ANALYSIS OF THE THERMAL BEHAVIOR OF CERTAIN BABY TEATS

Andreea MIHAILĂ, Ana-Maria ALISTAR, Roxana FLOREA, Gabriela LISA*

Department of Chemical Engineering, Faculty of Chemical Engineering and Environmental Protection "Cristofor Simionescu", "Gheorghe Asachi" Tehnical University, Iasi, 73 Prof.dr.doc. Dimitrie Mangeron street, 700050 Iasi, Romania

Abstract

The research was aimed at characterizing through thermal analysis, in dynamic conditions, in different work atmospheres, different types of teats used for baby feeding. For this purpose, dynamic thermal analysis (TG and DTG) and differential scanning calorimetry (DSC) were applied. The results reveal a degradation that occurs in two or more stages and follows a complex mechanism, with different mass losses, depending on their structure and the atmosphere in which thermal decomposition was achieved. It is able to conclude that, under isothermal conditions in air, the three baby teats under survey can be maintained at constant temperature (120°C) for 20 minutes without loss of mass after thermal treatment. Differential scanning calorimetry allowed gathering information about the composition of the materials which the tested baby teats were made of.

Key words: TG, DTG, DSC, Thermal stability, Baby teats

1. Introduction

The analysis of the thermal behavior of different types of materials is extremely important both theoretically and practically. From a practical point of view, tests analyzing the thermal behavior of materials may provide information about the conditions in which they may be processed or used without an alteration of their properties [1]. From a theoretical viewpoint, these studies may lead to obtaining information about thermal degradation mechanisms under different conditions. The main advantages of thermal analysis methods are: small sample size (3-10 mg), a wide range of temperature variation programs that can be used, the samples under analysis can be in solid, liquid or gel state and relatively short experimental time.

* Corresponding author: E-mail address: gapreot@ch.tuiasi.ro or gapreot@yahoo.com, (Gabriela Lisa)

The thermal analysis of materials which different utensils used for baby feeding are made of is extremely important because there may be cases where the inappropriate use of these tools may jeopardize their health [2-4].

Teats used to feed babies are subjected to the sterilization process by which all or part of the microorganisms on or inside them are removed or destroyed. There are several methods used, among which sterilization by boiling is the oldest and most used method of sterilization. However, boiling uses teats faster than other methods of sterilization. The boiling method is very cost effective, but teats, which are made of silicone or latex, get damaged and need to be replaced much more often, because thermal decomposition may result in a series of compounds that are left on the surface of the teats and that may have an impact on the baby's health. Chemical sterilization is another method used for this purpose. This sterilization method is based on sinking the teats into sterilizing liquid. The duration of sterilization is recommended by the manufacturer, and the ready-to-use sterilizing liquid is sold in pharmacies. The advantages of this method are the relatively low price of these solutions and the ease of sterilization. Furthermore, this solution may be used for up to 24 hours, so the parent has permanent access to the ready-to-use bottle to sterilize teats. The drawbacks of this method are the sterilization time (about 30 minutes), the taste and smell that may linger on the sterilized objects and the need to rinse bottles with boiled water after they are removed from the sterilizing solution. Another procedure that may be used is steam sterilization. This method involves the use of an electric sterilizer or of a microwave sterilizer, but the process is the same: the use of hot steam to destroy bacteria. The electric bottle sterilizer contains a bowl in which water and teats are inserted. The process is very simple and convenient for parents, and sterilization takes place in just a few minutes. The teats thus sterilized last up to 3-6 hours, but there are longer-lasting appliances or appliances that sterilize the bottles automatically when stored in the device, providing a sterile environment for up to 24 hours. The main advantage is ease of use, but also short sterilization time, long shelf life and high capacity. They also have a lot of useful accessories such as special trays to place the teats or an alarm at the end of the program. The disadvantages of these sterilizers are their high price and low portability. The microwave bottle sterilizer is inserted into the microwave to sterilize the objects inside. It also uses steam sterilization and keeps the bottles sterile for up to 3 hours. The advantages are their low price, simplicity, ease of use and the fact that they are easy to transport and hence useful for trips. The disadvantages of these sterilizers are the reduced capacity, the necessity of a microwave oven and the risk of burning (the teats are very hot when they are removed from the appliance) [5].

In this paper we aimed at analyzing the thermal stability of different types of teats, in order to determine at what temperature they begin to decompose and at what temperature the degradation products may become harmful to the health of the baby. Thermogravimetric (TG) and derivative thermogravimetric (DTG) analysis of various types of teats used for infant feeding in this paper provides information on their thermal stability in both air and nitrogen, as some of the sterilization methods involve heating them. Differential calorimetry enabled us to obtain information on the composition of the materials which the tested teats were made of.

2. Experimental

Materials

The materials subjected to thermogravimetric analysis are 3 types of baby teats of different thicknesses, colors and materials, marked: B1, B2 and B3. The teat marked B3 is made of yellow-brown latex. B1 and B2 are teats made of transparent silicone.

Methods

Thermogravimetric (TG) and derivative thermogravimetric (DTG) analyses are the most popular methods applied by researchers to assess the thermal stability of different types of materials. The TG technique measures the variation of the weight of the sample depending on temperature when it is subjected to a temperature increase process at a controlled rate within a certain interval [6]. The graphical representation of sample mass variation with temperature increase is the thermogravimetric curve (TG). The curve obtained by graphical derivation of the TG curve is marked DTG. TG and DTG curves are used to determine the main thermogravimetric characteristics of each degradation stage: T_{onset} - initial temperature at which degradation begins at each stage; T_{peak} - the temperature corresponding to the maximum degradation rate; T_{endset}- final temperature in each stage and W - percentage loss of mass.

Differential scanning calorimetry is a thermal analysis technique that shows how the temperature changes material heat capacity. Also, differential scanning calorimetry (DSC) is a thermoanalytical method in which the difference in the amount of heat required to increase the temperature of a sample and reference is measured as a function of temperature. For this method both samples need to have same temperature. DSC is used to measure specific heat, heat capacity, melting temperature, reaction energy and temperature, heat of fusion, denaturization and oxidation temperature. DSC technique is defined by the measuring of the amount of energy absorbed or released by a sample when it is heated or cooled. The measurement provides qualitative and quantitative data on endothermic (heat absorption) and exothermic (heat evolution) processes. In this case the sample holder temperature increases linearly function of time. The reference sample should have a well-defined heat capacity over the range of the temperatures to be scanned. Results of DSC analyses are represented by DSC curves, the result of a DSC experiment. These curves are the representation of heat flux versus time or versus temperature. Using the DSC curves, one may determine the following characteristics specific to the tested samples: T_m – melting temperature, T_c – crystallization temperature and T_g – glass transition temperature.

Instruments

The thermal analysis was carried out using a Mettler Toledo TGA-SDTA851^e derivatograph in nitrogen and air atmosphere, at 20ml/min flow rate, 10°C /min (25-700°C) heating rate and samples weight ranging between 4-6 mg. The DSC curves were recorded by a Mettler Toledo DSC1 device in inert atmosphere, at 10°C /min heating rate. We performed scans within the -80 - 200ºC temperature interval, two heating processes and one cooling process, the weight of the tested samples ranging between 4.4 and 5.1 mg.

3. Results and discussions

Thermogravimetric Analysis

The DTG curves recorded in air for the teats marked B1, B2 and B3 are shown in Figure 1, and those recorded in inert atmosphere are shown in Figure 2.

Table 1 includes the main thermogravimetric characteristics of the tested samples: T_{onset}– initial temperature at which degradation begins at each stage; T_{peak} - the temperature corresponding to the maximum degradation rate; T_{endset}– final temperature in each stage and W - percentage loss of mass. It also shows the residue at a temperature of 700°C.

The analysis of the main thermogravimetric characteristics shown in Table 1 reveals that the degradation of the baby teat marked B3 occurs in two stages in both air and nitrogen. The residual amounts obtained in this sample in the two working atmospheres are less than 3%. In the case of the teat marked B2, five stages of degradation in air and two stages in nitrogen are distinguished, and the amount of residue is 56% in air and 50% in nitrogen. The teat marked B1 also has a complex degradation mechanism, consisting of four decomposition stages when the working atmosphere is air, and three stages in nitrogen. In this case, in both working atmospheres, the highest residual amounts were obtained, thus proving a very good thermal resistance.

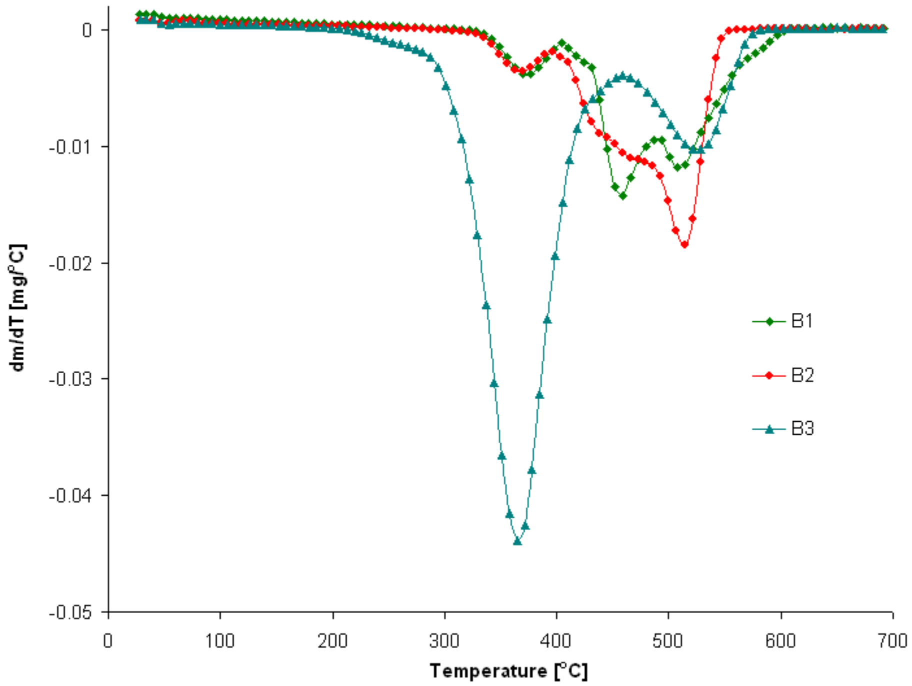

Fig. 1. DTG curves of the three baby teats recorded in air

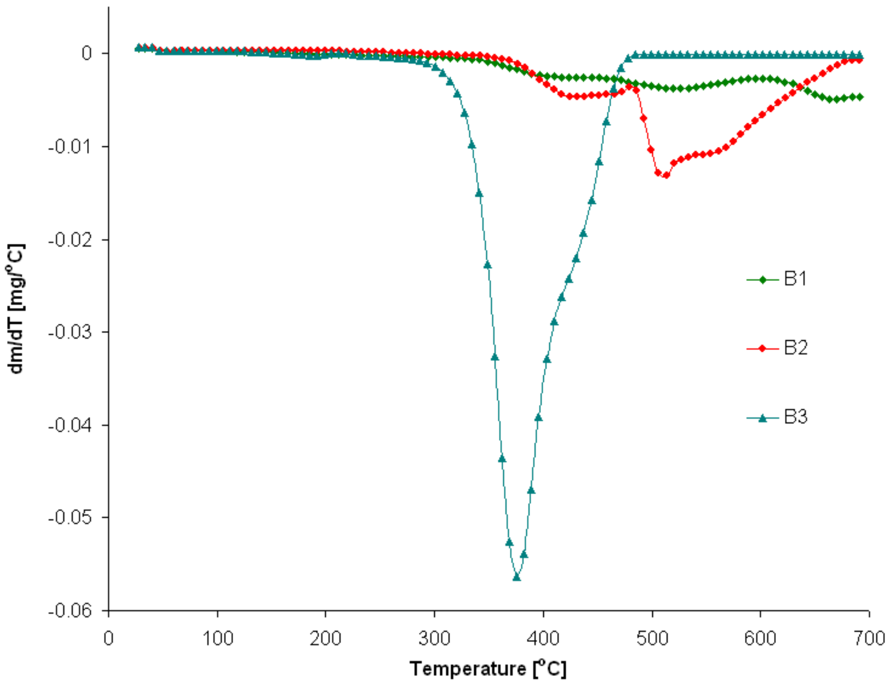

Fig. 2. DTG curves of the three baby teats recorded in nitrogen

Table 1

Thermogravimetric data

Sample	The working atmosphere	Stage of thermal degradation	T_{onset} (°C)	T_{peak} (°C)	T_{endset} (°C)	W (%)	Residue (%)
B1	air	I	354	373	401	4.11	64.08
		II	419	-	446	2.06	
		III	446	458	478	13.34	
		IV	497	509	588	16.41	
B2	air	I	349	367	393	4.78	56.20
		II	409	413	424	1.50	
		III	424	-	452	7.58	
		IV	452	465	493	12.35	
		V	493	514	535	17.59	
B3	air	I	309	366	408	78.01	2.72
		II	493	530	555	19.27	
B1	nitrogen	I	366	413	483	7.08	77.34
		II	483	522	563	7.85	
		III	644	666	-	7.73	
B2	nitrogen	I	387	429	486	1212	50.43
		II	498	506	659	37.45	
B3	nitrogen	I	339	376	394	62.39	2.33
		II	394	428	454	35.28	

When the degradation onset temperature in the first stage is considered to be a thermal stability criterion, the following thermal stability series are obtained:

-in air: **B3 < B2 < B1**

-in nitrogen: **B3 < B1 < B2**

The thermal resistance, under isothermal conditions, of the three baby teats was tested with a Mettler Toledo derivatograph, in air, by keeping them at constant temperature (120°C) for 20 minutes. There was no mass loss due to heat treatment in any of the samples.

Differential scanning calorimetry

Differential scanning calorimetry studies were performed to determine phase transitions. For the three types of baby teats, DSC curves (two heating and cooling cycles) were recorded in the temperature range -80 - 200°C. Taking into account the fact that the first heating cycle is influenced by the history of the sample, figure 3 comparatively shows the curves corresponding to the three teats for the second heating cycle. For the sample marked B3, Figure 3 also shows a detail with the variation of the heat flow within the 10 - 70°C range, in order to highlight the existence of the glass transition temperature at 34°C.

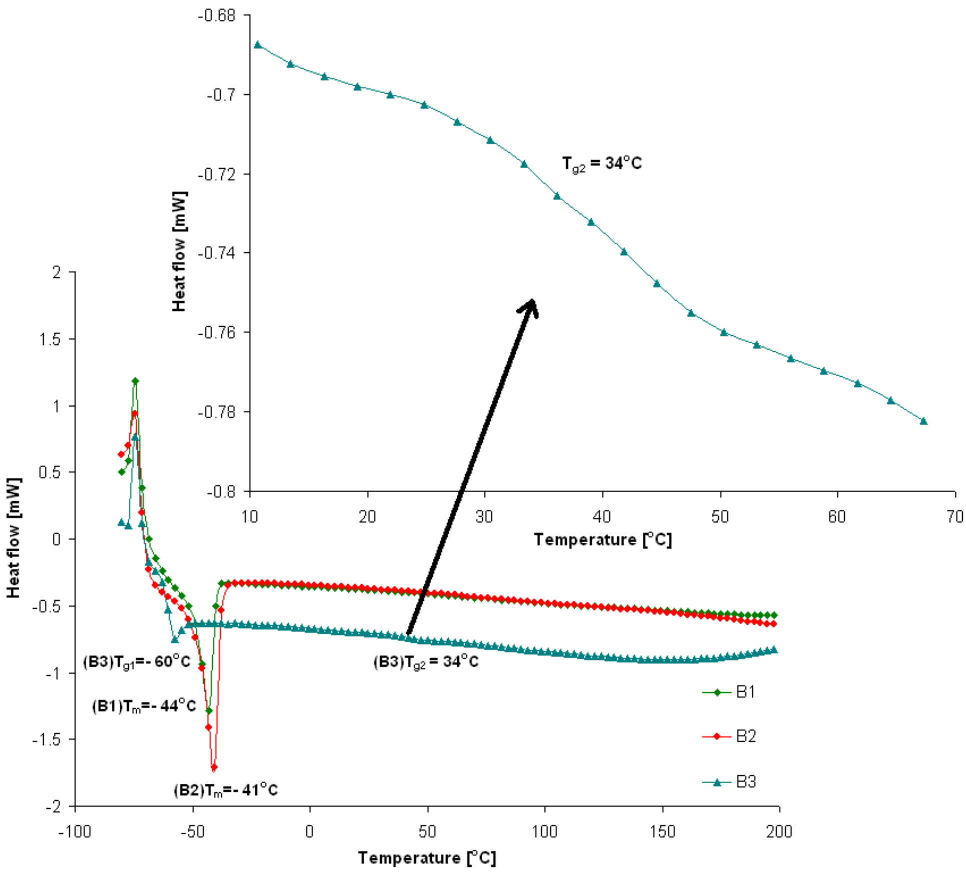

Fig. 3. DSC curves for B1, B2 and B3 for the second heating cycle

By analyzing the melting (T_m) and glass transition (T_g) temperatures, one may gather information about the components found in the structure of the materials which the baby teats are made of. For the teats B1 and B2, made of silicone rubber, according to the DSC curves shown in Figure 3, we identified T_m=-41°C for sample B2 and T_m=-44°C for sample B1. According to literature [7-12], these melting temperature values confirm the presence of polydimethylsiloxane in these samples. For sample B3 made of latex, we see in Figure 3 the existence of two glass transition temperatures T_{g1}=-60°C and T_{g2}=34°C. The analysis of literature [7] indicates the presence in this sample of butadiene-styrene rubber (T_g=-59.61°C) and possibly of 2-tert-butylaminoethyl methacrylate (T_g=33°C).

4. Conclusions

The research enabled us to collect information about the thermal stability of different types of baby teats in both air and inert atmosphere.

The thermal resistance, in isothermal conditions, of the three baby teats was tested using a Mettler Toledo derivatograph, in air, for 20 minutes. No mass losses were recorded in any of the samples, when they were kept at constant temperature (120°C).

Differential scanning calorimetry allowed the gathering of information about the composition of materials which the baby teats are made of.

REFERENCES

[1] Lisa G., Yoshitake Y., Michinobu T., Thermal degradation of some ferrocene-containing poly(aryleneethynylene)s, *Journal of Analytical and Applied Pyrolysis*, 120, (2016), 399–408.

[2] Lund K.H., Petersen J.H., Safety of food contact silicone rubber: Liberation of volatile compounds from soother and teats, *European food research and technology*, 214, (2002), 429-434.

[3] Bouma, K., Nab FM., Schothorst R.C., Migration of N-nitrosamines, N-nitrosatable substances and 2-mercaptobenzthiazol from baby bottle teats and soothers: a Dutch retail survey, *Food Additives and Contaminants*, 20(9), (2003), 853-858.

[4] Conn RE, Kolstad JJ, Borzelleca JF, Dixler DS, Filer LJ, LaDu BN, Pariza MW. Safety assessment of polylactide (PLA) for use as a food-contact polymer, *Food and Chemical Toxicology*, 33(4), (1994), 273-283.

[5] Renfrew M. J., McLoughlin M., McFadden A., Cleaning and sterilisation of infant feeding equipment: a systematic review, *Public Health Nutrition*, 11(11), (2008), 1188–1199.

[6] Mihailă A., Gherghel A., Pătrăuţanu O. A., Amariei M., Lisa G., Thermal Analysis of Human Hair in Non-Isothermal and Isothermal Conditions, *Annals of the Academy of Romanian Scientists Series on Physics and Chemistry Sciences*, 2(2), (2017), 33-42.

[7] De P.P., Choudhury N. R., Dutta N.K., *Thermal Analysis of Rubbers and Rubbery Materials*, Smithers Rapra Technology Ltd., United Kingdom 2010.

[8] Roland C. M., Aronson C. A., Crystallization of polydimethylsiloxane end-linked networks, *Polymer Bulletin*, 45(4-5), (2000), 439–445.

[9] Aranguren M. I., Crystallization of polydimethylsiloxane: effect of silica filler and curing, *Polymer*, 39(20), (1998), 4897-4903.

[10] De Jaeger R., Gleria M., *Inorganic Polymers, Chapter 2. Silicones in Industrial Applications*, Nova Science Publishers, 61-161, 2007.

[11] Choudhury N.R., De P.P., Dutta N.K., *Thermal Analysis of Rubbers and Rubbery Materials,* Smithers Rapra Technology, iSmithers 2010.

[12] Chavan S.N, Mandal D., Combined effect of ether and siloxane substituents on imidazolium ionic liquids, *RSC Advances*, 5(80), (2015), 64821-64831.