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Using Grapefruit and Tomato Waste in O/W Type Chicken Meat Emulsion

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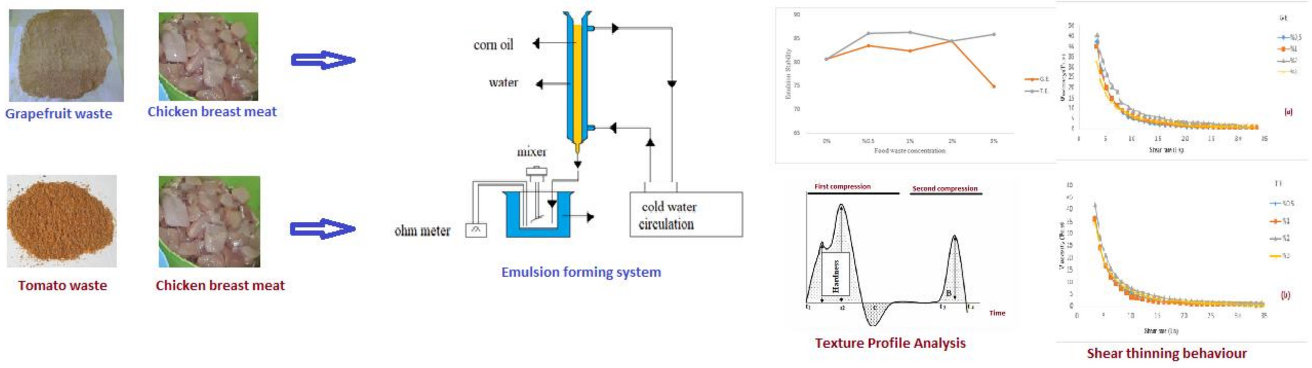
HIGHLIGHTS

- Food waste causes environmental pollution and valuable compounds loss
- Tomato and grapefruit processing and release significant food waste
- Emulsion stability is a very important parameter in O/W emulsion
- Both waste types increased emulsion stability
- These wastes contributed meat emulsions in many ways

Abstract: Utilizing food waste is crucial for several reasons, including preserving valuable ingredients, lowering formulation costs, taking advantage of its functional properties, and preserving the environment. Grapefruit waste (GW) and Tomato waste (TW) are used in oil-in-water (O/W) emulsion formulation to investigate their contributions to emulsion stability, textural parameters, and steady shear rheological properties of the model system. O/W emulsions were formed with four different concentrations (0.5%, 1%, 2%, and 3%) of GW and TW, and chicken breast meat and corn oil were the main components of emulsions. Both food wastes increased emulsion stability (ES) in most concentrations compared to the control. The best ES of 86.35 was observed at a concentration of 1% TW emulsion. Emulsions were subjected to texture profile analysis as both row and heat-treated. Heat-treated emulsions had higher hardness values (241.2-518.6 g) than the row emulsions (149.7-247.2 g). All emulsions were found to have pseudoplastic character and exhibit shear thinning behavior. All emulsion samples' apparent viscosity fit well with the Ostwald-de-Waele model (R^2>0.9). Food waste samples used in the study improved the chicken-type O/W emulsion properties in terms of emulsion stability and textural properties.

Keywords: Food waste; Grapefruit; Tomato; Emulsion Stability; Texture Profile Analysis; Emulsion Rheology.

GRAPHICAL ABSTRACT



INTRODUCTION

Large quantities of food waste are produced by food processing. The highest amount of food waste results from fruit and vegetable production. Plant-derived waste is generally rich in lignocellulose, protein, fat, sugar, phytochemicals, and other valuable compounds; they could be retained/re-used as valuable products that provide economic benefit for the food, cosmetic, and pharmaceutical industries. Disposal of this waste causes environmental problems and the loss of valuable compounds [1-3]. The recycling of these compounds from food waste not only reduces the environmental impact but also increases the sustainability and economic competitiveness of the agri-food industries [2]. Natural supplements and fiber-rich by-products are preferred by consumers, so they are valuable for the food industry.

Citrus fruits are one of the most widely cultivated fruit crops in the world [4] and processing citrus fruits produce waste of up to half their weight [5]. A little part of grapefruit waste is used as a fertilizer and a large portion of it is burnt [6]. Grapefruit pulp, peel, and seeds contain many biologically active components. Tomato is a second staple food after the potato and its waste is used for animal feed or disposed of as garbage [7]. A significant amount of tomato waste is released after tomato processing and contains many valuable components [8]. Every year 10,000 tons of tomato pomace are released by the production of tomato processing [9] and dry waste contains 44% of seeds and 56% of pulp [10]. Recent research focused on food waste; there are many studies about extracting biological active components or biological activity, [6, 11-13], using in food formulation [11, 14-16], or other purposes.

Emulsions are thermodynamically unstable systems very common in the food industry and their texture makes food appear attractive to consumers [17, 18]. Adding polysaccharides provides thickening, and reduces common destabilization mechanisms such as flocculation, creaming, sedimentation, or Ostwald ripening [17]. Using some vegetable proteins in emulsions has positive effects on binding, increasing emulsion capacity and stability, improving properties, and reducing the price of the formulation [19]. Understanding the variables that impact emulsion formation and stability is crucial for developing more effective emulsion investigations.

There is a lack of knowledge about food waste contributions to chicken-type meat emulsions. This study investigated grapefruit and tomato waste for emulsion properties, contribution to emulsion formation, emulsion texture and rheology, and the potential for usage in chicken meat-type emulsion. Emulsions made with grapefruit waste (GW) and tomato waste (TW) with 0.5%, 1%, 2% and 3% concentrations. Using GW with more than 3% concentration caused highly viscous suspension but lower emulsion hardness; for this reason, waste concentrations were not studied more than 3%. It is aimed at evaluating this food waste, recovering their beneficial components, and taking advantage of their functional features such as dietary fibers, and enhancing the stabilization of emulsions with natural components.

MATERIAL AND METHODS

Material

GW was obtained from the food laboratory; TW (the by-product of tomato paste production) was purchased from Limkon Gıda Company (Adana/Turkey). Food waste samples were sieved through a 750 µ sieve and kept at 4 °C in dark bottles until analysis time.

The skinless chicken breast was purchased from a local market in Samsun, Turkey. The chicken meat was minced, weighed, and packaged in equal amounts of 25 g each, then frozen in a freezer and stored at -18 °C until use.

Methods

Suspension preparation

This is the pre-emulsion step. To prepare the suspension, 25±0.5 g of meat samples, which were prepared and stored at -18 °C, were transferred into a jar still frozen, and 100 mL of 0.4 M NaCl (pH:6.6) at +4 °C solution was added. For the control samples, the suspension was prepared with chicken meat only; for the application samples, 0.5%, 1%, 2%, and 3% GW and TW were added to the suspension and homogenized at 13.000 rpm for 2 minutes by an ultraturrax (KA T25, Germany) [20].

Emulsion formation

O/W emulsions were obtained from the chicken meat using a described method [20]. 37.5 mL of 0.4 M NaCl solution was added to the 12.5 g suspension. This mixture was homogenized for 10 s in a glass blender (Waring-80011 S, USA) after adding 50 mL of corn oil. While homogenization continued in the system (see Figure 1.), the emulsion was obtained by adding corn oil at a rate of 0.9-1.0 mL/s from the burette. We monitored the changes in current through the copper conductors placed in the system to ascertain when to stop the process. During emulsion preparation, the temperature was kept below 15°C by using an ice bath.

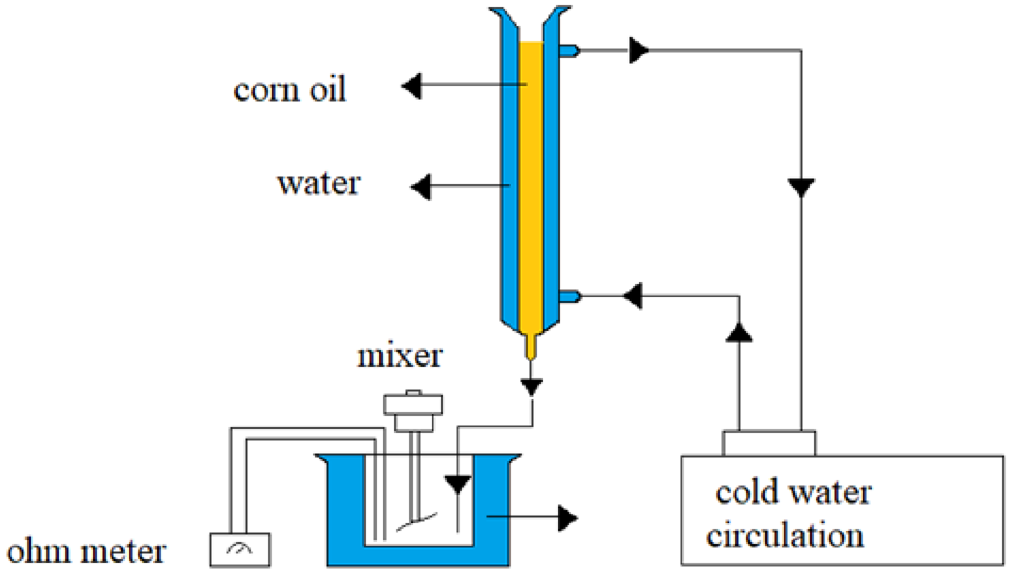


Figure 1. The model system used for O/W Emulsions.

Proximate composition of waste samples and chicken breast meat

Moisture content%, crude protein%, and crude oil% measured by AOAC standard analyses [21].

pH analysis

The pH of the heat-treated (80±2°C for 30 min) emulsions was measured by immersing the pH meter (Hanna Instruments HI2211) probe into the emulsions [22].

Measuring Emulsion Capacity (EC)

The suspension and oil mixture were placed in the emulsion system and homogenized continuously while the corn oil in the burette trickled into the suspension at a rate of 0.9-1.0 mL/s. The completion of the emulsion was determined by the instant change in the ammeter using copper conductor bars placed in the system. Electrical conductivity was monitored, and the system was stopped when a sudden drop appeared in conductivity. The emulsion capacity was determined from the total amount of oil in the emulsion [20].

Measuring Emulsion Stability (ES)

The prepared emulsions were weighed in a test tube and were found to be 10±0.9 g and then heat-treated in a water bath at 80±2 °C for 30 minutes. Once the samples cooled to room temperature, they were centrifuged at 2000 g for 10 minutes. After centrifugation the liquid phase was separated and measured in mL; the emulsion stability was calculated by the following formula [20].

$$ES\ (\%) = 100 - (\text{Volume of liquid separated from emulsion (mL)})*10 \quad (1)$$

Texture Profile Analysis (TPA)

Approximately 40 g of the prepared emulsion was placed in a 100 mL volume glass jar and heat-treated in a water bath at 80±2 °C for 30 minutes. After cooling to room temperature, the textural properties of the samples were measured by stretching samples to 50% of the original sample height using a 36 mm diameter cylindrical probe with a TPA device (TA.XT Plus, Texture Technologies Corp., UK). In the analysis where the two compaction intervals were 5 s, the force-time deformation curves were obtained with a load cell of 30 kg and a trigger force of 5 g at a speed of 1 mm/s. Time versus force is used to calculate TPA values such as hardness, adhesiveness, cohesiveness, springiness, and resilience [23].

Rheological Analysis

Rheological analysis was applied to the emulsion samples in a HAAKE Mars III Rheometer (HAAKE Co., Germany) which was equipped with cone and plate geometry (diameter: 35 mm, gap interval: 0.052 mm). The shear rate was applied to samples for 3 minutes between 0-100 s^{-1} for flow curve (steady-state), and analysis and measurements were performed at 25°C. The data were applied to an Ostwald-de Waele model given below.

$$\tau = K.\dot{\gamma}\ n \quad (2)$$

τ is shear stress (Pa), $\dot{\gamma}$ is the shear rate (s^{-1}), K is a consistent coefficient (Pa.s), and n is a flow behavior index (dimensionless).

Statistical Analysis

SPSS V.22 packet program was used for statistical analyses. Duncan's new multiple range-tests ($p<0.05$) were used to detect the differences among sample means.

RESULTS AND DISCUSSION

Proximate composition of waste samples and chicken breast meat

pH, moisture, crude protein, and crude oil analyses were done to evaluate the proximate composition of the samples. Table 1. indicates the proximate composition of grapefruit waste, tomato waste, and chicken breast meat.

Table 1. Proximate composition of waste samples and chicken breast meat

	Grapefruit waste*	**Tomato waste***	**Chicken meat**
pH	4.15±0.06	6.73±0.05	5.91+0.01
Moisture%	6.67±0.12	7.40±0.18	75.54+0.17
Crude protein%	3.28±0.17	13.60±0.43	19.53+0.20
Crude oil%	13.17±0.82	10.18±0.71	3.74+0.29

*For more details see our previous study [24].

pH analysis of emulsions

The pH values of the emulsions are given in Table 2. The pH values of the emulsions were determined to be between 4.61 and 6.36. The addition of GW in higher concentrations resulted in a lowering emulsion pH in GE. According to the Duncan's multiple comparison test result, the addition of GW to the emulsion significantly affected the pH value for all concentrations. pH value of GW (4.15) caused an important decrease for each concentration, because of grapefruit's acidic structure. The addition of tomato waste caused an increase in the pH of the emulsions formed with tomato waste (TE) for all concentrations. These results are also associated with the pH value of GW and its cellulosic structure.

Table 2. pH, EC, and ES values of emulsion samples

	%0 (Control)	%0,5	%1	%2	%3
			pH		
GE	5.96±0.04^{Aa}	5.73±0.08^{Bb}	5.51±0.03^{Cb}	5.03±0.07^{Db}	4.61±0.04^{Eb}
TE	5.96±0.04^{Ca}	6.31±0.02^{Aa}	6.36±0.11^{Aa}	6.15±0.03^{Ba}	6.12±0.01^{Ba}
			EC		
GE	184.71±5.97^{Aa}	168.52±1.71^{Bb}	163.17±1.29^{BCb}	147.37±1.25^{Db}	158.99±2.89^{CDb}
TE	184.71±5.97^{Aa}	188.75±0.82^{Aa}	188.01±1.29^{Aa}	169.22±1.29^{Ba}	168.81±2.87^{Ba}
			ES		
GE	80.60±2.12^{Ba}	83.43±0.59^{Ab}	82.43±0.21^{Ab}	84.51±1.27^{Aa}	74.90±4.75^{Bb}
TE	80.60±2.12^{Ba}	86.15±0.50^{Aa}	86.35±1.77^{Aa}	84.50±1.70^{ABa}	85.90±1.27^{Aa}

*Mean ± standard deviation. A-D: There is a statistically significant difference in the same line; a-b: there is a statistically significant difference in the same column (p <0.05).

Emulsion capacity (EC)

Emulsion capacity (EC) is the maximum amount of mL fat that 1 g protein can emulsify [20]. The effects of grapefruit and tomato waste addition in different concentrations on EC are shown in Table 2. The EC values of the emulsions were determined to be between 147.37-188.75 mL fat/g protein. The addition of GW to the emulsions caused a lower EC value than in the control. GE samples had lower pH causing a decrease in EC. According to Duncan's multiple comparison test results, the highest EC after the control sample was determined as 168.52 in the sample of 0.5% GW, and the lowest EC was 147.37 in the sample of 2% GW. The addition of 3%GW increased the EC value slightly compared to the emulsion with 2% GW. It was thought that this fluctuation could be caused by the structure of grapefruit, the solubility of its acids, and the solubility of proteins. It was found that the addition of TW in 0.5% and 1% increased the EC value by 188.75 and 188.01 mL of fat/g protein, respectively, and the best EC belongs to these emulsions. But using TW in higher concentrations (2% and 3%) lowered the EC value. This result was associated with TE pH; decreased with these concentrations, also can be related to acid solubility degree of the waste samples.

According to Duncan's multiple comparison test results, emulsions formed with TW yielded higher EC in all concentrations compared to the emulsions formed with GW. The fact that TW has a higher pH value and protein content; explains the high EC value of these emulsions.

The isoelectric point and the solubility of proteins are greatly impacted by the pH, a crucial environmental component [25]. In addition, the pectin content of tomato waste affected the EC value. Pectin chains contain hydrophobic groups and they contribute to the EC of emulsions [26]. It is known that the pH value of emulsions plays an important role in emulsion capacity values by affecting the solubility of proteins. Isoelectric pH is the least active protein and the lowest water solubility and water-holding capacity of proteins [20]. The isoelectric pH of myofibrillary proteins is between 4-5 and the functional properties of these proteins decrease as they get closer to the isoelectric point. All these factors caused higher EC for TE samples.

Emulsion Stability (ES)

The term "emulsion stability" refers to the ability of the emulsion to resist changes over time. The more stable the emulsion, the slower its properties change. Emulsions can become unstable due to several different physical and chemical processes. Creaming, flocculation, coalescence, partial fusion, phase inversion, and Ostwald ripening are physical instability, oxidation and hydrolysis are chemical instability [18, 27].

The effects of different concentrations of GW and TW addition on ES were shown in Table 2. The addition of 0.5%, 1%, and 2% GW increased the ES value of emulsions. However, the addition of 3% GW did not affect ES value statistically. The addition of TW increased the ES value for each concentration. According to the Duncan multiple comparison tests, 0.5%, 1%, and 3% concentrations had the same effect on the ES value of TW, and the lowest ES was found in the emulsion with a 2% concentration. Grapefruit and tomato waste are high in dietary fiber and both of them have high water and oil binding capacity and showed hydrocolloid properties [24]. Hydrocolloids have unique properties in texture, stability, and emulsion formation, and they are of great interest in low-fat processed meat due to their ability to bind water and form a gel [28]. Food wastes are high in dietary fiber and these fibers are effective on the texture and stability of foods due to their water-binding properties. It is thought that some substituents in these wastes played a role as an acting an effective emulsifiers, especially albedo in grapefruit waste and pectin in tomato waste.

Texture Profile Analysis (TPA)

The parameters of TPA applied to the emulsions were hardness, adhesiveness, cohesiveness, springiness, and resilience. The parameters of gumminess and chewiness were not given separately because they can be obtained from these given values.

The hardness of the emulsions

Hardness; is the maximum power required to compress the sample in the first compression cycle [29]. The hardness values of the emulsions are given in Table 3. It was determined that the hardness value of raw emulsions was between 149.7-247.2 g, and heat-treated emulsions were between 241.2-518.6 g.

The hardness value of the GE samples is not different from the control sample; there is no effect of the addition of GW to the row emulsions. Among the heat-treated GE, the control, 0.5%, and 1% GW added emulsions were statistically indistinguishable from each other, but the addition of more GW decreased the hardness value. In row TE samples, the highest hardness value was detected with 216.1 g of 1% TW, while the lowest hardness was seen in emulsion with 149.7 g of 3% concentration. The addition of TW to the chicken breast meat emulsion caused a decrease in the hardness value of heat-treated emulsions. The addition of food waste to the emulsion is expected to increase the hardness since pressed fruit and vegetable wastes contain large amounts of polysaccharides such as fiber and pectin and affect the cell wall thickness [30, 31]. But in this study waste addition caused no effect or decreased in hardness. The spongy nature of albedo in grapefruit imprisons many air spaces [4] and may have caused lower hardness. Also, grapefruit and tomato wastes contain a significant amount of dietary fiber [32, 33] and fibers have a good activity of water binding and oil binding. It was thought that these functional properties may have prevented the increasing hardness value.

Generally, heat-treated emulsions have a higher hardness value than row emulsions in this study. The heat treatment process caused an increase in the hardness value for both waste types of emulsions. Heat treatment increases the hardness and converts the high-viscosity solvent into a viscoelastic solid [28, 34]. In addition, the cooking process removes moisture and lipid migration occurs. For these reasons, heat-treated emulsions have higher hardness in our study.

Table 3. Texture profile analyses (TPA) of emulsion samples

	Control	%0.5	%1	%2	%3	Control	%0.5	%1	%2	%3
	Row Emulsion Hardness (g)					**Heat Treated Emulsion Hardness (g)**				
GE	163.8±9.2^{Aa}	218.8±16.4^{Aa}	217.3±18.9^{Aa}	184.8±57.4^{Aa}	163.3±33.6^{Aa}	480.3±41.9^{Aa}	518.6±28.9^{Aa}	495.5±4.7^{Aa}	272.7±38.3^{Cb}	351.1±27.9^{Ba}
TE	163.8±9.2^{BCa}	189.2±23.4^{ABb}	216.1±25.4^{Aa}	171.4±15.8^{Bb}	149.7±20.7^{Cb}	480.3±41.9^{Aa}	393.2±16.8^{Bb}	360.2±1.2^{Bb}	426.3±78.9^{ABa}	241.2±16.8^{Cb}
	Row Emulsion Adhesiveness (g.s)					**Heat Treated Emulsion Adhesiveness (g.s)**				
GE	-55.9±3.7^{Aa}	-86.2±8.2^{ABa}	-84.9±9.6^{ABa}	-127.5±47.0^{Bb}	-112.2±15.5^{Ba}	-107.4±20.4^{Aa}	-115.1±28.1^{Aa}	-162.4±20.8^{Ab}	-110.8±8.5^{Aa}	-565.3±89.1^{Bb}
TE	-55.9±3.7^{Aa}	-71.9±11.8^{Aa}	-74.9±15.9^{Aa}	-67.7±10.1^{Aa}	-331.8±45.4^{Bb}	-107.4±20.4^{Aa}	-94.3±10.0^{Aa}	-86.9±14.3^{Aa}	-225.1±80.2^{Bb}	-118.1±23.6^{Aa}
	Row Emulsion Cohesiveness (dimensionless)					**Heat Treated Emulsion Cohesiveness (dimensionless)**				
GE	0.56±0.01^{Aa}	0.54±0.02^{Aa}	0.55±0.02^{Aa}	0.53±0.00^{Ab}	0.53±0.02^{Aa}	0.54±0.01^{Aa}	0.46±0.03^{Bb}	0.46±0.04^{Ba}	0.47±0.01^{Bb}	0.38±0.07^{Cb}
TE	0.56±0.01^{ABa}	0.55±0.00^{Ba}	0.58±0.01^{Aa}	0.57±0.03^{ABa}	0.49±0.00^{Cb}	0.54±0.01^{Ba}	0.49±0.01^{Ca}	0.54±0.02^{Ba}	0.49±0.02^{Ca}	0.58±0.01^{Aa}
	Row Emulsion Spiringeness (mm)					**Heat Treated Emulsion Spiringeness (mm)**				
GE	0.935±0.01^{Aa}	0.954±0.01^{Aa}	0.960±0.01^{Aa}	0.944±0.03^{Aa}	0.946±0.01^{Ab}	0.949±0.01^{Aa}	0.932±0.02^{Ab}	0.969±0.03^{Aa}	0.961±0.00^{Aa}	0.814±0.14^{Ba}
TE	0.935±0.01^{Ba}	0.965±0.02^{ABa}	0.938±0.04^{Ba}	0.943±0.00^{ABa}	0.981±0.00^{Aa}	0.949±0.01^{Aa}	0.964±0.00^{Aa}	0.945±0.02^{Aa}	0.961±0.02^{Aa}	0.952±0.01^{Aa}
	Row Emulsion Resilience (dimensionless)					**Heat Treated Emulsion Resilience (dimensionless)**				
GE	0.067±0.01^{Aa}	0.042±0.01^{Ba}	0.039±0.00^{Ba}	0.041±0.00^{Ba}	0.034±0.00^{Bb}	0.056±0.01^{Aa}	0.047±0.01^{Ba}	0.036±0.00^{Ca}	0.028±0.00^{CDb}	0.027±0.00^{Db}
TE	0.067±0.01^{Aa}	0.047±0.00^{Ba}	0.048±0.00^{Ba}	0.053±0.00^{Ba}	0.042±0.01^{Ba}	0.056±0.01^{Aa}	0.043±0.01^{BCa}	0.048±0.01^{ABa}	0.037±0.00^{Ca}	0.041±0.00^{BCa}

*Mean ± standard deviation. A-C: There is a statistically significant difference in the same line, a-b: there is a statistically significant difference in the same column ($p < 0.05$)

Adhesiveness of emulsions

Adhesiveness: It is the energy required to overcome the attractive forces between the sample and the surface it is in contact with. The area under the apse after the first compression shows the adhesiveness value [29, 35]. The effects of GW and TW addition in different concentrations on the adhesiveness of emulsion samples are given in Table 3. In GE samples, the highest value was determined in the 3% GW added sample (-112.2 g.s), and there was no significant difference between 0.5%, 1%, and 2% with control in statistically (p> 0.05). Likewise, the highest value in TE samples was determined in 3% TW added emulsion (-331.8 g.s) and there was no significant difference between other concentrations than control (p> 0.05). The structure of the fiber because of the hydration properties of the wastes explains the increase in the adhesion values of the emulsions by increasing the waste concentration. According to Duncan's multiple comparison tests, food waste type has no effect on adhesion for 0.5% and 1% concentrations, but in 2% waste-added emulsions; the GE sample has the highest adhesiveness, and for 3% waste-added emulsions; the DE sample has the highest adhesiveness. It is thought that these results depend on the high water binding capacity and the amount of insoluble fiber in quince waste, as well as the structural properties of tomato pectin and grapefruit pectin.

Cohesiveness of emulsions

Cohesiveness is the strength of the inner bonds in the sample, calculated by dividing the first compression area of the sample by the second compression area, and is unitless [29]. The results are shown in Table 3. Statistically, the addition of GW onto the emulsion did not affect the adhesiveness value of row emulsions, and there was no significant difference between the grapefruit-added emulsions and the control emulsion (p> 0.05), but it caused a decrease in heat-treated emulsions, and the lowest cohesiveness value was 0.38 in 3% GW added emulsion. Tomato waste led to increases and decreases in the adhesion value of samples. For row and heat-treated emulsions, the highest cohesiveness was determined in tomato waste-added emulsions. We can explain this with TW's protein content. It has higher crude protein content than GW (see Table 1.). The increase in protein level can affect the gelling and emulsification abilities of the formulation and consequently cause an increase in textural properties such as flexibility and adherence. Generally, the heating process causes a lowering in adhesiveness for both waste types. The structural properties of meat emulsions are thought to vary depending on other ingredients such as protein, fat, and water levels [36].

Springiness of emulsions

Springiness is the ability to restore the original position of the sample after the deformation force applied to the sample is removed [35, 37]. The springiness value of the samples is shown in Table 3. Statistically, adding GW in different concentrations has no effect on row emulsion's springiness, only the addition %3 TW caused a decrease for heat-treated emulsions. TW caused an increase and decrease for row emulsions but does not affect heat-treated emulsion's springiness (p> 0.05). According to Duncan's multiple comparison test waste types are compared, there is no difference between the waste types at the concentrations of 0.5%, 1%, and 2% (p> 0.05). In emulsions with a concentration of 3%, the addition of TW had a greater effect on the springiness than GW. Generally, heat-treated emulsions had lower springiness than row ones. The heat-treatment process causes a decrease in springiness [34]. The high water binding capacity of food wastes leads to different springiness properties of emulsions compared to control emulsions. Water molecules act as a plasticizer between ingredients, making products less elastic and more susceptible to fracture after compression [30].

Resilience of emulsions

Resilience; is the elastic recovery of a product when the compression force is removed and is obtained by dividing the second compression distance by the first compression distance [35]. It is related to the feature of elasticity, and a decrease in resilience is an indication that elasticity is lost [37]. The results are shown in Table 3. The resilience values are between 0.034-0.067 for row emulsions and 0.027-0.056 for heat-treated emulsions. In general, the resilience values of emulsions decreased with the addition of both types of food wastes compared to the control. It is reported that the resilience value is positively affected by the ash and moisture content [30]. But resilience value of heat-treated GE and TE samples showed a decrease concerning the row ones for our study. It can be associated with food waste addition decreasing the moisture content of the emulsions, by the way, emulsion resilience decreased. The lowest resilience value was obtained in 3% GW-added emulsions among both row and heat-treated emulsions.

Rheological analysis

Food rheology is the study of the deformation and flow of raw materials, intermediates, and final products of the food industry. For many applications in food processing, it is necessary to know the rheological properties of the product during processing [38]. Emulsion samples were subjected to rheological analysis without any heat treatment.

Determination of viscosity properties of emulsions

Viscosity (resistance to flow) is defined as the ratio of shear stress to shear rate. Viscosity curves of GE and TE emulsions were given in Figure 2.1., (a), and (b), respectively. Viscosity curves depict that viscosity decreased with increasing shear rate, that is, GE and TE emulsion samples featured shear thinning behavior.

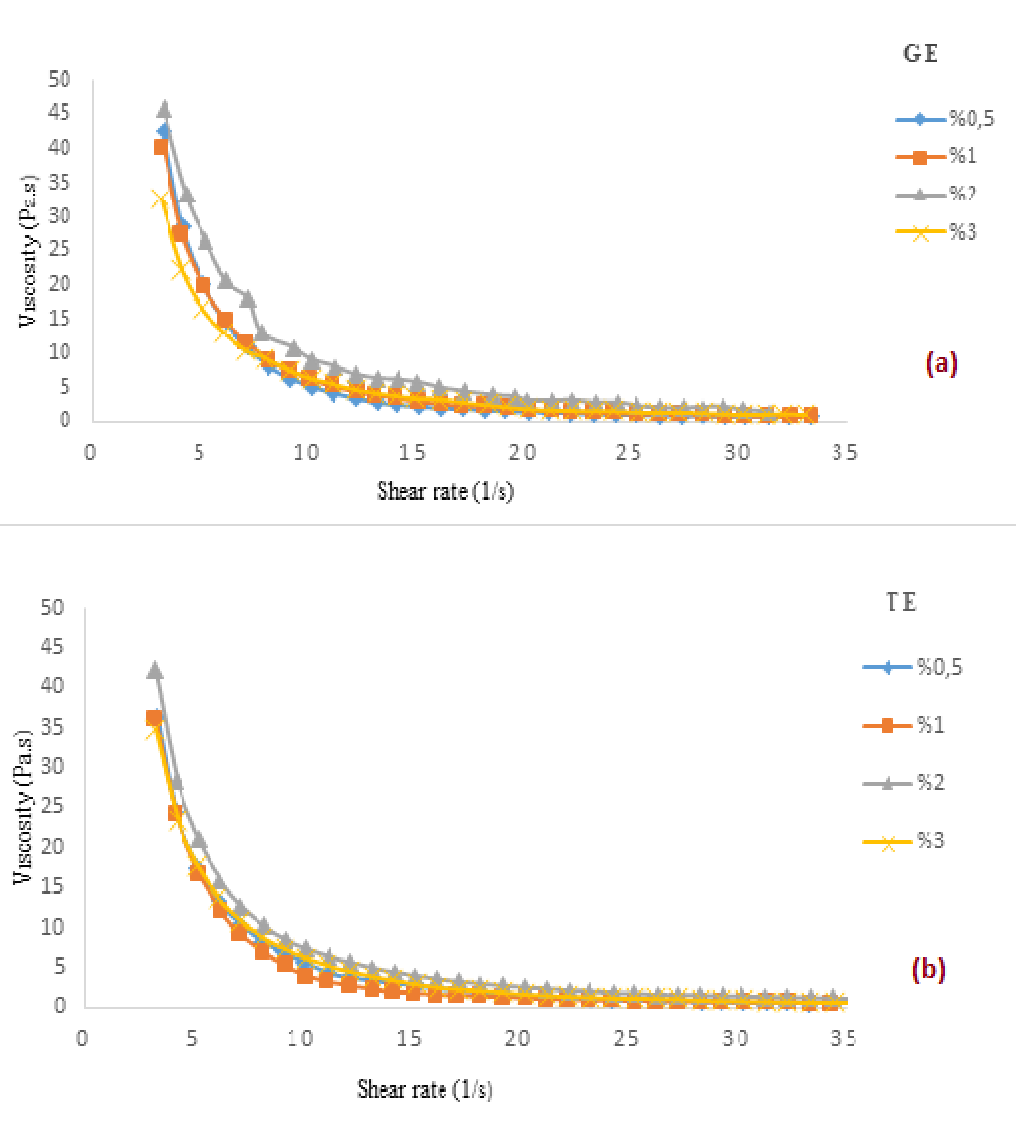


Figure 2.1. Viscosity curves of emulsion samples. (a); GE (grapefruit waste used) emulsion curves and (b); TE (tomato waste used) emulsion curves.

According to Figure 2.1. the highest viscosity was observed in 2% concentrations in both GE and TE emulsions. Increasing the concentration of GW and TW from 2% to 3% caused a decrease in viscosity in emulsions. The size and length of the fiber particles are known to have a major impact on the functional properties of the fibers. Although the wastes used in the study were passed through a 750 µm screen, the smaller particles also could be passed through the sieve, and the viscosity decrease with increasing concentration can be explained by the possibility of different particle sizes. Since citrus fiber solutions are generally non-Newtonian, the viscosity varies with the rate of shear; shear-thinning behavior is common for fruit purees [39].

One of the key physical qualities that affect the quality of food products is apparent viscosity; provides understanding of flow behavior, and helps with product quality control, energy input calculations, process design, and equipment selection [40, 41]. Comparison between viscosities was done using the apparent viscosity (η50) reference values at a shear rate of 50 s^{-1}, reported to be an effective shear rate [42]. The flow behavior of emulsions were shown in Figure 2.2.

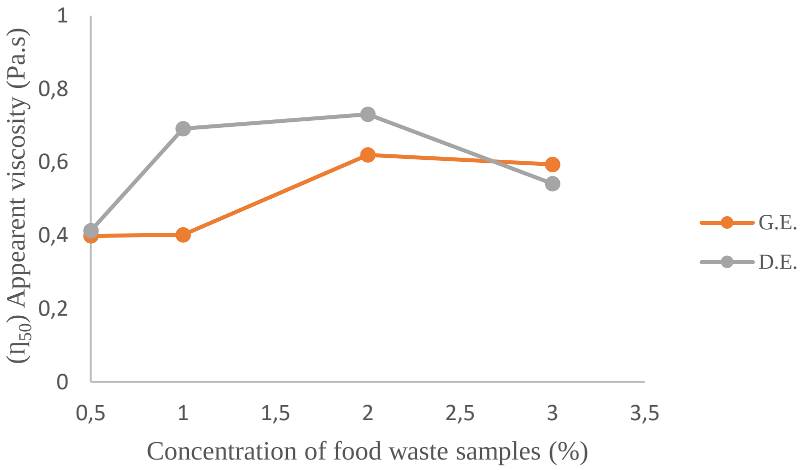


Figure 2.2. Flow behavior of GE and TE samples

In GE emulsions, the use of waste at the concentration of 0.5% and 1% did not considerably affect the emulsion viscosity, and the highest viscosity value was obtained by increasing the concentration to 2%. The addition of 3% GW reduced viscosity sharply. Higher concentrations could not be studied in this study since the grapefruit waste has a high water-holding capacity and dietary fiber absorbs up to 20 times its weight but does not form a viscous structure. In TE emulsions, the viscosity increased as the concentration increased up to 2%, but increasing concentration from 2% to 3% reduced viscosity. Water-soluble fibers are the main component that will increase the viscosity of a solution. Viscosity increases with increasing fiber concentration but decreases with the increasing shear rate. In a study examining the rheological properties of tomato and wheat fibers, the rheological measurements were made with 1%, 2%, and 5% concentrations. The viscosity vs. shear rate curves were found similar to our work and they had shear thinning behavior [42]. In a conducted study [1], peach and palm diet fiber suspensions were shown to be pseudoplastic fluids, and the apparent viscosity decreased suddenly with an increase in shear rate.

Determination of the flow behavior of emulsions

Flow behavior analysis involves determining and modeling the fluid type by creating a graph of shear rate ($\dot{\gamma}$) versus shear stress (τ). Flow analysis determines whether the substances are Newtonian or non-Newtonian. The fact that fluids have n=1 indicates that they are Newtonian, and have plastic properties at n<1, and dilatant at n>1 values [43]. The viscosity of a pseudoplastic material cannot be expressed with a single point, and the viscosity of these materials decreases as the sliding speed increases. Figure 2.3. represented the flow graph shear rate ($\dot{\gamma}$) versus shear stress (τ) of emulsions. The most concentrated sample (3% QE) at the same shear rate resulted in higher shear stress. In increasing concentrations, the polysaccharide aggregation probably forms a three-dimensional network structure, so it requires more energy to break the network structure [43].

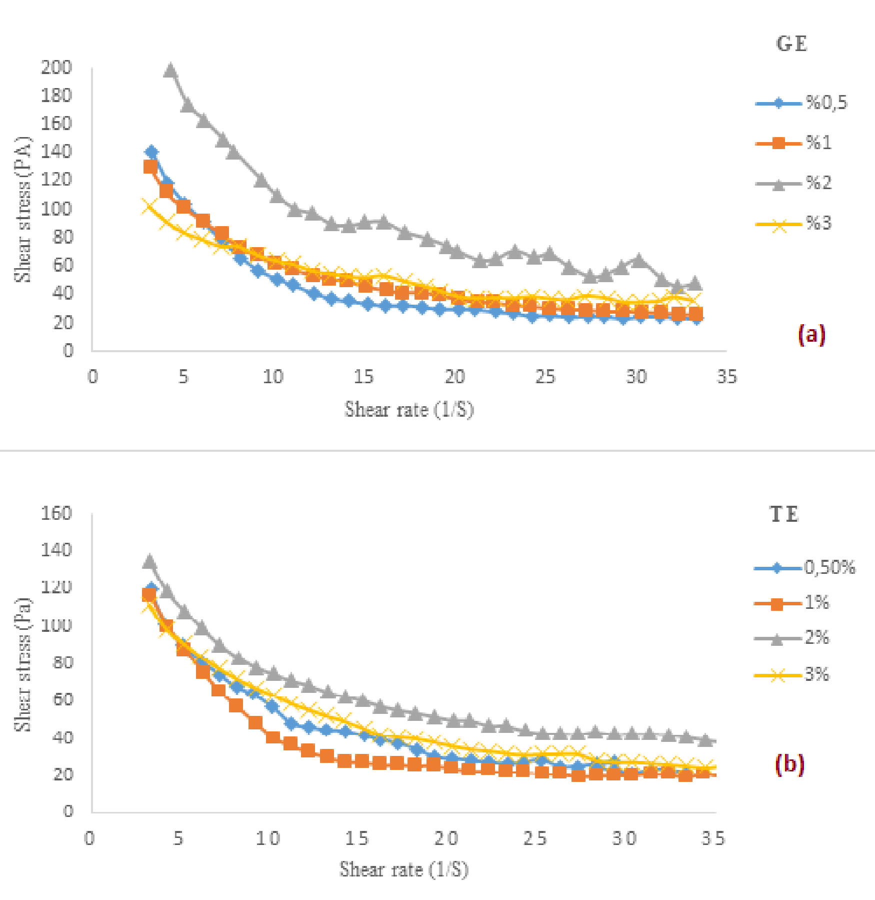


Figure 2.3. Flow behavior curves of emulsion samples. (a); GE (grapefruit waste added) emulsion curves and (b); TE (tomato waste added) emulsion curves.

Flow analysis graphs of GE and TE are given in Figure 2.1. For both types of emulsions, emulsions with a concentration of 2% waste at the same shear rate showed higher shear stress. In the viscosity analysis of GE and TE emulsions, the highest viscosity was seen in emulsions with a 2% waste concentration. The pectin, consisting mainly of galacturonic acid, rhamnose, arabinose, and galactose monomers, is thought to form a matrix with cellulose and hemicelluloses spread on the citrus plant cell wall. Although it is known that the degree of methyl esterification of citrus fiber pectin is in the range of 70-80%, some studies have reported a lower degree of esterification. The degree of methyl esterification causes changes in the functional properties of pectin [39]. Emulsions made with both waste types and concentrations showed the pseudoplastic flow pattern. Most polysaccharide solutions show non-Newtonian flow, and an increase in shear rate affects viscosity [44]. K; is the consistency index and is related to the increase in viscosity of solutions, n; It is the flow behavior index, a parameter that determines the shear-thinning quality of the solutions [39, 43]. Ostwald de Waele's model was successfully applied to the GE and TE, and the results are given in Table 4.

Table 4. Modeling parameters of GE and TE

Emulsion samples	Ostwald de Waele Model Parameters			Apparent viscosity (Pa.s)
	K (Pa.s^n)	n	R	η_{50}
GE				
0.5%	375.5	0.8158	0.9991	0.399
1%	274.7	0.6351	0.9996	0.402
2%	503.7	0.6380	0.9997	0.620
3%	172.8	0.4457	0.9993	0.594
TE				
0.5%	267.1	0.6749	0.9996	0.413
1%	302.7	0.7976	0.9985	0.692
2%	244.2	0.5064	0.9998	0.731
3%	212.1	0.5389	0.9992	0.542

The degree of pseudoplastic behavior can be measured by the flow behavior index (n). K and n values of GE emulsions are not in linear proportion with the waste concentration, n values are between 0.4457 - 0.8158 and K values are between 172.8 and 503.7. It is observed that K and n values of TE emulsions were independent of the waste concentration, and n values ranged from 0.5064 to 0.7976 and K values ranged from 212.1 to 302.7. A group researcher created a dispersion of a high methyl-esterified pectin fraction (STW-A) from Tamarillo fruit. They found that STW-A dispersions in shear-thinning behavior and stated their results were highly compatible with the Ostwald-de Waele model similar to our results [43].

CONCLUSION

In the present study, grapefruit and tomato waste was investigated in chicken meat-type O/W emulsion. During the analyses, it was observed that using over the 3% grapefruit waste formed highly viscous suspensions due to high water binding capacity but causes a decrease in the emulsion hardness due to the spongy structure of albedo. For this reason, concentrations up to 3% have been studied only. Emulsion's pH is significantly affected by food waste's pH and concentration. It's known that pH is one of the major factors for EC; so, GE has lower pH and lower EC values while TE has higher pH and higher EC concerning the control. GW addition increased the ES value from 80.6 up to 84.51 and TW addition increased to 86.35. In general, the addition of both food wastes improved the textural properties of the chicken meat-type emulsions. TPA analysis was done both row and heat-treated emulsions. Heat-treatment process affected all textural parameters. According to rheological analysis results, pseudoplastic character and shear thinning behavior, which is usually seen in polysaccharide solutions, were determined in emulsions. It was determined that both wastes had a positive effect on the stability, texture, and rheology of the emulsion, thanks to its high dietary fiber content. It is important to know the rheological and textural properties of grapefruit and tomato waste; will help manufacturers to produce a more conscious product and better product design while using these wastes. Using this food waste can provide evaluating many constituents and benefit their functional properties such as water and oil binding features. The results put forth positively affect and contribute to O/W emulsion's textural and rheological properties and evaluating such wastes can reduce the amount of garbage and prevent environmental pollution.

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