INVESTIGATION ON THE INFLUENCE OF THE TEMPERATURE ON THE RESISTANCE OF PET-BOTTLES TO PRESSURE

***Angelov Kalojan, Mihaylov Ivan**

University for Food Technologies – Plovdiv, Bulgaria

***Angelov Kalojan, kaloangelov@gmail.com**

Abstract: The storage and transportation of filled PET-bottles in packing (pallets) is an important stage in brewing. There are a variety of PET-bottles regarding to their capacity and design. In this article it is performed an investigation on bottles with three different capacity sizes. The obtained dependences provide opportunities for optimization in relation to material consumption and geometric parameters of PET-bottles.
Key words: PET-bottles, storage of PET-bottles, resistance to pressure

Introduction:

In recent decades, bottles made from PET (Polyethylene terephthalate) found exclusively wide application. They are sed for packaging of various products in the food industry, chemical industry, and pharmaceuticals. The main factor underpinning the massive use of PET - bottles are their advantages over other types of packaging: lightness, unbreakability, cleanliness, flexibility of design, recyclability and economical production. For example, a glass bottle holding 750 ml has mass of 350g to 600g, and its analogue made of PET has a mass of 50 g, i.e. PET – bottle is 7 to 12 times lighter than glass bottle with the same capacity. The unbreakability of PET - bottles greatly increases safety, both in production (filling, closing) and during transportation. It also increases security and safety in the commercial and retail stores [1,3,4].

Exposition:

The subject of this article are PET bottles used in brewing. According to the Union of Brewers, currently 37 % of beer is sold in PET bottles, 54 % in glass bottles, 2 % in cans and 7 % bulk. The trend is towards increasing the share of PET bottles at the expense of glass. The capacity of the used for bottling beer PET-bottles is from 0.5l to 2.5l, as predominant share have these holding 2l and 2.5l.

One of the main trends in contemporary production of PET-bottles is their lightening. There is a desire to reduce the material input to produce one bottle. For example, the average weight of a PET-bottle with a capacity of 1.5l in recent years has decreased from 46.7g to 40.2g, which is lighter by about 14%. Lightening is achieved by thinning and change of the size and shape of certain parts of the bottle as a major focus is on filler because there the thickness is greatest. As a result of the lightening it is achieved significant savings of material and energy. Meanwhile, the lightened PET bottle has some disadvantages, related with its resistance to tolerate stress [2,5].

In brewing for bottling in PET-bottles are kept in stock palletized bottles. Pallets as a transport packaging group was made because that is suitable for mechanized loading and unloading activities, convenient transportation, etc. In each pallet bottles are stacked in

layers (usually separated by cardboard panels) as the number of layers depends on the height (volume) of the bottles and the pallet is wrapped in shrink film. Number of layers can reach tens of bottles at a lower height of the bottle. This means that the lower layers of bottles are under considerable pressure due to the weight of the upper layers. Due to this pressure bottles of lower layers of the pallet are sometimes deformed. This deformation is most often expressed in unilateral pitting on the neck of the bottle and as a result, the pallet loses its right geometric shape (parallelepiped) and strongly inclines and often spills. The slanting pallet leans and often wedges at the adjacent pallets. This greatly hampers loading and transport operations and often leads to deterioration of the appearance of the bottles.

The ability of a PET-bottle to suffer downward pressure without deformation (compressive strength) depends mainly on two factors:

1. Compressive strength of the empty bottle;
2. Stabilizing action of internal pressure of bottled beer.

As a result of the pursuit for lightening the modern PET-bottles, it is reduced their resistance to pressure. In consequence of this it is growing the influence of the internal pressure on the sustainability of the bottle.

The internal pressure in a full beer bottle on its turn is not constant. It depends on many factors, but the strongest influence is the temperature of beer in the bottle.

It is known from physics that the solubility of gases in liquids decreases with increasing of temperature. This means that at elevated temperature internal pressure in the bottle will increase, and with decrease of temperature will decrease. Therefore, the increased temperature should increase the compressive strength of the bottle and the decreased temperature accordingly to reduce its resistance.

In order to establish how accurately the change in temperature affects the stability of the pressure of a full beer PET-bottle an experimental study was conducted.

Experiments were performed with three different volume sizes of PET-bottles of beer: 0,5; 1 and 2 liters, with each frame size there were three series of experiments. Each series consists of 10 pieces of bottles, pre-tempered, as shown in Table. 1.

Table 1

Standard size / Series	0,5 liters	1 liter	2 liters
I	8,4 °C	8,4 °C	8,4 °C
II	20°C	20°C	20°C
III	35°C	35°C	35°C

The selected temperatures are consistent with those in storage in brewing, which are mostly in the range 8 ÷ 35 °C.

The tempered bottles of each series were subjected to downward pressure and it was recorded the power at which they warp (soften).

The obtained resulting averages are presented in tabular form. In Fig. 1 it is shown the stability of pressure at different temperatures of a bottle holding 0.5 liters, and in Fig. 2 and Fig. 3 are shown the compressive strengths at various temperatures of bottles with capacity of 1 liter and 2 liters.

Assuming a "normal" temperature of 20°C are calculated as a percentage increase or a reduction of compressive strength of each of the three bottles in sizes depending on temperature. The results are presented in Table 2.

Table 2

Compressive strength versus "normal" temperature 20°C		
Dimensions of the PET-bottle	Temperature	
	8,4 °C	35°C
0,5 liters	Reduction with 6,4%	Increase in 9,1%
1 liter	Reduction with 4,4%	Increase in 4,1%
2 liters	Reduction with 20,8%	Increase in 6,3%

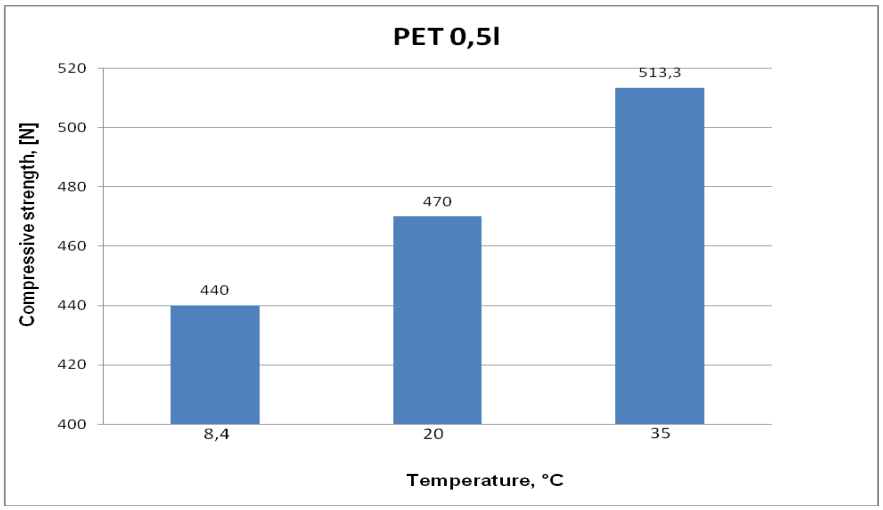

Fig. 1. Compressive strength of a 0,5 liters PET-bottle as a function of the temperature.

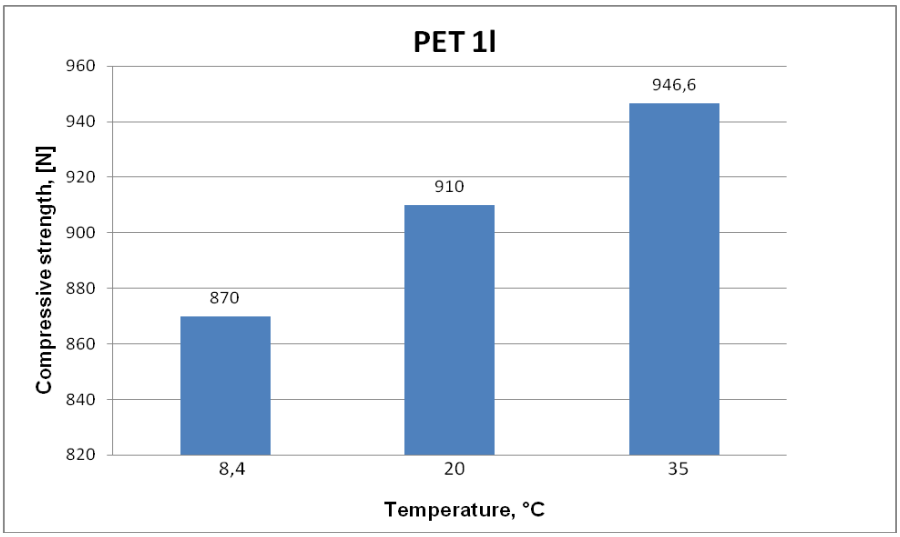

Fig. 2. Compressive strength of a 1 liter PET-bottle as a function of the temperature.

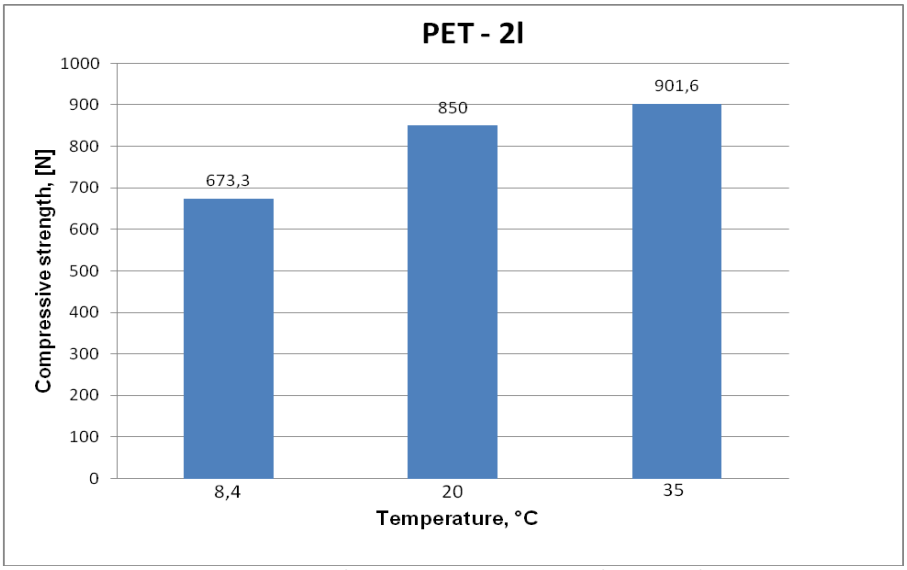

Fig. 3. Compressive strength of a 2 liters PET-bottle as a function of the temperature.

The analysis of the values of the relative change of resistance of pressure with the three sizes of PET-bottles to room temperature (20 °C) presented in Table 2 reveals:

1. When lowering the temperature of the bottled beer it is reduced the resistance to pressure. Upon reaching a temperature of 8,4 °C, the relative resistance decreases with 4,4 ÷ 20,8%, as the highest value (20,8%) is observed in PET-bottles of 2 liters.

2. When increasing the temperature of the bottled beer it is observed inverse relation – the compressive strength increases. The increase is in the range 6,3 ÷ 9,1%, as the minimum value is observed in bottles of 2 liters.

Conclusion:

1. It is determined experimentally the resistance of pressure of full beer PET-bottles.
2. It is defined the relative change of resistance of pressure of the bottles to temperature of 20 °C.
3. Graphic relationships are built on the resistance of pressure depending on the temperature of beer.

Literature:

[1] Sazdov, Ch.: Loads of packaging for food liquids from PET for carbonated products throughout their life cycle. *Magazine "Food Processing Industry"*, issue 11, 2011, pp. 41-44, (in Bulgarian)

[2] Sazdov, Ch.; Stefanov, S.: Testing of preforms and bottles for food liquids from PET. *Scientific conference with international participation "Food Science and Technology 2009"*, Plovdiv, 2009, Scientific Works of UFT, Volume LVI, part 2, pp. 307-312, (in Bulgarian)

[3] Stefanov, S.; Hristov, H.; Kostov, G.; Stefanova, I.; Sazdov, Ch.; Arabadjieva, N. & Stoeva, D.: Storage of packaged food products in modified atmosphere. *Scientific*

Works of Ruse University "Angel Kanchev", Chemical technology, biotechnology and food technologies, Volume 48, series 9, ISSN 1311-3321, pp. 125-129, (in Bulgarian)

[4] Stefanov, S.; Kostov, G.; Stefanova, I; Hristov, H.; Sazdov, Ch.; Arabadjieva, N. & Stoeva, D.: Opportunities for increasing the shelf life of certain food products by the application of active packaging. *Scientific Works of Ruse University "Angel Kanchev", Chemical technology, biotechnology and food technologies*, Volume 48, series 9, ISSN 1311-3321, pp. 154-159, (in Bulgarian)

[5] Ward, P. Next steps in PET bottle lightweighting, WRAP, 2007