators and canola oil. In this study, hydrogelators (gelatin, agar-agar, and xanthan) used as aqueous phase structuring agents and two types of emulsifiers (sorbitan monostearate and glycerol monostearate). Various variables (amount of hydrogelator, type of emulsifier, and water-to-oil ratio) considered in the preparation of emulsions, and finally that investigated properties of the emulsions, including thermal, oxidative, physical, sensory, and textural stability. The results showed that increasing the hydrogelator led to an increase in the hardness of the samples based on all three types of hydrogelators. While the choice of emulsifier type had different effects on other properties depending on the type of hydrogelator. Agar-agar and xanthan-based samples containing glycerol monostearate compared to sorbitan monostearate had better properties than gelatin-based samples.The results of this study generally indicate that the prepared gel-filled emulsions can be used to a suitable substitute for butter products in the food industry, without having any effect on the sensory and functional quality of the final product.

1-Introduction

Animal butter is one of the dairy products that has a variety of uses, although it has a large amount of saturated fatty acids and its consumption leads to cardiovascular diseases.]1[. Considering the limitations of using animal butter, in finding a suitable alternative for it, it is important to pay attention to things such as: 1) reasonable price and availability, 2) having appropriate and desirable nutritional characteristics. Considering that there is a large amount of saturated fatty acids and cholesterol in animal butter, alternative products should have less saturation (high unsaturated fatty acids). Vegetable oils, due to the presence of a large amount of unsaturated fatty acids in their structure, can be used as a substitute for animal butter in the form of margarine.]2، 3[. Normally, in the preparation of margarine, partially hydrogenated sources containing trans fatty acids are used. Considering that trans fatty acids are very important in creating product characteristics, paying attention to the effect of trans fatty acids in causing cardiovascular diseases and also finding a suitable solution in this field is considered important.]3[.

Various modification methods are used to remove and reduce trans fatty acids, especially for oil/fat based products, if each has its own advantages and disadvantages. One of the new correction methods is called oleogelation, which can be used to structure fats/oils. In the field of oleogelation, there is a topic called gel-filled emulsion, which is classified as structured emulsions, and it is an emulsion that includes a dispersed aqueous phase, a continuous oily phase, has a jelly-like state, and the gelling compound in them is soluble in the aqueous phase. Usually, 50-90% of gel-filled emulsions consist of water]4[. The main difference between emulsions filled with gel compared to other emulsions (including the structured emulsion of water in oil (oleogel)) is the use of gel-forming compounds specific to this type of emulsions called hydrogelators, so that these types of compounds, having the property of being soluble in water, create unique characteristics in the emulsion filled with gel.]4، 5[.

Various researches have been carried out in the field of emulsion filled with gel to prepare substitutes for Korean products. In the preparation of gel-filled emulsion based on inulin and extra virgin olive oil by Whichet al. (2019), the results showed that according to the components used in the production emulsion (presence of fiber, unsaturated fatty acids and phenolic antioxidants), this type of emulsion can be used as a substitute for spreads.]5[. Kangchaiet al. (2018) to prepare a type of margarine based on gel-filled emulsion using the formulaA paid; The results showed that the concentration of hydrogelator (formulaA) had an effect on textural and microstructural characteristics and also the use of soybean oil had a greater effect on the final characteristics of the product compared to commercial margarine.]6[. Hydrogelatory compounds, including gelatin, in gel-filled emulsions act as a structuring agent for the aqueous part and can lead to a change in product characteristics, including an increase in product viscosity.]6[. Garcia-Ortega et al. (2021) compared the properties of water-in-oil emulsion and gel-filled emulsion; reported that gel-filled emulsions had less solids, high elasticity and more stability]7[.

This research was carried out with the aim of designing an emulsion filled with gel based on canola oil, aqueous phase and three different types of hydrogelators. Canola oil can be used as a base oil in the preparation of margarine, because it has unique properties]3[. Canola oil has more unsaturation (oleic acid is about 60%) than saturation (less than 12%) in its structure.]3، 8[. According to the mentioned contents, canola oil has various advantages, including: 1) reasonable price, 2) availability and 3) nutritional value; So, if it is used as an alternative source of animal

[DOI: 10.22034/FSCT.22.165.86]

butter, it is also economical. In this research, three types of emulsion filled with gel as a substitute for animal butter based on three different types of hydrogelators (gelatin, agar-agar and xanthan), two emulsifiers (sorbitan monostearate and glycerol monostearate), aqueous phase and canola oil were prepared. In this research, the effect of formulation variables on the characteristics of gel-filled emulsion (the effect of the type and percentage of hydrogelator, the type and percentage of emulsifier, and the ratio of water to oil phase) was investigated.

2- Materials and methods

1-2- Materials

Refined canola oil and commercial butter samples were obtained from a grocery store in Sari, Iran. Glycerol monostearate emulsifier was obtained from Kiashimi Yasouj Cosmetics-Healthy Company, Iran, and sorbitan monostearate emulsifier was purchased from Vitfa Company, Iran. Halal cow gelatin (type 2), from Danesh Banyan Halal Pharmaceutical Processing Company Qazvin-Iran; Agar-agar was obtained from Janino Babol store, Iran, and xanthan gum was obtained from Temadkala Company (main source in China), Iran.

2-2-Research plan

The emulsions prepared in this study were gel-filled emulsions. The components used in this type of emulsions included: 1) base oil (canola oil), 2) hydrogelators (gelatin, agar-agar and xanthan), 3) emulsifier (glycerol monostearate and sorbitan monostearate) and 4) water (the role of the aqueous phase). In preparing the emulsions of this research, the consumption of emulsifier was fixed (7%), the consumption levels of hydrogelators were determined at 3 separate levels (1, 2 and 3%) and the total aqueous phase (water + hydrogelator) at 3 separate levels (30, 35, 40%). In general, the general components used in abbreviated form: formula A (gelatin), formula B (agar-agar), formula C (xanthan), emulsifier G (glycerol monostearate), emulsifier S (sorbitan monostearate) were In this research, a complete factorial design was used to examine the individual effect of each factor alone, the double effect, and the overall effect of the factors for each type of test.

2-3-Preparation of emulsion samples filled with gel

Emulsions filled with gel in this research based on the method provided by Gracia-Ortegaet al. (2021) were prepared with slight changes]7[. After weighing the components, two oil phases and water phase are separately-simultaneously subjected to heat treatment (formula A and B: ^{0}C70-90; Formula C: ^{0}C90) were placed using a mixer heater. After applying the mentioned heat treatment, emulsifier was added to the oily phase and hydrogelator to the aqueous phase, and then the samples were individually heat treated for 15-30 minutes and stirred. rpm375 were placed to create a turbid state, especially in the container of the total aqueous phase (aqueous phase + hydrogelator). After the mentioned treatment and complete dissolution of the components in the respective containers, transfer the contents of the container containing the entire aqueous phase (aqueous phase + hydrogelator) to the oil phase container (oil phase + emulsifier) and with Ultrathorax (SilentCrusherM (EU), P/N: 595-06000-00-3, S/N: 200017978, Heidolph Instruments GmbH & Co., KG, Germany) It was subjected to homogenization treatment. Sample homogenization treatment conditions based on the formulaA / formulaC2 minutes per round rpm12,000 and also based on the formulaB, only 1 minute away rpm It was 15000-12000. After the first homogenization treatment, the only sample based on formulaA / formulaC for 5 minutes at temp ^{0}C20- was kept and in the second homogenization of the sample for 3 minutes with rpm15,000 were homogenized. In the following, all the samples, after homogenization for 10 minutes in a water and ice bath with a stirrerrpm190 were mixed

[DOI: 10.22034/FSCT.22.165.86]

with a digital mixer. After the end of the said treatment, when the temperature of the sample decreased to 20 degrees Celsius; The water and ice bath was removed from the treatment and the said rotation conditions continued for 10 minutes. At the end, all the samples were kept overnight at room temperature ^{0}C20- were kept.

2-4-Measuring methods of emulsions filled with gel

1-4-2-Determining the thermal properties of emulsions filled with gel

1-1-4-2- Investigating the thermal behavior of emulsions filled with gel

In order to check the thermal behavior of the samples, 15-20 mg of the sample in the containers of the differential scanning calorimeter.[1](model 400, SANAF Electronic Industries, Tehran, Iran) was weighed Then the container containing the sample in the chamber of the device under the temperature range ^{0}C25-80 with rates ^{0}C/min5 was placed. Finally, the software of the device presented the characteristics related to thermal behavior as a result]9[. Thermal behavior indicators include: initial melting temperature (°C), peak temperature (°C), final melting temperature (°C) and peak enthalpy (J/kg).

2-1-4-2- Determination of sliding melting point of emulsions filled with gel

Standard AOCS to the number Cc 3-25 (1996), called the open capillary tube method, was used to check the amount of sliding melting point]10[.

2-4-2- Texture measurement of emulsions filled with gel

In this research, the only characteristic of difficulty in the field of texture is with the texture measuring device TA-XT2i (Stable Microsystems, Godalming, UK) was measured. In order to measure the hardness of the samples, the container containing the sample was exposed to the cone-shaped probe of the device with specific dimensions (4 x 4 x 4 cm) made of acrylic. Probe device with speed mm/s3 penetrated the sample by 23 mm. After penetration, probe the device with speed mm/s10 were separated from the sample. Finally, the hardness characteristic was measured by penetration force]11[.

3-4-2- Determination of oxidative and physical stability of emulsions filled with gel

1-3-4-2- Oxidation stability measurement-Oxy test[2] Gel-filled emulsions

Oxidative stability using the device Oximeter (Velp Scientifica, Usmate, Italy) and the oxytest method according to the standard AOCS to the number Cd 12c-16 (1996) was determined]10[. First, 10 grams of each sample was weighed in the round container of the machine and placed inside the machine. In the continuation of the imported samples under oxygen pressure bar6 and temperature ^{0}C90 were placed. Finally, the software of the device will induce the number by the hour with the title of period[3] presented, which was actually reported as the oxidative stability rate.

2-3-4-2-Determining the physical stability of emulsions filled with gel

1-2-3-4-2-centrifugation stability measurement of emulsions filled with gel

Centrifuge machineHermle Laboratechnik GMB, Type: Z 366, Germany), was used to check the

11-Differential scanning calorimetry (DSC)

2-Oxitest

3- Induction period (IP)

[DOI: 10.22034/FSCT.22.165.86]

stability of the samples against centrifugal force. First, a number of Falcons ml50 weighing (IN_a) and then 5 grams of sample was transferred to it. In the following, Falcon contains samples (IN_b) under conditions rpm3600, 30 minutes and ^{0}C25 was centrifuged. After fulfilling the mentioned conditions, the oily part separated by centrifugation (two-phase separation) was removed from the container containing the sample and the container containing the remaining sample was weighed.IN_c). Finally, centrifugation stability (CS) was determined using the following equation (Equation 1).]12[.

$$\text{Centrifugal stability (CS)} = \left(\frac{INc-INa}{INb-INa}\right) \times 100 \quad (1)$$

2-2-3-4-2-measuring the oil loss of emulsions filled with gel

The weighing method was used to check the oil loss index of the samples]13[. In order to check each sample, first a piece of filter paper (Whatman No. 4) was weighed.B). Then 10 grams of sample (S) was weighed on filter paper (pre-weighed). filter paper containing the sample for 4 hours at ambient temperature (^{0}C25) was placed. After the mentioned time, the sample was separated from the filter paper and the filter paper was weighed.A). Then, oil loss was determined based on the following equation (Equation 2):

$$\text{Oil loss (\%)} = (A - B) / S \times 100\% \quad (2)$$

3-2-3-4-2-measuring the refrigeration stability of emulsions filled with gel

In order to check the salinization index (refrigerated stability), the changes observed in the sample storage containers under refrigerated conditions were used.]14[. First, the samples inside the Falcons ml15 was transferred and its door was closed tightly. Then, the falcon containing the sample was placed in a tube holder and kept in the refrigerator at a temperature of ^{0}C4 was kept for three months. Calculation of the mentioned index using the amount of initial height + height of the sample before storage (H_0(and the amount of height in the pipe after storage due to phase separation)H) was done. The sodium concentration index was determined using the following equation (Equation 3).

$$\text{SI or RS (\%)} = (H/H_0)^* \ 100 \quad (3)$$

4-4-2-Examination of sensory characteristics of emulsions filled with gel

In order to check the sensory characteristics, the evaluation by people along with the use of water and apple slices to clean the sample from the mouth and also the scoring method was used.]11[. Examining characteristics in environmental conditions (^{0}C25) was done. The numerical range of 0-10 was considered as a score according to the chosen method. So that 10 was used as the highest score and zero as the lowest score.

3-Statistical analysis

Complete factorial design to investigate the effect of factors (single, double and overall), using softwareMinitab16 (Minitab Inc., State College, PA, USA) was done. All the treatments of this research were done in 3 repetitions and a significance level of less than 0.05 was selected. Also, the average results ± Standard deviation was reported.

4-Results and discussion

1-4-Thermal properties of emulsions filled with gel

1-1-4-Thermal behavior of emulsions filled with gel

1-1-1-4-Thermal behavior of emulsions filled with gel based on formula A

Thermal behavior results for gel-filled emulsions based on formulationA, presented in Table 1. In the field of thermal behavior

[DOI: 10.22034/FSCT.22.165.86]

based on the formulaAStatistical analysis of the final melting temperature index for all factors and their interactions (binary and overall), the hydrogelator factor in three indexes (initial melting temperature, peak temperature and peak enthalpy) and also on the interaction of the hydrogelator in the emulsifier type in terms of the peak enthalpy index had a significant effect (less than 0.05).

Minimum and maximum initial melting temperature respectively ^{0}C18/40 (the sample contains 1% formulaAEmulsifierS with the ratio of water to oil phase 30 to 70% (and ^{0}C25/79 (the sample contains 3% of the formulaAEmulsifierG with the ratio of aqueous to oily phase was 35 to 65% (Table 1). The lowest and the highest peak temperature respectively ^{0}C 27/48 (sample containing 1% formulaAEmulsifierS and the ratio of water to oil phase is 30 to 70 percent) and ^{0}C 33/10 (sample containing 2% formulaAEmulsifierG and the ratio of water to oil phase was 40 to 60 percent) (Table 1). The minimum and maximum final melting temperature are respectively as ^{0}C56/36 (samples containing 1% formulaAEmulsifierS and the proportions of the water phase to the oil phase are 30 to 70 and 35 to 65 percent) and ^{0}C 05/37 (Sample contains 3% formulaAEmulsifierG and the ratio of water to oil phase was 35 to 65 percent) (Table 1). The lowest peak enthalpy in the limit J/Kg 7/76 (sample containing 1% formulaAEmulsifierG and the ratio of aqueous to oily phase is 30 to 70 percent) and the maximum peak enthalpy in the limit J/Kg 9/49 (sample containing 3% formulaAEmulsifierG and the ratio of aqueous to oily phase was 30% to 70% (Table 1).

Results related to thermal behavior based on the formulaA showed that the emulsifierS plus 1% formulaA in creating the lowest values; If the emulsifierG along with 2 and 3 percent formulaA (other characteristics) played the greatest role in creating values (Table 1). Investigating the thermal behavior of emulsion filled with gel based on the formulaA In terms of the percentage of the aqueous phase, it showed that the initial melting temperature and the peak temperature had different percentages of the aqueous phase; The final melting temperature has different and similar water phase percentages; While Peak enthalpy The percentage of aqueous phase was similar in the lowest and highest amounts (Table 1).

Table 1- Sensory evaluation and thermal properties of gel-based emulsions formula A **(Avg±standard deviation)**

Sensory evaluation							Thermal properties					
Oral coating	like fat	sourness	Milk	melting	playability	difficulty	sliding melting point (0C)	peak enthalpy (J/Kg)	final melting temperature (^{0}C)	peak temperature (^{0}C)	initial melting temperature (^{0}C)	sample
35/1 ±00/0	54/1 ±00/0	11/0 ±00/0	52/0 ±00/0	80/0 ±00/0	70/2± 01/0	30/5 ±00/0	58/36 ±01/0	76/7± 02/0	58/36 ±00/0	49/27 ±00/0	34/19 ±00/0	1GeG 30W
41/1 ±00/0	67/1 ±00/0	14/0 ±00/0	45/0 ±01/0	73/0 ±00/0	66/2± 00/0	47/5 ±00/0	56/36 ±02/0	42/8± 01/0	56/36 ±00/0	48/27 ±00/0	40/18 ±00/0	1GeS 30W
39/1 ±00/0	58/1 ±00/0	12/0 ±00/0	39/0 ±00/0	55/1 ±00/0	80/2± 00/0	74/5 ±00/0	63/36 ±00/0	38/9± 00/0	60/36 ±00/0	05/31 ±00/0	48/25 ±00/0	2GeG 30W

[DOI: 10.22034/FSCT.22.165.86]

52/1 ±00/ 0	63/1 ±00/ 0	13/0 ±00/ 0	48/0 ±00/ 0	70/1 ±01/ 0	95/2± 00/0	48/5 ±00/ 0	60/36 ±01/0	37/9± 00/0	60/36 ±01/0	05/31 ±00/0	44/25 ±00/0	2GeS 30W
48/1 ±00/ 0	49/1 ±00/ 0	17/0 ±00/ 0	43/0 ±00/ 0	92/1 ±00/ 0	85/2± 00/0	62/5 ±00/ 0	04/37 ±62/0	49/9± 00/0	04/37 ±00/0	42/31 ±00/0	78/25 ±00/0	3GeG 30W
63/1 ±00/ 0	62/1 ±00/ 0	15/0 ±00/ 0	51/0 ±00/ 0	84/1 ±00/ 0	10/3± 00/0	55/5 ±00/ 0	66/36 ±01/0	39/9± 01/0	66/36 ±00/0	07/31 ±00/0	55/25 ±00/0	3GeS 30W
35/1 ±00/ 0	55/1 ±00/ 0	11/0 ±00/ 0	52/0 ±01/ 0	81/0 ±02/ 0	70/2± 01/0	31/5 ±00/ 0	57/36 ±00/0	97/7± 37/0	57/36 ±00/0	50/27 ±00/0	36/19 ±00/0	1GeG 35W
41/1 ±00/ 0	67/1 ±00/ 0	14/0 ±00/ 0	46/0 ±00/ 0	74/0 ±01/ 0	66/2± 01/0	48/5 ±00/ 0	62/36 ±01/0	47/8± 55/0	56/36 ±00/0	49/27 ±00/0	41/18 ±00/0	1GeS 35W
40/1 ±01/ 0	58/1 ±00/ 0	12/0 ±00/ 0	41/0 ±00/ 0	54/1 ±00/ 0	80/2± 01/0	75/5 ±00/ 0	62/36 ±01/0	39/9± 00/0	62/36 ±00/0	07/31 ±00/0	49/25 ±01/0	2GeG 35W
51/1 ±00/ 0	63/1 ±00/ 0	13/0 ±00/ 0	48/0 ±00/ 0	71/1 ±01/ 0	95/2± 02/0	49/5 ±00/ 0	56/36 ±01/0	39/9± 00/0	60/36 ±00/0	09/31 ±00/0	46/25 ±00/0	2GeS 35W
48/1 ±00/ 0	49/1 ±01/ 0	17/0 ±00/ 0	44/0 ±01/ 0	91/1 ±00/ 0	85/2± 00/0	62/5 ±00/ 0	04/37 ±63/0	46/9± 07/0	05/37 ±01/0	44/31 ±00/0	79/25 ±00/0	3GeG 35W
64/1 ±01/ 0	62/1 ±00/ 0	15/0 ±00/ 0	52/0 ±00/ 0	84/1 ±00/ 0	14/3± 05/0	57/5 ±01/ 0	67/36 ±00/0	84/8± 94/0	67/36 ±00/0	09/31 ±00/0	56/25 ±00/0	3GeS 35W
37/1 ±01/ 0	55/1 ±01/ 0	13/0 ±01/ 0	53/0 ±00/ 0	83/0 ±02/ 0	71/2± 02/0	31/5 ±00/ 0	57/36 ±01/0	00/8± 36/0	57/36 ±00/0	50/27 ±00/0	37/19 ±00/0	1GeG 40W
43/1 ±01/ 0	67/1 ±00/ 0	16/0 ±01/ 0	47/0 ±01/ 0	75/0 ±00/ 0	66/2± 02/0	47/5 ±00/ 0	61/36 ±05/0	75/8± 54/0	61/36 ±00/0	51/27 ±00/0	44/18 ±01/0	1GeS 40W
41/1 ±01/ 0	59/1 ±01/ 0	13/0 ±00/ 0	42/0 ±00/ 0	54/1 ±01/ 0	82/2± 01/0	75/5 ±01/ 0	62/36 ±02/0	42/9± 00/0	62/36 ±00/0	10/33 ±00/0	54/25 ±01/0	2GeG 40W
53/1 ±01/ 0	64/1 ±00/ 0	14/0 ±01/ 0	49/0 ±01/ 0	73/1 ±02/ 0	94/2± 01/0	49/5 ±00/ 0	61/36 ±00/0	41/9± 00/0	61/36 ±00/0	11/31 ±00/0	47/25 ±00/0	2GeS 40W
50/1 ±01/ 0	51/1 ±01/ 0	18/0 ±00/ 0	45/0 ±00/ 0	92/1 ±00/ 0	84/21 ±00/0	62/5 ±00/ 0	04/37 ±64/0	47/9± 07/0	04/37 ±00/0	49/31 ±00/0	81/25 ±00/0	3GeG 40W
65/1 ±01/ 0	63/1 ±01/ 0	17/0 ±00/ 0	53/0 ±00/ 0	85/1 ±00/ 0	17/3± 04/0	57/5 ±02/ 0	67/36 ±01/0	86/8± 95/0	67/36 ±00/0	11/31 ±00/0	57/25 ±01/0	3GeS 40W
91/2 ±00/ 0	28/7 ±00/ 0	49/1 ±00/ 0	09/2 ±00/ 0	41/5 ±00/ 0	94/7± 00/0	71/3 ±00/ 0	89/35 ±00/0	82/16 6±00/ 0	42/60 ±00/0	53/49 ±00/0	64/36 ±00/0	commercial butter

Average results± The standard deviation is based on three replicates. GeG/SW = different percentages of gelatin (1, 2 and 3%) along with glycerol monostearate or sorbitan monostearate and different proportions of the aqueous phase (30, 35 and 40%).

2-1-1-4-Thermal behavior of emulsions filled with gel based on the formula B

Thermal behavior results for gel-filled emulsions based on formulationB, presented in Table 2. Statistical analysis related to the thermal behavior of the formulaB It showed that jointly for the three indices of initial melting temperature, peak temperature and peak enthalpy, all factors and their interactions (binary and overall) had a significant effect (less than 0.05). Also, statistical analysis in the field of final melting temperature index related to the formulaBFor the hydrogelator factor, there was a significant difference (less than 0.05).

[DOI: 10.22034/FSCT.22.165.86]

Minimum and maximum initial melting temperature respectively ^{0}C26/19 (sample containing 1% formulaBEmulsifierS and the ratio of water to oil phase is 30 to 70 percent) and ^{0}C27/79 (sample containing 2% formulaBEmulsifierG and the ratio of aqueous to oily phase was 40 to 60 percent) (Table 2). Minimum and maximum peak temperature respectively ^{0}C28/78 (sample containing 1% formulaBEmulsifierS and the ratio of water to oil phase is 30 to 70 percent) and ^{0}C32/64 (samples containing 2 and 3 percent of the formulaBEmulsifierG and the ratio of aqueous to oily phase was 40 to 60 percent) (Table 2). Minimum and maximum final melting temperature respectively ^{0}C24/38 (sample containing 1% formulaBEmulsifierS and the ratio of the water phase to the oil phase is 40 to 60 percent) and ^{0}C 44/38 (sample containing 3% formulaBEmulsifierS and the ratio of aqueous to oily phase was 35% to 65% (Table 2). The lowest peak enthalpy in the limit J/Kg 81/8 (sample containing 1% formulaBEmulsifierS and the ratio of aqueous to oily phase is 30 to 70 percent) and the maximum peak enthalpy in the limit J/Kg 10/10 (the sample contains 3% of the formulaBEmulsifierS and the ratio of aqueous to oily phase was 40 to 60 percent) (Table 2).

Results related to thermal behavior based on the formulaB showed that the emulsifierS plus 1% formulaB in creating the lowest values; While in the highest amounts of both types of emulsifier (G and (S along with 2 and 3 percent formulaB played a role (Table 2). In terms of the percentage of the water phase, all the thermal properties are based on the formulaB They had different water phase percentages in the lowest and highest values (Table 2). The results of thermal properties showed the use of 1% formulaB, has led to the occurrence of the lowest values in characteristics (Table 2).

Table 2- Sensory evaluation and thermal properties of emulsions filled with gel based on formula B (average±standard deviation)

Sensory evaluation							Thermal properties					sample
Oral coating	like fat	sourness	Milk	melting	playability	difficulty	sliding melting point (^{0}C)	peak enthalpy (J/Kg)	final melting temperature (^{0}C)	peak temperature (^{0}C)	initial melting temperature (^{0}C)	
68/1 ±00/0	71/1 ±00/0	20/0 ±01/0	64/0 ±00/0	98/1 ±00/0	36/3 ±01/0	14/6 ±00/0	36/38 ±05/0	86/8± 00/0	36/38 ±00/0	83/28 ±00/0	30/19 ±00/0	1AgG 30W
60/1 ±01/0	77/1 ±00/0	24/0 ±01/0	59/0 ±00/0	13/2 ±00/0	24/3 ±00/0	24/6 ±00/0	30/38 ±00/0	81/8± 00/0	30/38 ±00/0	78/28 ±00/0	26/19 ±00/0	1AgS 30W
73/1 ±00/0	82/1 ±00/0	16/0 ±00/0	48/0 ±00/0	12/2 ±00/0	48/3 ±00/0	32/6 ±00/0	42/38 ±05/0	84/9± 00/0	42/38 ±00/0	59/32 ±00/0	74/26 ±00/0	2AgG 30W
14/2 ±00/0	88/1 ±00/0	24/0 ±00/0	58/0 ±00/0	24/2 ±00/0	54/3 ±00/0	37/6 ±00/0	36/38 ±00/0	82/9± 00/0	36/38 ±00/0	42/31 ±00/0	76/25 ±00/0	2AgS 30W
32/2 ±00/0	92/1 ±00/0	23/0 ±01/0	41/0 ±00/0	22/2 ±01/0	61/3 ±00/0	28/6 ±00/0	42/38 ±01/0	95/9± 00/0	42/38 ±00/0	59/32 ±00/0	49/26 ±00/0	3AgG 30W
28/2 ±00/0	89/1 ±00/0	29/0 ±00/0	38/0 ±00/0	29/2 ±00/0	42/3 ±00/0	40/6 ±01/0	40/38 ±00/0	93/9± 00/0	40/38 ±00/0	55/32 ±00/0	69/26 ±00/0	3AgS 30W
70/1 ±03/0	71/1 ±00/0	20/0 ±01/0	64/0 ±00/0	99/1 ±00/0	35/3 ±01/0	14/6 ±01/0	37/38 ±04/0	89/8± 00/0	37/38 ±00/0	89/28 ±00/0	37/19 ±00/0	1AgG 35W

[DOI: 10.22034/FSCT.22.165.86]

61/1 ±01/0	78/1 ±01/0	24/0 ±01/0	59/0 ±01/0	14/2 ±01/0	24/3 ±00/0	24/6 ±01/0	27/38 ±06/0	82/8± 00/0	27/38 ±00/0	80/28 ±00/0	27/19 ±00/0	1AgS 35W
72/1 ±00/0	82/1 ±00/0	16/0 ±00/0	49/0 ±01/0	12/2 ±01/0	47/3 ±00/0	32/6 ±00/0	42/38 ±05/0	86/9± 00/0	42/38 ±00/0	61/32 ±00/0	76/27 ±00/0	2AgG 35W
13/2 ±00/0	89/1 ±01/0	24/0 ±00/0	58/0 ±01/0	26/2 ±01/0	53/3 ±00/0	38/6 ±00/0	37/38 ±01/0	91/9± 00/0	37/38 ±00/0	44/31 ±00/0	79/25 ±00/0	2AgS 35W
33/2 ±01/0	92/1 ±00/0	22/0 ±02/0	41/0 ±01/0	23/2 ±01/0	61/3 ±01/0	28/6 ±01/0	42/38 ±01/0	99/9± 00/0	42/38 ±00/0	61/32 ±00/0	99/26 ±00/0	3AgG 35W
29/2 ±02/0	90/1 ±01/0	29/0 ±01/0	38/0 ±00/0	31/2 ±01/0	41/3 ±00/0	40/6 ±01/0	44/38 ±04/0	99/9± 00/0	44/38 ±00/0	59/32 ±00/0	71/26 ±00/0	3AgS 35W
71/1 ±03/0	73/1 ±01/0	22/0 ±01/0	64/0 ±01/0	02/2 ±06/0	36/3 ±01/0	14/6 ±02/0	37/38 ±04/0	91/8± 00/0	37/38 ±00/0	90/28 ±00/0	41/19 ±00/0	1AgG 40W
60/1 ±02/0	83/1 ±07/0	26/0 ±01/0	60/0 ±00/0	16/2 ±02/0	26/3 ±01/0	25/6 ±00/0	24/38 ±12/0	89/8± 00/0	24/38 ±00/0	82/28 ±00/0	30/19 ±00/0	1AgS 40W
74/1 ±00/0	83/1 ±01/0	18/0 ±00/0	50/0 ±01/0	13/2 ±01/0	48/3 ±00/0	33/6 ±00/0	42/38 ±05/0	91/9± 00/0	42/38 ±00/0	64/32 ±00/0	79/27 ±00/0	2AgG 40W
14/2 ±01/0	91/1 ±02/0	26/0 ±00/0	60/0 ±03/0	27/2 ±02/0	54/3 ±00/0	38/6 ±01/0	37/38 ±02/0	93/9± 00/0	37/38 ±00/0	49/31 ±00/0	83/25 ±00/0	2AgS 40W
35/2 ±02/0	93/1 ±01/0	23/0 ±01/0	43/0 ±01/0	24/2 ±01/0	63/3 ±01/0	28/6 ±02/0	43/38 ±01/0	04/10 ±00/0	43/38 ±00/0	64/32 ±00/0	01/27 ±00/0	3AgG 40W
30/2 ±03/0	91/1 ±00/0	31/0 ±00/0	39/0 ±00/0	33/2 ±02/0	44/3 ±01/0	40/6 ±01/0	41/38 ±01/0	10/10 ±00/0	41/38 ±00/0	61/32 ±00/0	75/26 ±00/0	3AgS 40W
91/2 ±00/0	28/7 ±00/0	49/1 ±00/0	09/2 ±00/0	41/5 ±00/0	94/7 ±00/0	71/3 ±00/0	89/35 ±00/0	82/16 6±00/0	42/60 ±00/0	53/49 ±00/0	64/36 ±00/0	commercial butter

Average results± The standard deviation is based on three replicates. AgG/SW = different percentages of agar-agar (1, 2 and 3%) along with glycerol monostearate or sorbitan monostearate and different proportions of the aqueous phase (30, 35 and 40%).

3-1-1-4-Thermal behavior of emulsions filled with gel based on the formula C

Thermal behavior results for gel-filled emulsions based on formulationC, presented in Table 3. The results of statistical analysis related to thermal behavior based on the formulaC It showed that a significant effect (less than 0.05) was observed in the field of hydrogelator factors and emulsifier type related to the initial melting temperature index, as well as all factors and their interactions (binary and overall) related to the peak enthalpy index.

The minimum and maximum initial melting temperature respectively ^{0}C18/65 (sample containing 1% formulaCEmulsifierS and the ratio of water to oil phase is 30 to 70 percent) and ^{0}C71/19 (sample containing 3% formulaCEmulsifierG and the ratio of aqueous to oily phase was 40 to 60 percent) (Table 3). Minimum and maximum peak temperature respectively ^{0}C28/91 (sample containing 1% formulaCEmulsifierS and the ratio of water to oil phase is 30 to 70) and ^{0}C29/66 (the sample contains 3% of the formulaCEmulsifierG and the ratio of aqueous to oily phase was 40 to 60 percent) (Table 3). Minimum and maximum final melting temperature respectively ^{0}C38/91 (sample containing 1% formulaCEmulsifierS and the ratio of water to oil phase is 30 to 70 percent) and ^{0}C 39/68 (sample containing 3% formulaCEmulsifierG and the ratio of aqueous to oily phase was 30 to 70 percent) (Table 3). and the lowest peak enthalpy in

[DOI: 10.22034/FSCT.22.165.86]

the limit J/Kg 9/64 (sample containing 1% formulaCEmulsifierS and the ratio of the water phase to the oil phase is 30 to 70 percent) and the highest peak enthalpy in the limit J/Kg 10/45 (sample containing 3% formulaCEmulsifierG and the ratio of aqueous to oily phase was 35 to 65 percent) (Table 3).

Results related to thermal behavior based on the formulaC showed that the emulsifierS plus 1% formulaC in creating the lowest values; While emulsifierG plus 3% formulaC They played the biggest role in creating values (Table 3). All characteristics based on the formulaC They had different water phase percentages in the lowest and highest amounts (30% in the lowest and 40% in the highest) (Table 3). Thermal behavior results based on the formulaC It showed that there is a direct relationship between the percentage of using the formulaC, percentage of aqueous phase and emulsifierG There was (Table 3).

4-1-1-4-Descriptions related to the thermal behavior of emulsions filled with gel

Comparing the thermal behavior of commercial butter and emulsions prepared based on hydrogelators, showed that the thermal properties of commercial butter were numerically higher than the prepared samples (Table 1, 2 and 3). Each of the components of the emulsion alone has a unique thermal behavior. After preparing the emulsion, the thermal behavior that appears as a result is under the general influence of the components]15، 16[. There is a direct relationship between the crystal lattice, the higher surface area of the gelator and the thermal behavior of the emulsion]17[.

Gelator agents that have more thermal stability have a lower peak enthalpy]18[. Hwang and Winkler-Moser (2020) in the field of preparing oleogel based on soybean oil and two types of wax, similar results with the thermal behavior of samples based on the formulaA (initial melting temperature) and formulaB (peak temperature) related to the present study]16[. Silva et al. (2021) studied the preparation of margarine using oleogels containing 35 and 60% of the oil phase and obtained different results from the present study, the reason for which could be the use of the type and amount of constituents in the preparation of the samples, especially the structuring factors.]15[. Yilmazand Öğütcü(2015) prepared a type of animal butter substitute product based on oleogels containing two types of oil and two types of wax, their results indicated that in addition to the type of gelator, the type of alternative oil source also had an effect on the thermal properties of the samples.]11[.

In the research of alternative preparation of commercial butter product based on two different types of oil and wax sources] 11[The results showed that the amount of thermal characteristics of the samples based on sunflower wax was higher. In comparing the thermal properties of commercial butter, oleogel based on walnut oil-sunflower wax and oleogel based on virgin olive oil-sunflower wax, the results showed that the highest initial melting temperature index is for oleogel based on walnut oil and the lowest for commercial butter; The peak temperature index was highest for oleogel based on virgin olive oil and the lowest was related to commercial butter, as well as the highest peak enthalpy index was related to commercial butter and the lowest was related to oleogel based on walnut oil. The results related to the thermal indices of commercial butter substitute products based on two types of oil and two types of wax]11[, was different from the present study. It is reported that some oleogels have good sensory and thermal properties, but numerically, they have lower thermal behavior.]11[.

Table 3- Sensory evaluation and thermal properties of emulsions filled with gel based on Formula C (Avg±standard deviation)

Sensory evaluation	Thermal properties

[DOI: 10.22034/FSCT.22.165.86]

Oral coating	like fat	sourness	Milk	melting	playability	difficulty	sliding melting point (^0C)	peak enthalpy (J/Kg)	final melting temperature (^0C)	peak temperature (^0C)	initial melting temperature (^0C)	sample
41/2 ±00/0	93/1 ±00/0	30/0 ±00/0	34/0 ±00/0	30/2 ±00/0	52/3 ±00/0	50/6 ±00/0	47/42 ±00/0	84/9± 00/0	43/39 ±00/0	30/29 ±00/0	37/19 ±00/0	1XaG 30W
38/2 ±00/0	88/1 ±01/0	28/0 ±00/0	40/0 ±01/0	35/2 ±01/0	47/3 ±00/0	45/6 ±00/0	44/42 ±01/0	64/9± 00/0	91/38 ±00/0	91/28 ±00/0	65/18 ±00/0	1XaS 30W
44/2 ±00/0	79/1 ±00/0	33/0 ±00/0	41/0 ±01/0	28/2 ±00/0	58/3 ±00/0	39/6 ±00/0	49/42 ±00/0	23/10 ±00/0	54/39 ±00/0	47/29 ±00/0	49/19 ±00/0	2XaG 30W
29/2 ±00/0	80/1 ±01/0	31/0 ±00/0	37/0 ±00/0	41/2 ±00/0	63/3 ±00/0	48/6 ±00/0	47/42 ±00/0	76/9± 00/0	10/39 ±00/0	11/29 ±00/0	82/18 ±00/0	2XaS 30W
17/3 ±01/0	76/1 ±00/0	32/0 ±00/0	47/0 ±00/0	49/2 ±00/0	60/3 ±01/0	61/6 ±02/0	52/42 ±00/0	40/10 ±00/0	65/39 ±00/0	58/29 ±00/0	62/19 ±00/0	3XaG 30W
43/3 ±00/0	78/1 ±01/0	29/0 ±00/0	44/0 ±00/0	55/2 ±00/0	68/3 ±00/0	69/6 ±00/0	50/42 ±02/0	90/9± 00/0	23/39 ±00/0	29/29 ±00/0	27/19 ±00/0	3XaS 30W
42/2 ±00/0	92/1 ±00/0	31/0 ±00/0	33/0 ±00/0	32/2 ±02/0	51/3 ±00/0	51/6 ±00/0	47/42 ±01/0	90/9± 00/0	46/39 ±00/0	36/29 ±00/0	40/19 ±00/0	1XaG 35W
39/2 ±02/0	88/1 ±02/0	28/0 ±00/0	40/0 ±02/0	34/2 ±00/0	47/3 ±01/0	45/6 ±00/0	45/42 ±01/0	66/9± 00/0	93/38 ±00/0	93/28 ±00/0	70/18 ±00/0	1XaS 35W
45/2 ±00/0	80/1 ±01/0	33/0 ±00/0	41/0 ±00/0	30/2 ±03/0	57/3 ±00/0	41/6 ±00/0	52/42 ±03/0	29/10 ±00/0	58/39 ±00/0	50/29 ±00/0	52/19 ±00/0	2XaG 35W
31/2 ±00/0	80/1 ±01/0	32/0 ±00/0	37/0 ±00/0	41/2 ±00/0	63/3 ±01/0	49/6 ±01/0	48/42 ±01/0	80/9± 00/0	14/39 ±00/0	16/29 ±00/0	87/18 ±00/0	2XaS 35W
16/3 ±01/0	77/1 ±01/0	32/0 ±00/0	48/0 ±01/0	50/2 ±02/0	59/3 ±01/0	62/6 ±05/0	53/42 ±01/0	45/10 ±00/0	65/39 ±00/0	62/29 ±00/0	67/19 ±00/0	3XaG 35W
44/3 ±01/0	78/1 ±01/0	30/0 ±01/0	44/0 ±00/0	55/2 ±00/0	68/3 ±01/0	70/6 ±01/0	51/42 ±02/0	96/9± 00/0	26/39 ±00/0	33/29 ±00/0	97/18 ±00/0	3XaS 35W
43/2 ±01/0	94/1 ±00/0	34/0 ±03/0	35/0 ±00/0	33/2 ±02/0	52/3 ±00/0	52/6 ±01/0	47/42 ±00/0	70/9± 00/0	50/39 ±00/0	41/29 ±00/0	44/19 ±00/0	1XaG 40W
41/2 ±03/0	89/1 ±02/0	29/0 ±01/0	41/0 ±02/0	36/2 ±00/0	49/3 ±01/0	47/6 ±01/0	46/42 ±01/0	70/9± 00/0	99/38 ±00/0	96/28 ±00/0	76/18 ±00/0	1XaS 40W
46/2 ±01/0	82/1 ±00/0	35/0 ±02/0	43/0 ±00/0	31/2 ±03/0	59/3 ±00/0	42/6 ±00/0	52/42 ±02/0	83/9± 00/0	61/39 ±00/0	53/29 ±00/0	56/19 ±00/0	2XaG 40W
33/2 ±00/0	81/1 ±01/0	32/0 ±01/0	38/0 ±00/0	44/2 ±01/0	64/3 ±01/0	49/6 ±00/0	48/42 ±01/0	83/9± 00/0	21/39 ±00/0	25/29 ±00/0	91/18 ±00/0	2XaS 40W
17/3 ±00/0	82/1 ±05/0	35/0 ±00/0	47/0 ±01/0	52/2 ±02/0	61/3 ±00/0	62/6 ±06/0	53/42 ±01/0	01/10 ±00/0	71/39 ±00/0	66/29 ±00/0	71/19 ±00/0	3XaG 40W

45/3 ±01/0	80/1 ±02/0	30/0 ±01/0	46/0 ±00/0	56/2 ±00/0	70/3 ±01/0	72/6 ±02/0	50/42 ±02/0	01/10 ±00/0	30/39 ±00/0	37/29 ±00/0	10/19 ±00/0	3XaS 40W
91/2 ±00/0	28/7 ±00/0	49/1 ±00/0	09/2 ±00/0	41/5 ±00/0	94/7 ±00/0	71/3 ±00/0	89/35 ±00/0	82/16 6±00/0	42/60 ±00/0	53/49 ±00/0	64/36 ±00/0	commercial butter

Average results± The standard deviation is based on three replicates. XaG/SW = different percentages of xanthan (1, 2 and 3%) along with glycerol monostearate or sorbitan monostearate and different proportions of the aqueous phase (30, 35 and 40%).

2-1-4-sliding melting point of emulsions filled with gel

The results of sliding melting point of emulsions filled with gel based on the formulaA It is presented in Tables 2, 1 and 3, respectively. The statistical analysis related to the sliding melting point showed that the hydrogelator factor had a significant effect (less than 0.05) for emulsions based on hydrogelators. Emulsifier type factor also for formula-based emulsionsC It had a significant effect (less than 0.05).

The sliding melting point rate for gel-filled emulsions based on formulaA, in the amount^{0}C 56.36 as the lowest amount related to the sample containing 1 percent of the formulaAEmulsifierS and the ratio of the water phase to the oil phase is 30 to 70%, as well as the sample containing 2% of the formulaAEmulsifierS And the ratio of aqueous to oily phase was 35 to 65% (Table 1). Also ^{0}C04/37 as the maximum sliding melting point for emulsions filled with gel based on the formulaA, corresponding to samples containing 3% of the formulaAEmulsifierG And the ratio of water to oil phase was 30 to 70, 35 to 65 and 40 to 60% (Table 1). The sliding melting point rate for gel-filled emulsions based on formulaB, has the lowest ^{0}C24/38 related to the sample containing 1% formulaB (Sample containing emulsifierS and the ratio of the water phase to the oil phase is 40 to 60 percent) and ^{0}C4438/ as the highest amount related to the sample containing 2% formulaB (Sample containing emulsifierS and the ratio of aqueous to oily phase was 35% to 65% (Table 2). The sliding melting point rate for gel-filled emulsions based on formulaC, in ^{0}C44/42 as the lowest amount related to the sample containing 1 percent of the formulaC (Sample containing emulsifierS and the water to oil phase ratio of 30 to 70 percent) and also ^{0}C53/42 as the highest amount related to 2 samples based on 3% formulaC (Samples containing emulsifierG and the ratio of aqueous to oily phase was 35 to 65 and 40 to 60 percent) (Table 3).

Sliding melting point results based on the formulaA showed that in the lowest amounts, emulsifier S along with 1 and 3 percent formulaA; If in the largest amounts, emulsifierG plus 3% formulaA played a role (Table 1). The ratio of aqueous to oily phase 40 to 60% leads to the creation of the lowest amount, as well as the ratio of aqueous to oily phase 30 to 70% and 35 to 65% in creating the highest amount of sliding melting point based on the formulaA played a role (Table 1). Sliding melting point results based on the formulaA showed that the use of 3% formulaA With emulsifierG It led to an increase in sliding melting point (Table 1). Melting point results based on the formulaB showed that in the values of the lowest 1% and the highest 3% formulaBEmulsifierS played a role (Table 2). Sliding melting point results based on the formulaB showed that the percentage reduction of the aqueous phase (40 to 35%) and the increase of the formula percentageB (1 to 3%) led to an increase in the melting point (Table 2).

A direct relationship between the use of components with a sliding melting point based on the formulaB There were (Table 2). The sliding melting point results of formula-based emulsionsC showed that in the lowest amounts, emulsifierS along with 1% formulaC; But in the most amount of emulsifierG plus 3% formula Cplayed a role (Table 3). The sliding melting point results of formula-based emulsions Cshowed that by increasing the formula percentageC (1 to 3 percent), increasing the percentage of

[DOI: 10.22034/FSCT.22.165.86]

aqueous phase (30 to 35 and 40 percent) and emulsifierG, the sliding melting point had an increasing trend (Table 3). Comparing the sliding melting point of commercial butter with research samples, it was concluded that the amount of sliding melting point of commercial butter was lower than the samples of this research (Tables 1, 2 and 3).

The sliding melting point can be used as an indicator to choose fat substitute products, especially Korean products]19[. Two important and influential factors in the amount of sliding melting point are the degree of saturation and the percentage of long chain fatty acids, so that there is a direct relationship between these two factors with the sliding melting point of the samples.]19[. The reason for the lower sliding melting point can be due to lower saturation and short chain fatty acids]19 and 20[. It should be noted that the melting point of margarines is in the range ^{0}C35-42 is located]20[. The present research with results Cheong et al. (2009), in the field of sliding melting point of samples based on the formulaA and the formula Bhave similar results; While the samples based on formula C had different results]20[. The results of the sliding melting point of the current research, especially the samples based on the formulaC with results Naeli et al. (2022), in the study of optimizing the preparation of oleogel-based undersaturated shortening, it was similar]21[. Luo et al. (2019) in the preparation of structured water-in-oil emulsion based on camellia oil and also da Silva et al. (2019) in the preparation of fat replacement for bologna type sausage based on oleogels rich in oleic acid, had different results with the current research in the field of sliding melting point.]19 and 22[.

2-4- Hardness of emulsions filled with gel

The results of texture hardness of emulsions filled with gel based on the formulaAFormulaB and the formulaC It is presented in Tables 4, 5 and 6. In terms of textural properties (hardness), the results of statistical analysis showed that all the factors alone and their interactions (binary and overall) were significant (less than 0.05) for all emulsions based on hydrogelators. The amount of texture hardness related to gel-filled emulsions based on the formulaA , as a minimum for 2 samples containing 1% formulaAEmulsifierG and the ratio of water phase to oil is 35 to 65 and 40 to 60% and also the most for samples containing 3% formulaA, two emulsifiers (G and S) and the ratio of water to oil was 35 to 65% (Table 4).

The minimum hardness of the texture related to the emulsions filled with gel based on the formulaB, for example containing 1% of the formulaBEmulsifierS And the ratio of water phase to oil is 40 to 60% and the highest amount is for the sample containing 3% of the formulaBEmulsifierG and the ratio of water phase to oil was 30 to 70% (Table 5). The minimum hardness of the texture related to the emulsions filled with gel based on the formulaC, for example containing 1% of the formulaCEmulsifierS and the ratio of the water phase to the oil phase is 40 to 60 percent, and the highest amount corresponds to the sample containing 3 percent of the formulaCEmulsifierG and the ratio of water to oil was 30 to 70% (Table 6). The results related to tissue hardness based on all three types of hydrogelator showed that there was a direct relationship between the percentage of hydrogelator use and the degree of hardness (Tables 4, 5 and 6). The hardness of the samples based on 3% hydrogelator was higher than the samples based on 1% hydrogelator (Tables 4, 5 and 6).

In investigating the role of emulsifiers in the hardness of samples, emulsifierG In examples based on the formulaA In the lowest amount and emulsifierS played the greatest role; While for samples based on the formulaB and the formulaC, in the lowest amount, emulsifierS And in the most amount, emulsifierG played a role (Tables 4, 5 and 6). In examples based on the formulaB and the formulaC, reducing the proportion of the aqueous phase (30-40%) along with the

[DOI: 10.22034/FSCT.22.165.86]

use of 3% hydrogelator led to an increase in hardness (Tables 5 and 6). Comparing the hardness of commercial butter and research samples, the results showed that the hardness of commercial butter was higher (Tables 4, 5 and 6).

One of the most influential characteristics in the field of Korean products is the hardness of the texture]23, 24 and 25[.Evil et al. (2003) in the comparison of animal butter and comparing its characteristics with samples based on plant sources, reported that the degree of hardness was more related to samples based on plant sources.]26[. Bascuaset al. (2019) in the preparation of edible oleogel based on unsaturated oils-hydrocolloids, found that the alternative products prepared had less hardness compared to the animal butter sample, and the degree of hardness was influenced by the type and amount of use of ingredients, especially gelators.]24[.

In the study of preparation of edible oleogel based on unsaturated oil sources]24[The results showed that the type and percentage of the use of auxiliary components as well as the amount of the main substitute factors (water and oil) had an effect on the hardness of the prepared samples, so that there was a similarity between the mentioned research and the current research in terms of the influence of the components used in the preparation of the samples. In the research conducted in the field of preparation of oleogel as a spreadable product based on two types of oil and two types of wax]11[, the results showed that despite the use of the same oleogelator, if one component (oily base) is changed, the degree of hardness is different, so that the mentioned research with the current research on the effect of emulsifierG It was similar in all samples. Examining the hardness results of margarine samples based on several waxes]25[and also oleogels based on pumpkin seed oil]27[, showed that the results of these researches are similar to the results of the oil drop index and the hardness of the samples based on the formulaC The research was present.

Table 4-Physical properties, physical and oxidative stabilities of emulsions filled with gel based on formula A (average±standard deviation)

Physical stability			Oxidative stability - oximeter (hours)	texture hardness (gforce)	sample
Refrigerant stability (percent)	oil drop (percentage)	Centrifugation stability (percentage)			
75/3±01/0	41/1±03/0	00/100±00/0	85/2±00/0	03/54±05/0	1GeG30W
00/0±00/0	26/1±05/0	00/100±00/0	01/4±00/0	40/53±01/0	1GeS30W
37/9±00/0	00/0±00/0	00/83±00/1	37/8±00/0	47/67±31/2	2GeG30W
00/0±00/0	00/0±00/0	00/89±25/0	17/14±00/0	10/63±01/0	2GeS30W
00/0±00/0	30/1±01/0	43/95±25/1	34/12±00/0	30/69±01/0	3GeG30W
00/0±00/0	44/1±04/0	44/93±48/0	14/16±00/0	42/64±02/0	3GeS30W
73/3±01/0	41/1±03/0	00/100±00/0	85/2±00/0	66/49±05/0	1GeG35W
00/0±00/0	27/1±04/0	00/100±00/0	01/4±00/0	44/52±00/0	1GeS35W
37/9±00/0	00/0±00/0	78/82±19/1	35/8±00/0	41/63±02/0	2GeG35W
00/0±00/0	00/0±00/0	93/88±24/0	17/14±01/0	10/62±01/0	2GeS35W
00/0±00/0	31/1±00/0	28/95±29/1	35/12±01/0	50/68±00/0	3GeG35W
00/0±00/0	45/1±05/0	41/93±47/0	48/15±15/1	50/68±00/0	3GeS35W
74/3±02/0	41/14±03/0	00/100±00/0	85/2±00/0	66/49±11/0	1GeG40W
00/0±00/0	27/1±04/0	00/100±00/0	00/4±00/0	44/52±00/0	1GeS40W

[DOI: 10.22034/FSCT.22.165.86]

37/9±00/0	00/0±00/0	80/82±17/1	36/8±01/0	41/63±01/0	2GeG40W
00/0±00/0	00/0±00/0	94/88±24/0	15/14±01/0	10/62±01/0	2GeS40W
00/0±00/0	31/1±01/0	93/91±38/5	34/12±00/0	50/68±01/0	3GeG40W
00/0±00/0	44/1±04/0	40/93±48/0	48/15±14/1	33/63±00/0	3GeS40W
00/0±00/0	00/0±00/0	00/100±00/0	61/41±00/0	45/193±00/0	commercial butter

Average results± The standard deviation is based on three replicates. GeG/SW = different percentages of gelatin (1, 2 and 3%) along with glycerol monostearate or sorbitan monostearate and different proportions of the aqueous phase (30, 35 and 40%).

Table 5-Physical properties, physical and oxidative stabilities of emulsions filled with gel based on formula B (average±standard deviation)

Physical stability Refrigerant stability (percent)	oil drop (percentage)	Centrifugation stability (percentage)	Oxidative stability - oximeter (hours)	texture hardness (gforce)	sample
62/5±00/0	00/0±00/0	00/100±00/0	48/1±00/0	41/62±01/0	1AgG30W
25/6±01/0	10/1±01/0	00/91±75/0	23/2±00/0	03/59±05/0	1AgS30W
00/0±00/0	22/1±02/0	00/100±00/0	52/7±01/0	32/68±01/0	2AgG30W
00/0±00/0	02/2±06/0	00/100±00/0	21/8±00/0	03/67±05/0	2AgS30W
00/0±00/0	03/1±07/0	00/88±37/0	40/16±00/0	00/73±01/0	3AgG30W
00/0±00/0	42/1±08/0	00/87±50/0	14/17±00/0	34/72±05/0	3AgS30W
62/5±00/0	00/0±00/0	00/100±00/0	50/1±01/0	91/60±01/0	1AgG35W
23/6±01/0	10/1±10/0	94/90±82/0	24/2±00/0	48/58±03/0	1AgS35W
00/0±00/0	22/1±02/0	00/100±00/0	52/7±00/0	32/67±02/0	2AgG35W
00/0±00/0	10/2±01/0	00/100±00/0	21/8±00/0	84/66±01/0	2AgS35W
00/0±00/0	07/1±06/0	16/88±47/0	44/16±04/0	40/71±02/0	3AgG35W
00/0±00/0	43/1±10/0	76/86±55/0	15/17±01/0	22/71±02/0	3AgS35W
62/5±00/0	00/0±00/0	00/100±00/0	49/1±01/0	24/59±00/0	1AgG40W
23/6±02/0	06/1±11/0	98/90±81/0	30/2±10/0	79/57±00/0	1AgS40W
00/0±00/0	22/1±02/0	00/100±00/0	51/7±00/0	44/66±01/0	2AgG40W
00/0±00/0	06/2±11/0	00/100±00/0	20/8±00/0	32/65±00/0	2AgS40W
00/0±00/0	07/1±06/0	16/88±48/0	40/16±01/0	31/70±02/0	3AgG40W
00/0±00/0	42/1±08/0	73/86±49/0	14/17±01/0	79/70±01/0	3AgS40W
00/0±00/0	00/0±00/0	00/100±00/0	61/41±00/0	45/193±00/0	commercial butter

Average results± The standard deviation is based on three replicates. AgG/SW = different percentages of agar-agar (1, 2 and 3%) along with glycerol monostearate or sorbitan monostearate and different proportions of the aqueous phase (30, 35 and 40%).

Table 6-Physical properties, physical and oxidative stabilities of emulsions filled with gel based on formula C (average±standard deviation)

Physical stability Refrigerant stability (percent)	oil drop (percentage)	Centrifugation stability (percentage)	Oxidative stability - oximeter (hours)	texture hardness (gforce)	sample
00/0±00/0	29/0±02/0	00/100±00/0	05/6±00/0	03/79±05/0	1XaG30W
00/0±00/0	24/0±01/0	70/95±16/0	21/10±00/0	21/78±01/0	1XaS30W
87/6±00/0	35/0±02/0	25/91±21/0	49/6±00/0	32/82±01/0	2XaG30W
17/10±04/1	33/0±05/0	62/94±06/0	38/12±00/0	84/81±00/0	2XaS30W
50/7±10/0	00/0±00/0	00/100±00/0	42/16±00/0	50/91±01/0	3XaG30W
12/8±00/0	00/0±00/0	00/100±00/0	23/17±00/0	82/89±00/0	3XaS30W
00/0±00/0	31/0±02/0	00/100±00/0	05/6±00/0	89/78±00/0	1XaG35W
00/0±00/0	24/0±00/0	68/95±15/0	22/10±00/0	90/77±01/0	1XaS35W
87/6±00/0	36/0±01/0	88/90±76/0	49/6±01/0	96/81±00/0	2XaG35W

[DOI: 10.22034/FSCT.22.165.86]

86/9±74/0	34/0±06/0	63/94±07/0	37/12±00/0	52/81±00/0	2XaS35W
47/7±15/0	00/0±00/0	00/100±00/0	41/16±00/0	74/90±01/0	3XaG35W
12/8±00/0	00/0±00/0	00/100±00/0	24/17±00/0	68/89±00/0	3XaS35W
00/0±00/0	30/0±01/0	00/100±00/0	05/6±00/0	72/78±01/0	1XaG40W
00/0±00/0	24/0±01/0	67/95±16/0	22/10±02/0	60/77±00/0	1XaS40W
87/6±00/0	35/0±02/0	87/90±67/0	49/6±01/0	90/80±00/0	2XaG40W
96/9±77/0	34/0±06/0	63/94±06/0	37/12±01/0	46/81±05/0	2XaS40W
50/7±10/0	00/0±00/0	00/100±00/0	40/16±00/0	78/89±00/0	3XaG40W
12/8±00/0	00/0±00/0	00/100±00/0	23/17±01/0	14/89±00/0	3XaS40W
00/0±00/0	00/0±00/0	00/100±00/0	61/41±00/0	45/193±00/0	commercial butter

Average results± The standard deviation is based on three replicates. XaG/SW = different percentages of xanthan (1, 2 and 3%) along with glycerol monostearate or sorbitan monostearate and different proportions of the aqueous phase (30, 35 and 40%).

4-3-Oxidative and physical stabilities of emulsions filled with gel

1-3-4- Oxidative stability of emulsions filled with gel-oxytest

Oxidative stability results based on oximeter related to emulsions filled with gel based on formulaAFormulaB and the formulaC It is presented in Tables 4, 5 and 6, respectively. The statistical analysis related to Oxytest showed that the factors of hydrogelator, type of emulsifier and the interaction of hydrogelator in the type of emulsifier had a significant effect (less than 0.05) for emulsions based on hydrogelators. Also in the field of oxytest emulsions based on the formulaBThe results of the statistical analysis showed that the interaction of the hydrogelator in the emulsifier type had a significant effect (less than 0.05) on the percentage of the aqueous phase (less than 0.05), although the statistical analysis of the oxytest showed no significant effect (more than 0.05) for the ratio of the aqueous phase and other factors on the interactions. Oxidative stability of gel-filled emulsions based on formulationA, for samples based on 1 percent formulaAEmulsifier Gand the proportions of water phase to oil 30 to 70, 35 to 65 and 40 to 60% have the lowest amount; If the sample contains 3% of the formulaAEmulsifierS And the ratio of aqueous to oily phase was 30 to 70%, the highest amount (Table 4). Oxidative stability of gel-filled emulsions based on formulationB, for example containing 1% of the formulaBEmulsifierG and the ratio of the water phase to the oil phase is 30 to 70% with the lowest amount; If the sample contains 3% formulaBEmulsifierS And the ratio of aqueous to oily phase was 35 to 65 percent (Table 5). The lowest oxidative stability of gel-filled emulsions based on formula CFor samples containing 1% formulaCEmulsifier Gand the ratio of water phase to oil is 30 to 70, 35 to 65 and 40 to 60% and the highest amount of oxidative stability is related to the sample containing 3% of the formulaCEmulsifierS and the ratio of water phase to oil was 35 to 65% (Table 6).

The results of oxidative stability based on all three types of hydrogelator showed that the use of 3% hydrogelator led to an increase in oxidative stability (Tables 4, 5 and 6). Use of emulsifierS than the emulsifierG, led to an increase in the stability of samples based on all three types of hydrogelators (Tables 4, 5 and 6). Investigation of oxidative stability based on the formulaA and the formula Cshowed that the ratio of aqueous to oily phase 60 to 40% leads to oxidative stability with the lowest amount for samples containing 1% of the formulaA/ formulaC and emulsifierG (Table 4 and Table 6). Commercial butter had more oxidative stability than the samples prepared in this study (Tables 4, 5 and 6).

Dinetteet al. (2017) in evaluating the oxidative stability of frying oils, reported that the type of measurement method affects the amount of results related to oxidative

[DOI: 10.22034/FSCT.22.165.86]

stability.]28[. The amount of oxidative stability of the samples is affected by the temperature of the treatment, so that the numerical value of the oxidation stability related to the treatment under temperature is higher. ^{0}C110 compared to lower temperature (^{0}C8/97).]28[. In the present study, there was a direct relationship between the percentage of hydrogelator and the ratio of aqueous to oily phase with the results of oxidative stability (Tables 4, 5 and 6). Merchantet al. (2020) in the preparation of an oleogel based on rapeseed oil, reported that there was a direct relationship between the degree of saturation and the oxidative stability of the samples.]29[.

The results obtained by Merchantet al. (2020) was different from the oxidative stability of the samples of the present study]29[. Rare et al. (2018) investigated the addition of monoacylglycerol to canola oil, the results showed that the addition of monoacylglycerol led to an increase in the oxidative stability of canola oil.]30[. Research done by Rare et al. (2018) regarding the effect of monoacyl glycerol have similar results with the effect of samples containing emulsifierS It was related to the present study]30[. Hakimzadehet al. (2020) prepared low-saturated shortening based on oleogel, the results showed that different oxidative stability results will be obtained due to the use of different components with different percentages.]31[. Research done by Hakimzadehet al. (2020) had different results from the present study]31[.

2-3-4-Physical stability of emulsions filled with gel

1-2-3-4-Centrifugation stability of emulsions filled with gel

Centrifugation stability results of emulsions filled with gel based on the formulaAFormulaB and the formulaC It is presented in Tables 4, 5 and 6. The statistical analysis related to centrifugation stability, jointly for all emulsions based on all three hydrogelators, showed a significant effect (less than 0.05) for the hydrogelator, the type of emulsifier, and the interaction of the hydrogelator with the type of emulsifier. According to the results of centrifugation stability (Tables 4, 5 and 6), some samples have good stability (100 percent); while others were less stable. Samples with proper centrifugation stability based on 1% formulaA with both types of emulsifiers (Table 4); Based on 1 and 2 percent formula Balong with both types of emulsifiers (Table 5), based on 2% of the formula Bwith emulsifierS (Table 5); Based on 1 and 2 percent formulaC With emulsifierG (Table 6) and also 3 percent of the formulaC With emulsifier S (Table 6) was.

The lowest centrifugation stability for gel-filled emulsions based on formulationA, corresponding to the sample containing 2% of the formulaAEmulsifierG And the ratio of water to oil phase was 35% to 65%, 82.78% (Table 4). Appropriate centrifugation stability (100%) of gel-filled emulsions of 6 samples based on 1% formulationA (Samples containing emulsifierGEmulsifierS and also the ratio of aqueous to oily phase was 30 to 70, 35 to 65 and 40 to 60 percent) (Table 4). The lowest centrifugation stability for gel-filled emulsions based on formulationB, in the amount of 73.86% corresponding to the samples containing 3% formulaB (Samples containing emulsifierS and the ratio of aqueous to oily phase was 30 to 70 percent) (Table 5). Good centrifugation stability (100%) for gel-filled emulsions based on the formulationB, related to 9 samples, 3 of which are based on 1% formulaB (Samples containing emulsifierG and the ratio of aqueous to oily phase 30 to 70, 35 to 65 and 40 to 60 percent) and 6 samples based on 2 percent formulaB (Samples containing emulsifierGEmulsifierS and the ratio of water to oil phase is 30 to 70, 35 to 65 and 40 to 60 percent) (Table 5).

The lowest centrifugation stability of 90.87% related to emulsion filled with gel

[DOI: 10.22034/FSCT.22.165.86]

based on 2% formulaC (Sample containing emulsifierG and the ratio of aqueous to oily phase was 40 to 60 percent) (Table 6). Good centrifugation stability (100%) related to gel-filled emulsions based on the formulation CCorresponding to 2 samples based on 1% formulaC (Samples containing emulsifierG and the ratio of water to oil phase 30 to 70, 35 to 65 and 40 to 60 percent) and also 6 samples based on 3 percent formulaC (Samples containing emulsifierGEmulsifierS and the ratio of aqueous to oily phase was 30 to 70, 35 to 65 and 40 to 60 percent) (Table 6). The results related to the centrifugation stability based on hydrogelators generally showed that the lowest centrifugation stability in terms of percentage corresponds to 2% of the formula A and the formulaC And also 3% formulaB; In terms of emulsifier, emulsifier G (for formula A andC) and emulsifierS For the formulaB (Tables 4, 5 and 6). Also, the lowest centrifugation stability in terms of aqueous phase ratio, respectively, at 30% for formulaB, 35 percent for formulaA and 40 percent for formulaC (Tables 4, 5 and 6).

Both emulsifiers and all three proportions of the aqueous phase played a role in creating the highest centrifugation stability (Tables 4, 5 and 6). The percentage of hydrogelator in the context of centrifugation stability of emulsions based on hydrogelators and creating the highest values, including 1% in samples based on the formulaA, 1 and 2 percent based on the formula BAnd also 1 and 3 percent based on the formulaC played a role (Tables 4, 5 and 6). The centrifugation stability of the commercial butter sample was similar to the results of the present research samples (Tables 4, 5 and 6). In general, the number of samples with centrifugation stability based on the formulaA including 6 items (Table 4), based on the formulaB Including 9 items (Table 5) and based on the formulaC included 9 cases (Table 6).

Nourbehesht et al. (2018) in investigating the effect of sound treatment on emulsions filled with gel containing rice bran oil and inulin, in terms of the lower stability of the samples, they had similar results to the present study.]32[. Research done by Merchantet al. (2020) in the context of the effect of oleogelator on oleogel based on rapeseed oil, the results indicated that the samples containing candelilla wax had good centrifugal stability.] 29[. Research done by Merchantet al. (2020) had similar results with the current research in terms of the stability of the samples in terms of centrifugation]29[. The type of gelator can lead to centrifugation stability, such that ethyl cellulose in rapeseed oil-based oleogel]33[, led to the centrifugation stability of oleogels and was similar to the results of the present study. The gelator generally leads to the proper stability of the oleogel by creating a strong network, so this can be caused by using the right gelator with a certain amount.]34[.da Silva وDanthine(2022) in the study of the effect of sound treatment on the properties of oleogels, found that the stability of centrifugation has a direct relationship with the amount of gelator, so that passing the appropriate percentage of consumption led to the instability of the samples.]35[.

2-2-3-4-oil drop of emulsions filled with gel

The results of the oil loss rate of emulsions filled with gel based on the formulaAFormulaB and the formulaC It is presented in Tables 4, 5 and 6. The statistical analysis of oil loss showed that for all emulsions based on all three hydrogelators, the hydrogelator factor and the interaction of the hydrogelator in the emulsifier type had a significant effect (less than 0.05). Also, emulsifier type factor in statistical analysis for formula hydrogelators Band the formulaC, had a significant effect (less than 0.05). It should be noted that the numerical value of this index has an inverse relationship with stability, so that the number zero represents stability and an increase in the numerical value indicates the state of instability.]15، 22[.

[DOI: 10.22034/FSCT.22.165.86]

Oil loss index in percent for gel-filled emulsions based on formulaA, has the lowest stability and is about 1.45% of the sample containing 3% of the formulaAEmulsifierS with the ratio of aqueous to oily phase 35 to 65% and the highest level of stability (zero number) jointly for 6 samples based on 2% of the formulaAEmulsifierGEmulsifierS with the ratio of aqueous to oily phase was 30 to 70, 35 to 65 and 40 to 60% (Table 4). Oil loss index in percent for gel-filled emulsions based on formulaB, has the lowest stability of about 2.10% for the sample containing 2% of the formulaBEmulsifierS with the ratio of water to oil phase was 35 to 65%. While the highest stability (zero number) is related to 3 samples containing 1% formulaBEmulsifierG with the ratio of aqueous to oily phase was 30 to 70, 35 to 65 and 40 to 60% (Table 5).

Oil loss index in percent for gel-filled emulsions based on formulaC, has the lowest stability of about 0.24% jointly for 3 samples based on 1% formulaCEmulsifierS with the ratio of water to oil phase was 30 to 70, 35 to 65 and 40 to 60%; If the highest stability (zero number) jointly corresponds to the samples containing 3% of the formulaC, both emulsifiers and water-to-oil phase ratios were 30 to 70, 35 to 65 and 40 to 60% (Table 6). In the field of oil loss index based on hydrogelators, the results showed that instability (mostly in terms of numerical value) for samples containing 1% of the formulaC, 2 percent formulaB and 3 percent formulaA was observed (Tables 4, 5 and 6). Good stability in terms of oil loss index based on hydrogelators (zero number), for samples containing 2% of the formulaA, 1 percent formulaB and 3 percent of the formulaC was observed (Tables 4, 5 and 6).

It was expected that the increase in the proportion of the aqueous phase would lead to instability and an increase in the oil loss index; While in all the samples, according to the type of hydrogelator, due to the use of different percentages of hydrogelator, different stabilities were observed (Tables 4, 5 and 6). EmulsifierS played a role in creating the oil loss index to a greater extent; While both types of emulsifiers play a role in creating stability in terms of oil drop index (Tables 4, 5 and 6).

The results of oil loss showed that the amount of oil loss of formula samplesB More than formulaA And also the formulaA More than formula C(Tables 4, 5 and 6). Regardless of the type of emulsifier used and the ratio of the aqueous phase, the amount of oil loss of the samples containing 2% of the formulaA was zero (Table 4). Also, the oil loss is zero for samples containing 3% of the formulaC was observed (Table 5). Stable samples were similar to commercial butter samples in terms of oil loss index (Tables 4, 5 and 6).

Choi et al. (2020) in the study of preparing oleogel based on grape seed oil found that samples with the highest oil loss index have less stability in keeping oil in their structure.]36[. Research results Choi et al. (2020) had similar results with the current research in the field of oil loss index]36[. Research Silva et al. (2021) in the field of margarine preparation based on oleogels containing different fat percentages (35 and 60%), with similar results in the field of oil loss index with the results of the samples of the present study for 1 and 3% of the formulaA Along with both emulsifiers as well as 3% formula BWith emulsifier Swas]15[. The results of some researches on the use of alternative fat based on oleogel in sausages]22[, investigation on the interaction of candelilla wax and triacylglycerol]34[as well as the effect of sound treatment]35[, indicates that the samples containing the lowest amount of oil loss have a more elastic state (high pseudo-solid state) and one of the reasons for this can be the use of hard fat components in the preparation of these types of samples. In addition to the type and amount of components used in the preparation of samples, the type of treatment used in the preparation of oleogels (including sound treatment) can lead to a numerical reduction

[DOI: 10.22034/FSCT.22.165.86]

of the oil loss index.]36[. Among the research conducted in the field of using oleogel for the structuring of grape seed oil] 36[With the current research on the effect of emulsifierG There was a similarity in increasing the numerical value of the oil loss index, so that this effect is in the context of some samples based on the formulaA (Table 6) as well as samples based on the formulaC (Table 8) was also observed.

3-2-3-4-Refrigeration stability of emulsions filled with gel

The results of the refrigeration stability of emulsions filled with gel based on the formulaAFormulaB and the formulaC It is presented in Tables 4, 5 and 6, respectively. The statistical analysis of the refrigeration stability showed that it had a significant effect (less than 0.05) for all emulsions based on all three hydrogelators, hydrogelator factors, emulsifier type, and the interaction of hydrogelator with emulsifier type. The samples with lower refrigeration stability had a larger numerical value than the samples with good stability (zero numerical value).]22[. Refrigeration stability index for gel-filled emulsions based on formulaA, in the form of the lowest stability of 9.37%, jointly related to the samples containing 2% of the formulaAEmulsifierG It was 30% to 70%, 35% to 65% and 40% to 60% with different water to oil phase ratio (Table 4).

Adequate refrigeration stability (zero number) was common for 11 samples, including samples based on 1% and 2% of the formula.A (Samples containing emulsifierS and the ratio of water to oil phase 30 to 70 and 35 to 65 percent) as well as samples based on 3 percent formulaA (Commonly for the samples containing both types of emulsifier and with the ratio of water to oil phase 30 to 70, 35 to 65 and 40 to 60 percent) (Table 4). In the investigation of the amount of the index of refrigeration stability in terms of percentage for emulsions filled with gel based on the formulaB, the lowest stability of 6.25% corresponding to the sample containing 1% formulaBEmulsifierS with the ratio of aqueous to oily phase was 30 to 70 percent) (Table 5). Adequate refrigeration stability (zero number) was related to 12 samples, including samples based on 2 and 3% of the formula.B (Commonly, the samples containing both types of emulsifier with the ratio of water to oil phase was 30 to 70, 35 to 65 and 40 to 60 percent) (Table 5).

Refrigerant stability index in percent for gel-filled emulsions based on formulaC, the lowest stability of 10.17% corresponding to the sample containing 2% formulaC, emulsifier S with the ratio of water to oil phase was 30 to 70 (Table 6). Adequate refrigeration stability (zero number) was related to 6 samples, including samples based on 1 and 2% formula.C (commonly it contained both types of emulsifiers and the ratio of water to oil phase was 30 to 70, 35 to 65 and 40 to 60 percent) (Table 6). The results related to the refrigeration stability of samples based on hydrogelators showed that the use of 1% formulaAFormulaB and the formulaC It led to glacial instability in the samples (Tables 4, 5 and 6).

EmulsifierG In examples based on the formulaA And also emulsifierS In examples based on the formulaB and the formulaC had a role; While both types of emulsifiers play a role in creating appropriate stability in terms of refrigeration in all samples (Tables 4, 5 and 6). In examining the role of the proportion of the aqueous phase in all samples, contrary to stability, in the occurrence of instability percentages of 30% (for the formulaAFormulaB and the formulaC), 35 percent (for formulaA) and 40 percent (for formulaA) played a role (Tables 4, 5 and 6). Using the appropriate percentage of hydrogelator, type of emulsifier and proportion of aqueous phase led to the creation of glacial stability (Tables 4, 5 and 6). There was a similarity between the commercial butter sample and the stable samples prepared in the present study in the field of glacial stability (Tables 4, 5 and 6).

[DOI: 10.22034/FSCT.22.165.86]

In the research conducted with the aim of preparing margarine from oleogel with different percentages of fat]15[The results showed that all the samples did not have any instability during the storage period and were similar to the results of the present research in the field of stable samples in terms of refrigeration conditions based on all three types of hydrogelators. The results of some researches showed that the factors affecting the instability of emulsions can include the type and amount of ingredients used, the type of emulsion composition and the conditions of emulsion storage (temperature and time).]19 and 38[. Luo et al. (2019) in the structuring of camellia oil in water-in-oil emulsion using tea polyphenol palmitate, found that there was an inverse relationship between the percentage of hydrogelator used and the stability of the emulsions.] 19[. Similarity in the context of formula-based examples C Related to the present research with the research conducted in the field of the effect of formula gumC On the characteristics of oil-in-water emulsions with whey protein isolate carried out by Sun et al. (2007), so that in the mentioned research, there is an inverse relationship between the percentage of using the formulaC It was established with the stability of emulsions]37[. Similarity in the field of effect of oleogelators of the present study (except formulaC) on the refrigerator stability by researching the preparation of margarine based on oleogel containing different percentages of fat]15[there was Szumałaand February (2016) reported that gelators (according to the type and appropriate amount of consumption) can improve the stability of emulsions through the stagnation and stabilization of emulsion particles.]38[.

4-4- Sensory properties of emulsions filled with gel

1-4-4- Sensory properties of emulsions filled with gel based on the formulaA

Sensory characterization results for gel-filled emulsions based on formulationA, presented in Table 3. Statistical analysis of sensory properties based on the formulaA It showed that the factors of hydrogelator, type of emulsifier, ratio of aqueous phase and also on the interaction of hydrogelator in the type of emulsifier had a significant effect (less than 0.05) for all sensory characteristics. It should be noted that the statistical analysis related to the property of spreadability showed significance (less than 0.05) for only factors (type of hydrogelator, type of emulsifier) and the interaction of hydrogelator with type of emulsifier. The water phase ratio factor had a non-significant effect (more than 0.05) for the spreadability characteristic and also on other interactions.

Sensory properties of gel-filled emulsions based on formulationA It is explained separately. 1) Hardness: the lowest amount corresponds to the sample containing 1% of the formulaAEmulsifierG And the ratio of the water phase to the oil phase is 30 to 70%, and the highest amount is for the samples containing 2% of the formulaAEmulsifierG And the ratio of water to oil phase was 35 to 65 and 40 to 60% (Table 1). 2) Spreadability: the lowest amount corresponds to samples containing 1% of the formulaAEmulsifierS and the ratios of the water phase to the oil phase are 30 to 70, 35 to 65 and 40 to 60%, and the most related to the sample containing 3% of the formulaAEmulsifierS And the ratio of water to oil phase was 40 to 60% (Table 1). 3) Melting: in the lowest form related to the sample containing 1% of the formulaAEmulsifierS and the ratio of the aqueous to oily phase is 30 to 70% and the most related to the samples containing 3% of the formulaAEmulsifierG And the ratio of water to oil phase was 30 to 70 and 40 to 60 percent (Table 1). 4) Milk: the least related to the sample containing 2% formulaAEmulsifierG and the ratio of the water phase to the oil phase is 30 to 70 percent; If the most related to the samples containing 1 and 3 percent of the formulaA, both emulsifiers and the ratio of water to oil

[DOI: 10.22034/FSCT.22.165.86]

phase was 40 to 60% (Table 1). 5) Sourness: related to samples containing 1% formulaAEmulsifierG and the ratios of aqueous to oily phase are 30 to 70 and 35 to 65%, and the most related to the sample containing 3% of the formulaAEmulsifierG And the ratio of water to oil phase was 40 to 60% (Table 1). 6) Fat-like: the least related to the samples containing 3% of the formulaAEmulsifierG and the ratios of the aqueous phase to the oily phase 30 to 70 and 35 to 65 percent) and the most related to the samples containing 1 percent of the formulaAEmulsifierS And the ratio of water to oil phase was 30 to 70, 35 to 65 and 40 to 60% (Table 1). 7) Covering the mouth: the least relevant to the sample containing 1% of the formulaAEmulsifierG And the ratio of water to oil phase is 30 to 70% and the most related to the sample containing 3% of the formulaAEmulsifierS And the ratio of water to oil phase was 40 to 60% (Table 1).

The results of the sensory properties according to the percentage of the formulaA It showed that the lowest amount of sensory properties based on 1% formulaA for hardness, spreadability, melting, tartness and mouth coating; 2 percent formulaA For milk and 3% formulaA was visible for fat-like (Table 1). If creating the maximum amount of sensory properties, 1% of the formulaA For milky, fat-like properties; 2 percent formulaA For hardness and 3% formulaA For spreadability, melting, milkiness, sourness and mouth coating were involved (Table 1). In creating the least amount of sensory properties, emulsifierG It has an effect in creating some characteristics such as: hardness, milkiness; While emulsifierS For properties such as spreadability, melting plays a role (Table 1). In creating the maximum amount of sensory properties based on the formulaAEmulsifierG for hardness, melting, milky; If the emulsifierS For spreadability, milky, fat-like and mouth coating were effective (Table 1). The results of the sensory characteristics of the samples based on the formulaA showed that the ratio of the aqueous phase had the lowest and the largest role in creating the values, and it should be noted that in addition to the ratio of the aqueous phase, the selection of the type of emulsifier and the percentage of the formulaA were also effective in creating characteristics (Table 1).

2-4-4- Sensory properties of emulsions filled with gel based on formulaB

Sensory characterization results for gel-filled emulsions based on formulationB, presented in Table 2. Statistical analysis of sensory properties based on the formulaB It showed that there was no significant difference (more than 0.05) for the difficulty characteristic in the field of factors alone and on their interactions (binary and overall). Also the statistical analysis of the formulaB It showed that for the factors of hydrogelator (milky properties and oral coating), the type of emulsifier (oral coating property) and also the proportion of aqueous phase (milky property) had a significant effect (less than 0.05). Individual parameters (except in the field of milk and oral coating), have a significant effect (less than 0.05) in the field of other sensory characteristics based on the formula.B were Also, the interaction of hydrogelator in the emulsifier type for all sensory characteristics based on the formulaB It had a significant effect (less than 0.05).

Sensory properties of gel-filled emulsions based on formulationB It is explained separately. 1) The lowest amount of hardness for the sample containing 1% formulaBEmulsifierG with the ratio of water to oil phase 30 to 70, 35 to 65, 40 to 60 and the highest hardness for the sample containing 3% formulaBEmulsifierS with the ratio of aqueous to oily phase was 30 to 70, 35 to 65 and 40 to 60 percent (Table 2). 2) The lowest spreadability for samples containing 1% formulaBEmulsifierS and the ratio of aqueous to oily phase is 30 to 70 and 35 to 65%, and the maximum spreadability of the sample containing 3% of the formulaBEmulsifierG And the ratio of aqueous to oily phase was 40 to 60% (Table

2). 3) Melting as a sensory characteristic has the lowest amount for the sample containing 1% of the formulaBEmulsifierG and the ratio of aqueous to oily phase is 30 to 70% and the highest amount for the sample containing 3% of the formulaBEmulsifierS And the ratio of aqueous to oily phase was 40 to 60% (Table 2). 4) Sensory characteristics of milk for samples containing 3% formulaBEmulsifierS and the ratios of the water phase to the oil phase of 30 to 70 and 35 to 65% have the lowest amount and for samples containing 1% of the formulaBEmulsifierG And the ratio of aqueous to oily phase was 30 to 70, 35 to 65 and 40 to 60 percent (Table 2). 5) Souring has the lowest amount for samples containing 3% formulaBEmulsifierG and the ratios of the aqueous phase to the oily phase are 30 to 70 and 35 to 65% and the highest amount for the sample containing 3% of the formulaBEmulsifierS And the ratio of aqueous to oily phase was 40 to 60% (Table 2). 6) For samples containing 1% formulaBEmulsifierG and the ratios of the water phase to the oil phase are 30 to 70 and 35 to 65%, the lowest amount of fat-like characteristic and the highest amount for the sample containing 3% of the formulaBEmulsifierG And the ratio of aqueous to oily phase was 40 to 60% (Table 2). The minimum mouth coverage for the sample containing 1% formulaBEmulsifierG and the ratio of water to oil phase is 30 to 70%, as well as the sample containing 1% of the formulaBEmulsifierS and the ratio of aqueous to oily phase is 40 to 60% and the maximum amount of oral coverage for the sample containing 3% of the formulaBEmulsifierG And the ratio of aqueous to oily phase was 40 to 60% (Table 2).

In the occurrence of sensory characteristics based on the formulaB, the results showed that different percentages of formulaB Contains: 1% formulaB for hardness, spreadability, melting and fat-likeness and mouth coating; 2% formula B for pickling and 3% formulaB For milk, they played a role in creating the lowest results (Table 2). In the context of creating the most results for samples based on the formulaB, samples containing 1% formulaB For the milky character and 3% of the formulaB played a role for other characteristics (Table 2). In the field of sensory properties based on the formulaBEmulsifierG played a role in creating the lowest rate for all characteristics except playability and milkiness; While emulsifierS Only for the property of spreadability, milkiness, mouth coating resulted in the lowest amount.

In the event of creating the maximum amount of sensory characteristics of formula-based emulsionsBEmulsifierG played a role in creating spreadable, milky, fat-like and oral coating properties; While emulsifierS It had an effect in creating the properties of hardness, melting and pickling (Table 2). The results of sensory properties based on the formulaB In general, it showed that in the occurrence of creating the lowest amount of all 3 types of formula percentageB played a role; While in the creation of the highest amount, 1 and 3 percent of the formulaB had an effect Choosing the right formula percentageB, the type of emulsifier and the ratio of aqueous phase in creating sensory properties based on the formulaB played a role (Table 2).

3-4-4- Sensory properties of emulsions filled with gel based on the formulaC

Sensory characterization results for gel-filled emulsions based on formulationC, presented in Table 3. Statistical analysis of sensory properties based on the formulaC For the hardness characteristic, it showed that the factors had a significant effect (less than 0.05) individually (except the ratio of the aqueous phase) and also on the interaction of the hydrogelator in the emulsifier type. Statistical analysis based on milky properties of the formulaC It showed that the factors (except the type of emulsifier) had a significant effect (less than 0.05) on the interaction of the hydrogelator in the type of

[DOI: 10.22034/FSCT.22.165.86]

emulsifier. It should be mentioned that the statistical analysis is based on the formulaC Related to other sensory characteristics (except hardness and milkiness), there was a significant difference (less than 0.05) in the fields of factors individually, on the interaction of hydrogelator in emulsifier type and also on the interaction of emulsifier type in aqueous phase ratio (for sourness).

Sensory properties of gel-filled emulsions based on formulationC is described separately. 1) Hardness: as the minimum amount for the sample containing 2% formulaCEmulsifierG and the ratio of aqueous to oily phase is 30 to 70% and the highest amount for the sample containing 3% of the formulaCEmulsifierS And the ratio of aqueous to oily phase was 30 to 70% (Table 3). 2) Spreadability: the lowest amount for samples containing 1% formulaCEmulsifierS and the ratios of the aqueous phase to the oily phase are 30 to 70 and 35 to 65% and the highest amount for the sample containing 3% of the formulaCEmulsifierS And the ratio of aqueous to oily phase was 30 to 70% (Table 3). 3) Melting: the lowest amount for the sample containing 2% of the formulaCEmulsifierG and the ratio of aqueous to oily phase is 30 to 70% and the highest for the sample containing 3% of the formulaCEmulsifierS And the ratio of aqueous to oily phase was 30 to 70% (Table 3). 4) Milk: in the lowest amount for the sample containing 1% formulaCEmulsifierG And the ratio of aqueous to oily phase is 35 to 65% and the highest amount for the sample containing 3% of the formulaCEmulsifierG And the ratio of aqueous to oily phase was 35 to 65% (Table 3). 5) Acidity: the lowest amount for samples containing 1% formulaCEmulsifierS and the proportions of the water phase to the oil phase are 30 to 70 and 35 to 65% and the highest amount for samples containing 2 and 3% of the formulaCEmulsifierG And the ratio of aqueous to oily phase was 40 to 60% (Table 3). 6) Fat-like: the lowest amount for the sample containing 3% of the formulaCEmulsifierG and the ratio of the aqueous to oily phase is 30 to 70% and for the sample containing 1% of the formulaCEmulsifierG And the ratio of aqueous to oily phase was 40 to 60% as the highest amount (Table 3). 7) Mouth coating: the lowest amount for the sample containing 2% formulaCEmulsifierS and the ratio of aqueous to oily phase is 30 to 70% and the highest amount for the sample containing 3% of the formulaCEmulsifierS And the ratio of aqueous to oily phase was 30 to 70% (Table 3).

The results of the sensory characteristics of samples based on the formulaC It showed that in creating the lowest amount of results: 1% of the formulaC for spreadability, milkiness and sourness; 2 percent formulaC For hardness, melting and coating of the mouth and 3% of the formulaC were involved for fat (Table 3). While creating the maximum amount of sensory properties results: 1% of the formulaC For fat like; 2% formulaC For sourness and 3% formulaC They played a role for other characteristics (hardness, spreadability, melting, milkiness, sourness and mouth coating) (Table 3).

In the field of sensory properties based on the formulaCEmulsifierG in creating the lowest values of properties including hardness, melting, milkiness, oral coating; EmulsifierS Only in the properties of spreadability, tartness, oral coating resulted in the lowest amount (Table 3).

EmulsifierG To make the most of the samples based on the formulaC Effective for hardness, milkiness, sourness and fat-like characteristics; While the emulsifierS For hardness, spreadability, meltability and mouth coating, it played a role (Table 3). Results related to some sensory characteristics (sourness and fat-like) for formula-based samplesC, indicating the effect of a large proportion of the aqueous phase (40% of the aqueous phase); If in the rest of the characteristics and even the lowest values related to sourness and fat-like, the

[DOI: 10.22034/FSCT.22.165.86]

aqueous phase did not contribute 40% (Table 3).

4-4-4-Descriptions related to sensory characteristics of emulsions filled with gel

In comparing the sensory properties of the prepared samples in comparison with the commercial butter sample, the results indicated that the sensory properties of the commercial butter were higher (Tables 1, 2 and 3). Important factors have an impact on the results of sensory characteristics, among others, we can mention the method of examining the characteristics, the selection of the desired characteristics, and the examiners.]39[. In the context of the property of spreadability, the research results of preparation of emulsion filled with gel containing extra virgin olive oil-inulin]39[, there was a similarity with the present study. Among the results of the sensory characteristics obtained by the research conducted to prepare substitutes for Korean products by Yilmazand Öğütcü(2015) and also Pandule et al. (2020), the results obtained were similar to the results of the present study]11 and 40[.

The research conducted in the field of investigating the effect of hydrogelator (whey protein isolate and kappa-carrageenan) on the sensory properties of emulsion filled with gel.]41[As well as research on the preparation of margarine based on oleogels containing sunflower oil with high oleic content]42[, it was a sign of the difference between the results of these researches and the present research, so that one of the reasons is the difference of different components used in the preparation of samples, especially gelators. In the research conducted in the preparation of margarine with the aim of investigating the effect of changes in the amount of fat and emulsifier, the results showed that in addition to the type of fat/oil as an alternative source, the type and amount of gelator/emulsifier were also effective in the occurrence of sensory characteristics.] 43، 44[. The results of sensory properties can be affected by the type of oleogel, type and amount of oleogelator/hydrogelator.]44،42[. The similarity between the current research on the effect of the type and amount of hydrogelator on sensory properties with the research on the use of linseed oil and hydrocolloids in the preparation of emulsion filled with gel]40[There was a similarity.

5-Conclusion

The results obtained from this research showed that gel-filled emulsions based on canola oil, various hydrogelators and water can be used as a substitute for animal butter in food products. It should be noted that in the emulsions of this research, the aqueous phase is structured with hydrogelators and can be used as an alternative. Increasing the amount of hydrogelator and the ratio of the total aqueous phase in this type of emulsion has improved the physical characteristics, including hardness. Choosing the type of emulsifier had a significant effect on the properties of emulsions; So that the samples based on all three types of hydrogelator contain emulsifierG, having more physical, oxidative, thermal and sensory stability than samples containing emulsifierS were Also in formula-based examplesA, both types of emulsifiers (Gand S) were effective in thermal and sensory properties. On the other hand, these emulsions, in addition to having favorable characteristics based on the type of hydrogelator, have appropriate sensory characteristics that can influence the acceptance of consumers. In general, the findings of this research showed that by using vegetable oils such as canola oil, water, hydrogelators and aqueous phase structuring methods, it is possible to create products with high nutritional value and similar or even better characteristics than Korean products. This issue can lead to the preparation of products that are not only low in saturated and trans fatty acids, but also healthy and nutritionally quality. It is suggested that in the field of research based on gel-filled emulsion with the aim of preparing

[DOI: 10.22034/FSCT.22.165.86]

alternatives to Korean products, things like 1) selection of new hydrogelatory compounds, 2) selection of suitable emulsifying compounds, 3) selection of appropriate proportions of components (hydrogelation, emulsification, water and oil) are suggested.

6-Resources

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[DOI: 10.22034/FSCT.22.165.86]

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مقاله علمی_پژوهشی

تهیه امولسیون های پر شده با ژل بر پایه روغن کانولا- هیدروژلاتور های مختلف (ژلاتین، آگار-آگار و زانتان) بعنوان جایگزین کره

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اطلاعات مقاله

تاریخ های مقاله :

تاریخ دریافت: ۱۴۰۳/۶/۱۷

تاریخ پذیرش: ۱۴۰۴/۴/۱۰

کلمات کلیدی:

روغن کانولا،

امولسیون،

ژل،

ژلاتین،

آگار-آگار،

زانتان

DOI: 10.22034/FSCT.22.165.86.

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چکیده

این مطالعه به بررسی تولید و ارزیابی امولسیون های پر شده با ژل بر پایه روغن کانولا، آب و هیدروژلاتورها به عنوان جایگزین کره تجاری پرداخته است. با توجه به نیاز روز افزون، این پژوهش تلاش نمود با بهره گیری از ساختاردهی فاز آبی با کمک هیدروژلاتورهای مختلف و روغن کانولا، امولسیون هایی را ایجاد نماید که از نظر ارزش عملکردی و تغذیه ای، مشابه یا حتی برتر از نمونه های کره های تجاری و در دسترس باشند. در این پژوهش، از هیدروژلاتورها (ژلاتین، آگار-آگار و زانتان) به عنوان عامل ساختارهی فاز آبی و دو نوع امولسیفایر (سوربیتان مونواستئارات و گلیسرول مونواستئارات) استفاده شده است. متغیرهای مختلفی (میزان هیدروژلاتور، نوع امولسیفایر و نسبت آب به روغن) در تهیه امولسیون ها مدنظر قرار گرفتند و در نهایت خصوصیات امولسیون ها از جمله پایداری حرارتی، اکسایشی، فیزیکی، حسی و بافتی مورد بررسی قرار گرفت. نتایج نشان داد که افزایش هیدروژلاتور منجر به افزایش سختی نمونه های بر پایه هر سه نوع هیدروژلاتور شد. در حالی که انتخاب نوع امولسیفایر تاثیرهای مختلفی را بر سایر خصوصیات با توجه به نوع هیدروژلاتور داشت. نمونه های بر پایه آگار-آگار و زانتان و حاوی گلیسرول مونواستئارات در مقایسه با سوربیتان مونواستئارات، دارای خصوصیات بهتری نسبت به نمونه های بر پایه ژلاتین بودند. نتایج حاصل از این پژوهش بطور کلی نشان می دهد که امولسیون ها پر شده با ژل تهیه شده می توانند به عنوان جایگزین مناسبی برای کره تجاری در صنعت غذا مورد استفاده قرار گیرند، بدون اینکه هیچ گونه تاثیری در کیفیت حسی و همچنین عملکردی محصول نهایی داشته باشند.