



Composition, Morphology, Optical, Thermal and Mechanical Properties of Yogurt Containers

Gizem Cihanoğlu¹, Merve Karabıyık², Iklima Odabaşı³, Devrim Balköse⁴

¹ İzmir Institute of Technology, Department of chemical engineering, Gülbahçe, Urla, İzmir (payergizem@gmail.com)

² İzmir Institute of Technology, Department of chemical engineering, Gülbahçe, Urla (merveozpirin@gmail.com)

³ USCA winery Urla İzmir Turkey (iklimaodabaşı@gmail.com)

⁴ İzmir Institute of Technology, Department of chemical engineering, Gülbahçe, Urla, İzmir (devrimbalköse@gmail.com)

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Corresponding author: *Devrim Balköse*

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ABSTRACT

The morphology, composition, optical, thermal and mechanical properties of two randomly selected commercial yogurt containers, container 1 and container 2 were determined using advanced analytical techniques in the present study. The container 1 which was based on polypropylene labelled as “5” had 18.1 % CaCO₃ and 1.2% TiO₂. On the other hand container 2 which was based on polystyrene labelled as “6” had 1.2 % TiO₂, CaCO₃ and olivine. The melting point of container 1 was 166.4 °C and the glass transition point of container 2 was 99.9°C. The surface of the container 1 was smoother than the container 2 with the average surface roughness values of inside surfaces 10.3 and 19.4 nm respectively. Both containers were white in color and had very low values of light transmission. The samples had close values of tensile strength and tensile modulus. The presence of fillers made the containers had lower tensile strength and higher stiffness than their base polymers. the future recycling methods for yogurt packing materials. The containers labelled as “5” and “6” should be collected separately from the source since they will have different processes for reuse.

1. INTRODUCTION

The goal of food packaging is to contain food in a cost-effective way that satisfies industry requirements and consumer desires, maintains food safety, and minimizes environmental impact [1]. People consume yogurt, which is one of the most important food product that is made of fermented milk [2]. This fermented feed product was stored in containers derived from animal skins and earthenware pots approximately fifteen thousand years ago. By the time of progress, yogurt diversity increased so packaging technology needed to develop. Muniandy et al. [3] investigated the antioxidant activity of probiotic yogurt set in disposable plastic containers during refrigerated storage. Preferable materials, which are used recently in yogurt containers, are polystyrene (PS) and polypropylene (PP). While polystyrene is clear, hard and brittle, polypropylene is resistant to chemicals, heat and over fatigue and has lowest density among plastics suitable for packaging. Aroma compound sorption of yogurt with polystyrene and polypropylene packing was investigated by Saint-Eve et al. [2]. It was found that polystyrene packaging seemed to be preferable for limiting aroma compound losses and subsequent fruity note intensities, and for avoiding the development of odor and aroma defects. Less significant packaging effect was observed for 4% fat

yogurts [2]. At the storage temperature, 4°C in refrigerator, polystyrene is totally amorphous in a vitreous state, while polypropylene is a semi-liquid crystalline polymer in a rubbery state. Thus, these differences in the structure could explain why the kinetics of aroma compound sorption was slower in polystyrene packaging than in polypropylene packaging [4].

The main disadvantage of polystyrene as a rigid or semi-rigid container is the fact that it is brittle. This can be overcome by blending with styrene butadiene copolymer, SB or SBC, an elastomeric polymer. The blend is known as high-impact polystyrene or HIPS. Blending produces a tougher material. It is translucent and is often used in a white pigmented form. The sheet can be thermoformed for short shelf life. The high impact polystyrene (HIPS) is the most popular material used in yogurt containers. It is normal to add pigments such as TiO₂ to the HIPS in order to improve the appearance of the package and to provide some barrier to light. This also helps in heating and softening the HIPS sheet for thermoforming when radiant heating is used. White is most often used, but other colors are also common [5].

In the present study, the characterization of randomly selected two yogurt containers was aimed. Advanced instrumental techniques such as Fourier Transform Infrared Spectroscopy(FTIR), X-ray diffraction, scanning electron

microscopy (SEM), Energy dispersive analysis(EDX), atomic force microscopy(AFM), Differential scanning calorimetry (DSC), Thermal Gravimetric analysis (TG), visible spectroscopy and tensile testing were used to determine the chemical composition, morphology, thermal and mechanical properties.

2. EXPERIMENTS

2.1. Samples

Samples selected from the market shown in Figure 1 were container 1, which is polypropylene based, and container 2, which is polystyrene, based. They were stamped at the bottom as recyclable polymers as 5 (polypropylene) and 6 (polystyrene) respectively. The bottom parts of the containers were examined by FTIR, X-ray, SEM, EDX, AFM, DSC and TG analysis. The samples cut from sides of the containers were used for mechanical tests.

Shimadzu-8400S infrared spectrophotometer was used as an instrument for the transmission technique of infrared spectroscopy. The microstructure of samples was investigated with Scanning Electron Microscopy (SEM), FEI Quanta250, with a field emission gun. The scissor cut surfaces from the bottom of the samples examined. The fracture surface of sample d after tensile test was also investigated with SEM. Before viewing the sample, sputter coater was used to coat surface of sample with this layer of gold at 15 mA under vacuum condition at 7×10^{-2} mbar during 75 s to increase its surface conductivity.

The inner and outer surfaces of the 1 cm x 1 cm pieces from the bottom part of the yogurt cups were examined by atomic force microscopy. Contact mode of AFM was used to determine the surface topography. AFM (Nanoscope IV) and silicon tip was used to obtain surface morphology and roughness of the film. 1 Ohm Silicon tip has coating: front side: none, back side: 50 ± 10 nm Al. Cantilever properties are T:3.6-5.6 μ m, L:140-180 μ m, k:12-103 N/m, fo:330-359 kHz, W:48-52 μ m. USRS 99-010, AS 01158-060 serial no OD57C-3930 standard was used in reflection mode.

DSC analysis of samples was made by using Perkin Elmer Jade DSC. The samples were heated at 10°C/min rate from room temperature up to 200°C under 50 cm³/min nitrogen gas flow. Thermal gravimetric analysis of the samples was made using Mettler Star SW 8.10 thermal gravimetric analyzer. 70 μ m³ open cap-alumina crucibles were used for experiments. Samples were heated at 10°C/min rate from 25°C to 650°C under 50 cm³ min⁻¹ N₂ gas flow, at 20°Cmin⁻¹ rate from 650°C to 1000°C in 50 cm³ min⁻¹ air flow and kept at 1000°C for 5 minutes in 50 cm³ min⁻¹ air flow.

Perkin Elmer 25 UV-Vis spectrophotometer was used in obtaining visible spectrum of the samples in transmission and reflection modes. The inside and outside surfaces of the films were examined in reflection mode. The effect of the exposed surface first to light was investigated in transmission mode.

Stress-strain measurements of the samples cut from the side surface of the containers were performed on a tensile test machine (Shimadzu AGS-J) equipped with a 5 kN load cell. The cross-head speed used was of 5 mm min⁻¹. The width of the test sample was 5.0 mm and gauge length was 50 mm.

3. RESULTS AND DISCUSSION

The two samples container 1 and container 2 examined in the present study carried the symbols 5 and 6 indicating

they were basically polypropylene and polystyrene respectively.

3.1 Functional Groups by FTIR Analysis

The FTIR spectrum of Container 1 in Figure 2 displays the bands assigned to different stretching vibrations of the methyl and methylene groups. In the 3800–2700 cm⁻¹ four prominent bands at 2959, 2920, 2873, and 2839 cm⁻¹ assigned to asymmetric and symmetric stretching vibrations of methyl and methylene groups respectively are observed. The bands at 1458 and 1377 cm⁻¹ are assigned to CH₃ asymmetric and symmetric bending vibrations. The peak at 1362 cm⁻¹ belonged to CH bending and CH₂ wagging vibrations. Other important bands are located at 1166 and 1044 cm⁻¹ are assigned to C-C chain stretching vibration, 998 cm⁻¹ is assigned to CH₃ rocking, CH₂ wagging and CH bending vibrations, 973 and 941 cm⁻¹ are assigned to CH₃ rocking and C-C chain symmetric stretching vibration, 899 cm⁻¹ is assigned to C-C chain symmetric stretching vibration, 841 cm⁻¹ is assigned to CH₂ rocking and C-CH₃ stretching vibrations and 809 cm⁻¹ is assigned to C-C chain symmetric stretching vibration and CH₂ rocking vibration [6-7]. Thus, FTIR spectrum of Container 1 confirmed that it was mainly made of polypropylene.

Additionally, the peaks at 1460 and 712 cm⁻¹ indicated the existence of calcium carbonate (CaCO₃) in container 1, because these peaks are the characteristic peaks of the CaCO₃ [8].

The FTIR spectrum of Container 2, which is seen in Figure 2, had characteristic peaks of polystyrene [9] as expected. The peaks at 3025 and 2850 cm⁻¹ are due to aromatic and aliphatic C-H stretching vibrations respectively. The peaks at 1492 and 1452 cm⁻¹ are assigned to the aromatic ring stretching vibrations. Besides, the unique peaks at 1601 and 1580 cm⁻¹ are caused by the aromatic C=C stretching vibration. The C-H deformation vibration band of benzene ring hydrogen's (5 adjacent hydrogen's) appeared at 758 cm⁻¹. Ring deformation vibration was observed at 698cm⁻¹ [10].

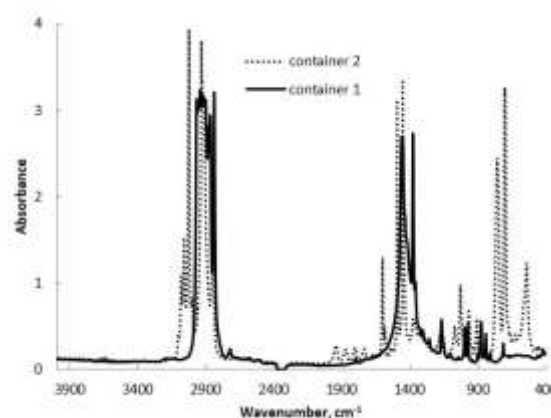


Figure 2. FTIR transmission spectra of container 1 and container 2

The presence of polybutadiene in polystyrene could not be detected by FTIR spectroscopy since both polystyrene and polybutadiene have similar functional groups. The FTIR and Raman peaks of the cis and trans polybutadiene was investigated by Nallasamy et al. [11] and they coincided with the FTIR peaks present in polystyrene. Further studies with composites prepared from polystyrene and polybutadiene is necessary to make a quantitative analysis.

3.2. X-Ray Diffraction Analysis of Samples

The x-ray diffraction diagram of container 1 is shown in Figure 3. The first six XRD peaks observed at 2θ values of 14.2° , 17.1° , 18.7° , 21.2° , 22° , and 25.6° are the well-known “fingerprint” of α -phase isotactic polypropylene (JCPDS 50-2397), which are also consistent with the XRD results in the literature carried out by Wang et al.[12], Obadal et al.[13] and Ulku et al.[14]. When these results are compared to the reference data of alpha phase polypropylene, it can be said that container 1 mainly consist of α -phase isotactic polypropylene. The peaks observed at 27.6° , 36.2° , 39.4° in x-ray diffraction diagram of container 1 in Figure 3 indicated the presence of rutile titanium dioxide (JCPDS file number of 04-0551). The peaks 29.4° , 31.6° , 36° , and 39.4° indicated the presence of calcium carbonate in calcite form with JCPDS 83-0578 [15].

The x-ray diffraction diagram of Container 2 is shown in Figure 3 also. The broad peak in the range of 14° and 24° (maximum at around 19°) indicate the existence of polystyrene. These obtained peaks are consistent with the data stated for polystyrene in Alsharaeh et al [16], Wu et al.[17] and also Hu et al.[18]. The peak at 27.4° for container 2 shows the presence of rutile titanium dioxide (JCPDS file number of 04-0551), and the peaks at 29.4° , 31.6° and 39.4° strongly fit to that of calcite (JCPDS 83-0578). The sharp peaks at 2θ values of 20° and 28.5° , fit well to the olivine group- $Mg_2(SiO_4)$ JCPDS 87-2039[19].

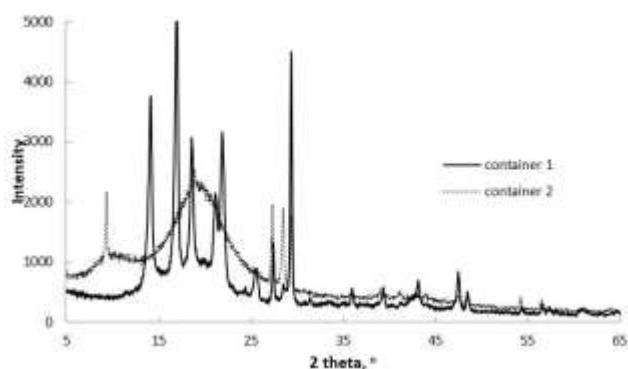


Figure 3. X ray diffraction diagrams of container 1 and container 2

3.3. Morphology of scissor cut surfaces

The SEM micrographs of cross sections of container 1 and 2 are shown in Figure 4. As shown in Figure 4a and 4b, their thicknesses are $275.1\ \mu\text{m}$ and $256.5\ \mu\text{m}$, respectively. When the scissor cut surfaces were examined closely in 100 000 x magnification the presence of solid particles are clearly seen. Container 1 in Figure 4c had more particles than container 2 in Figure 4d. These particles could be TiO_2 and calcite as their presence were indicated by X-ray diffraction. Additionally olivine particles could be seen in container 2.

3.4. EDX Analysis of the Particle Surfaces in Cross Sections and Cross sections

The surface of the particles was analyzed by EDX for elemental composition. The hydrogen free composition of the surface of the particles is reported in Table 1. The particles contained mainly C, Ca and Ti in both container 1 and container 2 confirming the presence of calcite and titania. The Container 2 had a minor quantities of

magnesium and silicon confirming the presence of olivine (Mg_2SiO_4).

Distribution of elements in an area in the cross sections of containers 1 and 2 are shown in Figure 5a and 5b respectively. Ca element which is shown by green color for container 1 is present in the particles only. Ca element shown by fucia color for Container 2 is also present only in particles which are few in number. Distribution of C element which is shown by red color for both samples were different for container 1 and container 2. While the surface of the particles were partially covered by C element in container 1, C was present as a continuous matrix in container 2. Ti element represented by blue color in container 1 and green color in container 2. Ti element was scarcer in container 1 and more abundant in container 2.

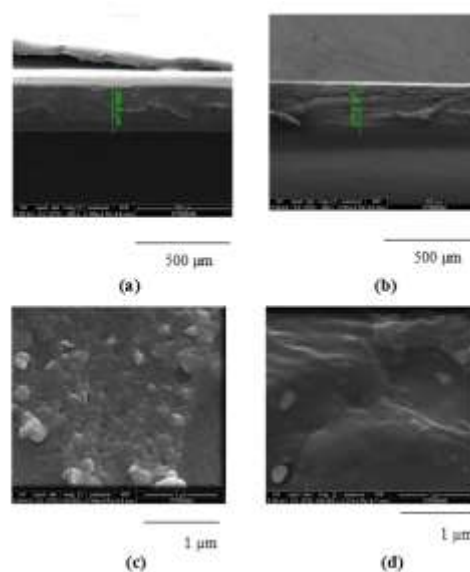


Figure 4. SEM micrographs of the crosssections of Container 1 at a. 250x c. 100 000x , Container 2 b. at 250x d. 100 000x magnification

TABLE 1.

ELEMENTEL COMPOSITIONS IN MASS % OF POINTS ON THE PARTICLES ON THE SCISSOR CUT SURFACES

Elem ent	Container 1			Container 2				
	P 1	P 2	P 3	P 1	P 2	P 3	P 4	P 5
C	71.7	11.3	11.7	92.4	94.8	65.4	64.0	54.4
O	-	-	-	6.82	4.65	19.1	20.8	32.2
Si	-	-	-	0.05	-	-	-	0.33
Mg	0.20	-	-	-	-	0.13	0.13	0.21
Ca	26.9	88.7	88.3	0.47	0.19	15.4	14.9	12.5
Ti	1.15	-	-	0.22	0.36	-	0.11	0.29

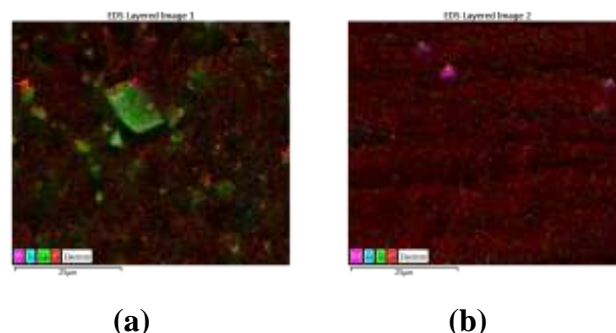


Figure 5. Element distribution in an area in crosssections of a. container 1, b. container 2

3.5. Atomic Force Microscopy

Atomic Force Microscopy was used to examine the surface topography of yogurt containers by using contact mode.

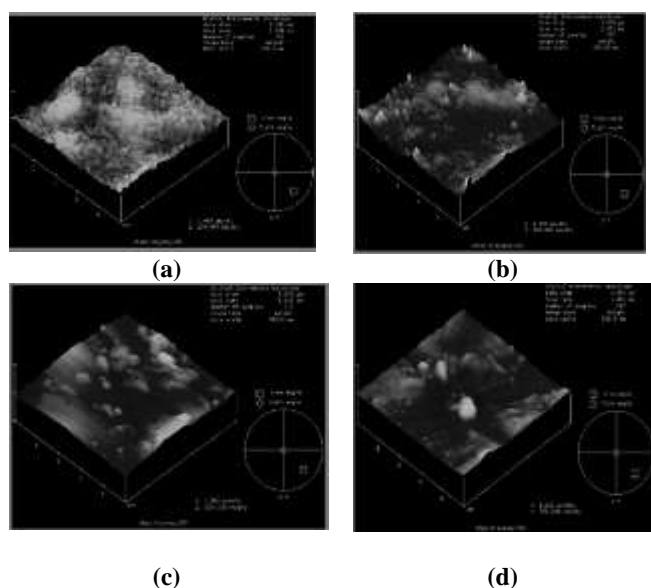


Figure 6. AFM 3D images of a. outer surface, b. inner surface of container 1, c. outer and d. inner surface of container 2 at scanning range of 5 μm

The AFM three dimensional (3D) images of the outer and inner surfaces of containers 1 and 2 are seen in Figure 6. The darker and lighter parts in the images are the lower and higher parts of the surfaces respectively. The outer surface of container 1 in Figure 6a consisted of many spherical particles. However, the inner surface seemed to be smoother with less number of particles. These particles could be either the filler particles coated with the polymer phase or the spherulites formed during crystallization of polypropylene phase. The outer surface of container 2 had smaller number of particles compared to that of container 1. Container 2 is mainly polystyrene. However, it could have a second dispersed phase of a second polymer such as polybutadiene to improve its impact resistance. Thus, these particles could be polymer coated filler particles or dispersed phase of the second polymer. Arithmetic-mean surface roughness, R_a , root-mean-square surface roughness, R_q ; and maximum peaks height, R_{max} values of the surfaces are reported in Table 2. The outer and inner surfaces had close R_q values (9.8 nm and 10.3 nm respectively) for container 1. Container 2 surfaces had higher R_q values than that of container 1, 20.4 and 19.4 nm for outer and inner surfaces respectively. Funke et al. [20] studied the polystyrene/polypropylene mixture droplets surfaces by atomic force microscopy. They showed that the surface of the droplets were covered with α isotactic polypropylene with characteristic crosshatched lamellar structure both for mixtures of 50/50 and 95/05 Polystyrene/Polypropylene blends. However, in the container 1 these crosshatched structures were not observed.

TABLE 2

AFM SURFACE CHARACTERISTICS OF OUTER AND INNER SURFACES OF CONTAINER 1 AND CONTAINER 2 IN 5 MM SCALE.

Sample	Surface	R_a , nm	R_q , nm	R_{max} , nm
Container 1	Outer	7.2	9.8	188.3
Container 1	Inner	8.1	10.3	77.1
Container 2	Outer	15.5	20.4	175.8
Container 2	Inner	13.8	19.4	20.3

3.6. Thermal Analysis

The DSC and TG curves of the containers are shown in Figure 7 and the thermal properties determined from the curves are reported in Table 3a and Table 3b. The DSC curves in Figure 7a indicated that container 1 had melting temperature (T_m) of 166.6°C and The container 2 did not have a melting peak and had only glass transition temperature (T_g) of 99.9 °C. DSC analysis also confirmed that container 1 had the melting temperature of

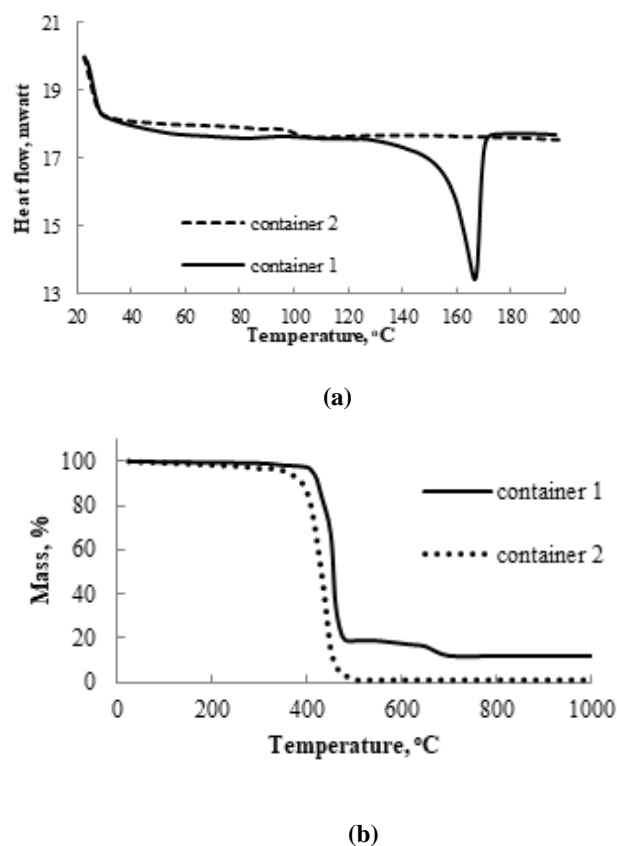


Figure 7. a.DSC, b. TG curves of container 1 and container 2

polypropylene [8] and container 2 had the glass transition temperature of polystyrene[21]. The heat of melting of container 1 was determined as 74.7 J g^{-1} from the area of the melting curve of container 1 in Figure 7a. The TG curves of the samples in Figure 7b indicated that the onset temperature (T_{onset}) of thermal degradation was 400°C and 250°C for container 1 and container 2 respectively. The degradation of container 1 had two steps. Container 1 lost 80.7 % mass up to 505°C in the first step corresponding to degradation of the polypropylene phase. The remaining mass at 505°C is due to presence of inorganic fillers in the sample. The second step in TG curve of container 1 started at 505°C and end at 719°C with 7.97 % mass loss, which is due to decomposition of the CaCO_3 filler to CO_2 and CaO according to Equation 1 [8].



Container 1 should have 18.1 % in mass of CaCO_3 as calculated from the mass % of CO_2 evolved. The total ash at 1000°C, 11.3% is due to CaO from CaCO_3 decomposition and TiO_2 present in the sample. Thus, there is 1.2 % TiO_2 in the Container 1. In Table 4, the

composition of Container 1 is reported.

TG curve of Container 2 in Figure 7b had only one step. The mass loss up to 505°C, 98.1% should be due to decomposition of polystyrene. The mass loss from 505°C up to 1000°C did not have a step change. Thus, the remaining mass at 1000°C, 1.9 % should be due to presence of inorganic additives such as calcite, olivine and TiO₂ as x-ray diffraction and EDX analysis indicated. The presence of CaCO₃ in Container 2 was very low and could not be detected by TG analysis even if its presence was indicated by x-ray diffraction and EDX analysis. Table 4 also reports the composition of the container 2.

Table 3.a

TG PROPERTIES OF CONTAINER 1 AND CONTAINER 2

Sample	T _{onset} , °C	T _{max} , °C	Mass % at		
			505°C	719°C	1000°C
Container 1	400	458	20.3	12.33	11.3
Container 2	250	539	1.9	1.9	1.9

Table 3.b

DSC PROPERTIES OF CONTAINER 1 AND CONTAINER 2

Sample	T _m , °C	T _g , °C	ΔH _m , J g ⁻¹
Container 1	166.6	Lower than room temperature	74.7
Container 2	Does not melt	99.3	-

DSC evaluation can be used to measure amount of crystallinity in a crystalline polymer sample. Crystallinity is indication of amount of crystalline

Table 4.

THE COMPOSITION (% IN WEIGHT) OF CONTAINER 1 AND CONTAINER 2 BY TG ANALYSIS

	Container 1	Container 2
Polypropylene	80.7	0
Polystyrene	0	98.1
CaCO ₃	18.1	-
TiO ₂	1.2	-
CaCO ₃ +TiO ₂ +olivine		1.9

region in polymer with respect to amorphous content. High crystallinity leads to increase in hardness, strength, wear resistance. Low crystallinity causes good processability, better transparency in polymers. The degrees of crystallinity (%) of the sample from DSC melting peak was determined as follows. The percentage of crystallinity (X_c) was calculated from the melting enthalpy (ΔH_m) using Equation 2.

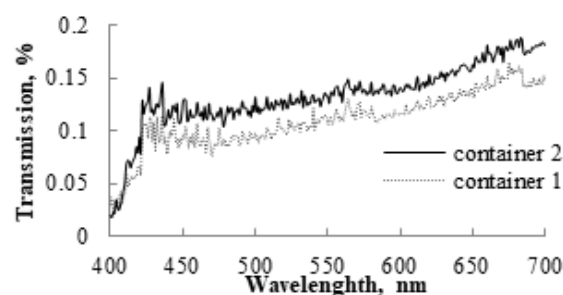
$$X_c(\%) = \frac{\Delta H_m}{w\Delta H_f} \times 100 \quad (2)$$

where ΔH_m is the melting enthalpy of the samples (J g⁻¹) and ΔH_f is the heat of the fusion of polypropylene at 100% crystallinity, corresponding to 207 J g⁻¹ and w is the weight

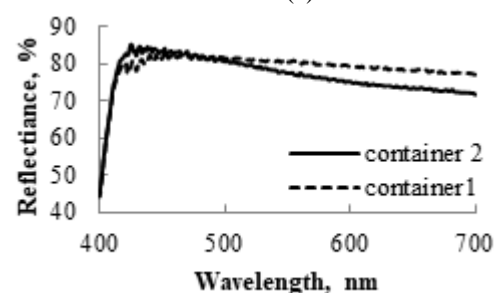
fraction of polypropylene in the sample [8]. The crystallinity of polypropylene in Container 1 was found as 44 % from Equation 2.

3.7. Optical Properties

The polypropylene and polystyrene are polymers, which are transparent to light. However, the fillers and pigments in the yogurt containers make them nontransparent. In both samples, calcite and titania were present and additionally olivine was present in container 2. It was shown that nano calcite assists better dispersion of TiO₂ particles in polypropylene [22]. The light transmission at 680 nm from both containers is very low as seen in Figure 8a, while container 2 transmits only 0.19%, container 1 transmits 0.16 % of light. The yogurt inside both containers was protected from the harmful effects of light. The container 2 and container 1 reflected 72 % and 78% of light at 680 nm respectively. In 400-420 nm region, the reflection increased from 45 % to 81% and 84 % for container 2 and container 1 respectively. The containers do not transmit light but reflect all the visible light making them to appear as white colored. However, the PS-grafted-TiO₂-PS hybrid films at 0.20 and 0.52 wt % showed high transmittance in the visible light region accompanied by ultraviolet absorption characteristic of TiO₂ due to the fine dispersion of nanoparticles in the PS matrix [23]. The Container 2 was not transparent in the visible region. This indicated that the TiO₂ particles were not nano sized.



(a)



(b)

Figure 8. Visible spectra of container 1 and container 2 in a. transmission, b. reflection mode

3.8. Mechanical Properties

Representative stress-strain diagrams of container 1 and container 2 are seen in Figure 9 and the tensile properties are reported in Table 5. Average tensile strengths for container 1 and container 2 are 21.2 and 21.9 MPa, respectively. Also, their average elastic modulus values are 2870 and 2829 MPa, respectively. The examination of the samples with other methods such as FTIR, XRD, SEM and EDX indicated that CaCO₃ and TiO₂ were used as fillers or

pigments and as a main polymer matrix polypropylene for Container 1, and high impact polystyrene for Container 2 was used. The yield strength for pure polypropylene is between 31 and 37 MPa whereas it is around 28 MPa and higher HIPS [24]. A sharp yield point was not observed for container 1. The point at which the stress strain diagram started to deviate from the linearity was taken as the yield point. The yield strength was 14.9 MPa and 14.2 MPa for container 1 and container 2 respectively. Both of these results are lower than the values of their pure polymers. Therefore, it can be said that these results are consistent with the findings of Zuiderduin et al.[25] and Parparita et al. [6] since the solid inorganic particles were used as fillers, the tensile strength for both samples are lower than that of the pure polymers. This can be because of the debonding of the filler particles from the polymer matrix, which do not contribute to the yield stress. Most probably, fillers lead to the weak interfacial interactions between the filler and the polymer matrix, which decreased the strength.

Elastic Modulus for pure polypropylene is between 1.14 and 1.55 GPa, and for pure HIPS it is between 2 and 3.30 GPa. The modulus of elasticity of the the container 1 and container 2 (2.87 GPa and 2.82 GPa respectively) are higher than the modulus of elasticity of pure polymers. The fillers in container 1 and 2

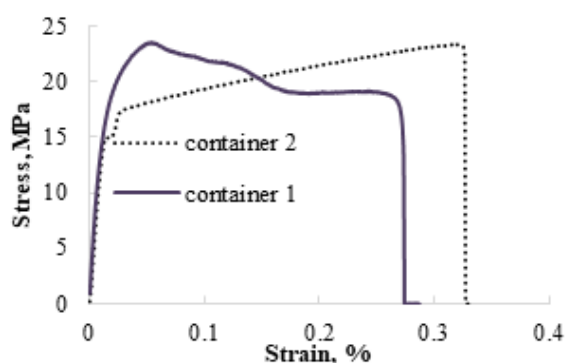


Figure 9. Representative stress-strain diagrams of container 1 and container 2

Table 5.

MECHANICAL PROPERTIES OF CONTAINER 1 AND CONTAINER 2

Property	container 1	container 2
Yield Stress, MPa	14.9±2.9	14.2±0.43
Yield strain	0.016±0.003	0.012±0.001
Elastic Modulus, MPa	2870±619	2829±122
Tensile stress, MPa	21.2±2.6	21.9±1.4
Tensile strain, %	0.19±0.08	

caused stiffening of the materials increasing the modulus of elasticity similar to the studies of Zuiderduin et al. [25], Parparita et al.[6] and Zhang et al [15].

The fracture surfaces SEM micrographs of container 1 and container 2 are shown in Figure 10. While Container 1 shows a fibrillary structure due to orientation of crystallites in polypropylene phase during the drawing of the Container 1, The Fracture of Container 2 seemed to be brittle as expected from the amorphous nature of polystyrene. Indeed the Container 2 has longer elongation at break value (0.30%) than that of Container 1 (0.18%).

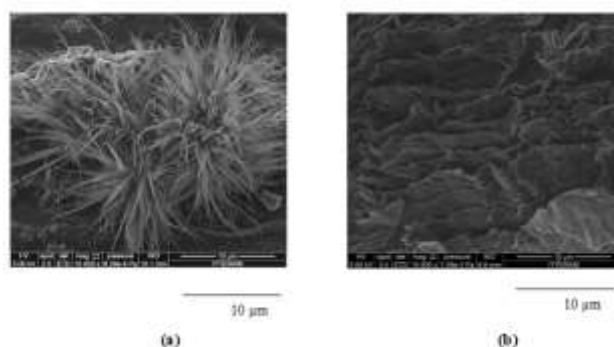


Figure 10. SEM micrograph of the fracture surfaces after tensile tests a. container 1, b. container 2 at 10 000x magnification

4. CONCLUSION

The two yogurt containers selected with plastic codes 5 (polypropylene) and 6(polystyrene) were characterized in the present study. FTIR spectra of the samples indicated the presence of polypropylene and calcium carbonate in container 1 and polystyrene in container 2. X ray diffraction diagram of container 1 indicated that it mainly consisted of alpha phase isotactic polypropylene with the evidence of characteristic well-known fingerprints at 2θ values of 14.2° , 17.1° , 18.7° , 21.2° , 22° , and 25.6° . In addition to this, it was demonstrated that calcite and rutile titanium oxide were used as fillers represented with the peaks at 29.4° and 27.6° respectively. Unlike container 1, container 2 was mainly formed by high impact polystyrene with a peak in a wide range of 14° and 24° , and calcite at 2θ 29.4° , olivine group (Mg_2SiO_4) at 2θ 28.5° , and also again rutile titanium dioxide at 2θ 27.4° were also present. The presence of particles in SEM micrographs of fracture surfaces confirmed the existence of additives, which could be titanium dioxide and calcium carbonate in the samples. The EDX analysis of the particles in crosssections indicated the presence of C, Ca, Ti, O in both samples and additionally presence of Mg element in container 2. The addition of TiO_2 was used in packaging materials as pigments in order to improve the appearance of the package and to provide some barrier to light. The containers did not transmit light but reflected all the visible light making them to appear as white colored. The surface roughness values of the front and back sides of container 1 were found as 8.12 nm and 7.17 nm respectively for $5\mu m$ scanning range. On the other hand, the surface roughness values of the front and back sides of Container 2 were found as 13.84 nm and 15.47 nm respectively for $5\mu m$ scanning range. From these values, it could be said that container 2's surface was rougher than that of container 1's. The melting point of container 1 was $166.4^\circ C$ and the glass transition point of container 2 was $99.9^\circ C$ confirming they were based on polypropylene and polystyrene. The container 1 which had 18.1% $CaCO_3$, 1.2% TiO_2 and container 2 which was based had 1.2% TiO_2 , $CaCO_3$ and olivine as indicated by TG analysis. The samples had close values of tensile strength and tensile modulus. The container 2 has longer elongation at break value (0.30%) than that of container 1 (0.18%). The presence of fillers made the containers had lower tensile strength and higher stiffness than their base polymers. The two yogurt containers were characterized in terms of the type of the polymers, the fillers, thermal properties such as the melting point or the glass transition point, the onset temperature of thermal degradation, surface roughness and

mechanical properties. This information could be used determining the future recycling methods for yogurt packing materials. The containers labeled 5 and 6 should be collected separately from the source since they will have different processes for reuse.

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BIOGRAPHIES

Gizem Cihanoğlu received her BSc degrees in Chemical Engineering in 2010 from Yıldız Technical University. She got her MS and PhD degrees from Izmir Institute of Technology in 2014 and 2021, respectively. She worked as a research assistant in Chemical Engineering at Izmir Institute of Technology between 2013 and 2021. Now, she is doing a postdoc in Ebil's group in Chemical Engineering at Izmir Institute of Technology. Her research interests are the synthesis of nanomaterials for zinc electrodes, the development of polymers for gas diffusion layers in gas diffusion electrodes for metal-air batteries, and the evaluation of electrochemical performance gas diffusion electrodes.

Merve Özpürin had her BS and MS degree in chemical engineering from İzmir Institute of Technology in 2014 and 2016 respectively. She is continuing her studies for PhD degree in chemical engineering in the same university. She worked as TÜBİTAK 1001 project assistant in 2014-2016 in the same department . Her research interests are production of thin film coatings by cold vapor deposition, development of protective coatings for electro-optical systems, production of polymeric coatings and sensory technologies.

İklîma Odabasi graduated from Bilecik Şeyh Edabali University as chemical and process engineering in 2013. She completed MS studies in 2017 in chemical engineering department of Izmir Institute of Technology. She worked as TÜBİTAK 1001 project assistant in 2014-2017 in the same department. She worked as process engineer in USCA winery in 2017-2019 and as process director since 2019. Her research areas are winemaking, viticulture, production style of winemaking, blending wine, filtration and stabilization for wine, tasting technique, the human factors in the winery that influence style, quality and price.

Devrim Balköse graduated from Middle East Technical University Chemical Engineering Department in 1969. She got her MS and PhD degrees from Ege University in 1974 and 1977 respectively. She worked as research assistant, assistant professor, associate professor and professor between 1970-2000 at Ege University. She was the head of Chemical Engineering Department at İzmir Institute of Technology between 2000 and 2009. She is a retired faculty member at the same department since 2013. Her research interests are in polymer reaction engineering, polymer foams and films, polymer additives and adsorbent development and adsorption