GSICA
THE ITALIAN SCIENTIFIC GROUP
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The Korean Society of Food
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SLIM 2012
SHELF LIFE INTERNATIONAL MEETING

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Shelf-life International Meeting

Changwon, May 30 - June 1 2012

Edited by

Dong Sun Lee & Gi Hyung Ryu

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In cooperation with

KFN

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STRESS-CRACKING OF PET BOTTLE AS AN UNPREDICTABLE FACTOR LIMITING THE COMMERCIAL LIFE OF CARBONATED SOFT DRINKS

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ABSTRACT

The shelf life of carbonated beverages mainly depends on the carbon dioxide retention performances of the PET bottle, however the commercial life of such products can be compromised by ruptures and crackings of the material, which can occur in certain conditions. The so-called "stress cracking" of PET bottles occurs in correspondence with the injection point, which is more susceptible due to its amorphous nature, unlike the sides of the bottles, whose strength is a result of a certain degree of orientation. Stress cracking can be a consequence of various factors, which usually act in combination and are difficult to isolate: excessive internal pressure (excess carbonation), material distribution, altered intrinsic viscosity, exposure to UV rays and/or high temperatures, but most important is the contact with caustic substances (for example, the lubricant of the conveyors belts), etc. The present contribution focuses on a case study occurred at SIBEG s.r.l., concerning the non conformity of 1.5 L PET bottles of a popular carbonated soft drink, which caused the loss of an important amount of bottles, the disposal of defective products, and the careful inspection and selection of in-house stocks. Inspections revealed no failure in the blowing process, leading to hypothesize over-carbonation and transport conditions as the triggering events. Moreover, the analysis of intrinsic viscosity (IV) of bottles and preforms revealed the non-conformity with specification. Despite the product conformity concerning thermal stability, burst test and stress cracking test performed in alkaline conditions, PET bottles quality and performances may become altered if the IV of the material does not fulfill specifications. There-

fore, the IV determination plays a key role, complementary with other routine determinations, in the quality control of PET bottles addressed to carbonated soft drinks packaging. The use of such tool is fundamental for the prevention of severe problems which might occur along the distribution chain, such as claims, withdrawal and disposal of defective products.

Key words: Environmental stress-cracking (ESC), intrinsic viscosity (IV), over-carbonation, quality control, PET.

INTRODUCTION

The shelf life of carbonated beverages mainly depends on the CO_2 retention performances of the PET bottle. CO_2 starts decreasing just after bottling due to permeation through the packaging material, hence it is clear how the improvement of the PET bottle performance represents a competitive tool for the carbonated soft drinks industries and a means to guarantee the consumers with the original characteristics and quality (Coriolani *et al.*, 2007; Licciardello *et al.*, 2011). However, the quality of PET bottles is not only related with an adequate barrier to CO_2. Indeed, the commercial life of such products can be compromised by ruptures and crackings of the material occurring in certain conditions. The so-called "Environmental Stress Cracking" (ESC) of PET bottles is responsible for about 15% of the overall problems concerning packaging materials for carbonated beverages (Demirel and Daver, 2009). ESC occurs in correspondence with the injection point, which is more susceptible due to its amorphous nature, unlike the sides of the bottles, whose strength is a result of a certain degree of orientation. The problem of ESC appeared in the carbonated soft drink world with the introduction of "one piece" (or "stand-alone") bottles, typically with a petaloid base.

ESC can be a consequence of various factors, which usually act in combination and are difficult to isolate: excess carbonation, material distribution, altered intrinsic viscosity, exposure to UV rays and/or high temperatures, contact with caustic substances (for example, the lubricant of the conveyors belts), etc.

The present contribution focuses on a case study occurred at SIBEG s.r.l., concerning the non conformity of 1.5 L PET bottles of a popular carbonated soft drink, which caused the loss of an important amount of bottles, the disposal of defective products, and the careful inspection and selection of in-house stocks. The conventional determination performed on preforms and bottles could not be put in relation with the phenomenon, hence further investigations were carried out, with special regards for the intrinsic viscosity (IV) determination.

MATERIALS AND METHODS

Sibeg s.r.l routinely performs analyses on the preforms (*incoming inspection*), while other tests on bottles are performed at every change (design, volume etc.) of the package in order to verify the correspondence to standard specifications. The following tests were carried out on bottles in order to very their compliance with specifications given by The Coca-Cola Company: visual inspection; burst

test; thermal stability; stress cracking. All analyses were performed according to Guidelines by The Coca-Cola Company (Packaging Authorization for Non-Refillable Plastic Bottles).

In addition, the intrinsic viscosity (IV) of PET preforms was evaluated according to the standard method ASTM D 4603, with a phenol/tetrachloroethane solution (60/40 v/v) at 30°C.

RESULTS

The burst test performed on 12 bottles revealed the perfect conformity with standards, as the minimum and average values obtained were 11.59 and 12.52 bar, respectively, compared with 6.8 and 8.6 bar, which is the standard requirement. All of the 12 bottles sampled for visual inspection complied with requirements.

The stress cracking test carried out on twenty-four, 1.5-litre bottles coming from 2 different blowing lines, and on eight, 0.5-litre bottles, did not evidence content losses or bursts before 10 minutes, which is the minimum threshold. Smaller bottles recorded the lowest times, with minimum 11 min and average 12.5 min, while 1.5-litre bottles scored minimum 13 min (1 sample out of 24) and an average value of 16.8 min, which is far more than the specified standard.

Samples belonging to the batch where bottle crackings occurred, complied with requirements, as far as burst and stress cracking tests and visual inspection were concerned. Basing on the above tests, the occurring crackings to bottles could not be explained. For this reason further analyses were considered necessary. Intrinsic viscosity determination was carried out on preforms which produced defective and regular bottles, respectively. The IV test revealed the non-conformity for the first batch (Fig. 1), while the regular batch fell in the tolerance range for this parameter.

Further IV analyses were performed on three different preforms and on the corresponding bottles in order to select the most suitable products which could guarantee the company from future ESC episodes. Fig. 2 shows that the blowing process does not substantially alter the IV of preforms, but highlights significant differences in IV among different preform batches.

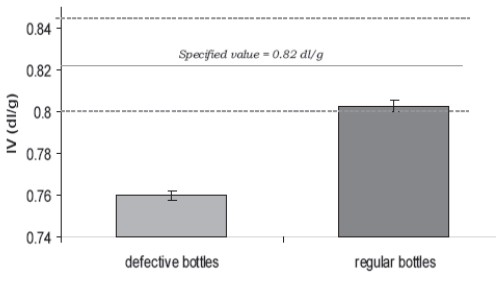

Fig. 1 - Intrinsic viscosity (IV) measured in bottles from a defective and regular batch.

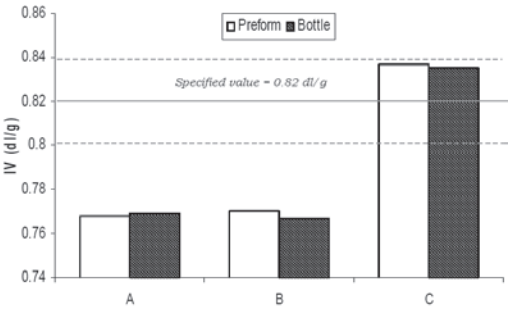

Fig. 2 - Intrinsic viscosity (IV) of preforms and bottles from different suppliers.

CONCLUSIONS

Stress cracking does not occur in normal conditions, but over-carbonation and extreme transport conditions might represent triggering events. Despite the product conformity concerning thermal stability, burst test and stress cracking test performed in alkaline conditions, PET bottles quality and performances may result altered if the intrinsic viscosity of the material does not fulfil specifications. The intrinsic viscosity determination plays a key role, complementary with other routine determinations, in the quality control of PET bottles addressed to carbonated soft drinks packaging. The use of such tool is fundamental for the prevention of severe problems which might occur along the distribution chain, such as claims, withdrawal and disposal of defective products.

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