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Openability of soft drinks PET packagings

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Abstract. Studies on packaging accessibility are still incipient in Brazil. Many of these packagings can represent a challenge to users, whether due to non-informative labels, tricky tabs or seals, or even those that need strength to open. This paper brings a simple test to determine the necessary torque force to open PET bottles, and to predict the amount of users that could not open it. The findings suggest that a considerable amount of users could not open it or would have some difficulties to exert the necessary force.

Keywords: design, openability, usability, soft drinks, packaging.

1. Introduction

Packagings exist since ancient times to protect or preserve food and others goods. However, it is in recent times that news materials and processes revealed new possibilities and new appeals. Thus, the implementation of new materials in packaging production provided significant improvements to storage conditions, transportation and even other attributes, such as the "packaging that sells the product". In this aspect, the polymers had a huge impact by taking place of metals or glasses, either because their mechanical properties or a greater freedom of design, which make products more attractive.

As many others Daily Life objects, packagings should provide to human beings more safety and comfort. Most of them are meant to be handled and sometimes, opened by hands. But several packagings are hard to handle or to open, impairing usability and challenging users to access the product they paid for. Several studies indicate that, despite the recent changes from manufacturing aspects towards user centered design; the packaging became more difficult to open in the last ten years [3].

Hand interface design, such as packaging design, depends on knowledge related to ergonomic and biomechanical forces involved in handling objects for different subject groups, like age and gender related groups.

1.1. Ergonomic design in packagings

Ergonomic design aims to evaluate and to propose design parameters that could improve the usability and accessibility of products. To do that, interface evaluations are usually made for collecting biomechanical and perceptive data, considering the abilities and limits of the users to generate design parameters. Nowadays, besides work tools, there is a great demand for Daily Living Activities (DLA) and the products that take places at user's home of the, including packagings.

Packagings of common goods with interface problems can potentially lead to injuries, although difficulties or inadequate opening occurs much more frequently. Most people prefer opening mechanisms that do not require the use of any kind of gadget [13]. These mechanisms should allow access to the product without the use of knives, scissors or other instruments.

Besides troubles to find instructions for opening procedures, or even finding tabs or seals to break, there are much more consolidated problems that have received a little or no treatment, particularly the vacuum jar packaging [3]. For these types of packages users have full knowledge of the opening procedure, but they are often unable to open it simply because they cannot apply the necessary forces.

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Assessments on the maximum torque forces in packagings are scarce. A few studies have assessed the necessary torque forces to open jars and its implications to gender and age related groups [2-4, 10]. In an evaluation of vacuum jars of 75mm in diameter, 235 individuals have participated (97 women and 138 men) of various ages [3]. The results indicate that the average strength of women over 75 years old was lower than necessary to open the jar. The authors also estimate that about 40% of women aged 25 years old would have difficulties to open that packaging, as well as 10% of men over 75 years old.

Another study had a purpose of assessing manual torque forces of infants to open chlorine bleaches packaging [9]. That study discussed the importance of biomechanical aspects on packaging design, since those individuals **should not access** the product, for safety reasons. Hence, 104 subjects (2-5 years old) of both genders have participated in an experiment with three instrumented bottles. The packagings were distinct in shape, and their respective lids had different sizes.

The results indicated a strong influence of lid size in subjects torque exertion. Thus, the lid with the smallest diameter has been recommended to **prevent** such individuals from accessing the product in a real situation. The author also points out that, because it is a common situation for many DLA, the parameters obtained can help to improve the usability and safety of other designs.

1.2. Soft Drinks bottles

The soft drinks bottles are among the most commonly packages used in DLA. Soft drinks are non-alcoholic beverages that are flavored, acidified, colored and carbonated artificially. They are usually composed of concentrated syrup, aspartame, caffeine and preservative agents, like benzoic acid or its derivatives, which are mixed together with artificially carbonated water (added CO_2) and then bottled [6].

Its origins date back to ancient times in Greece and Rome, where it occurred naturally in the form of mineral water. It was known for its medicinal properties and refreshing. In 1767, the British chemist Joseph Priestley discovered that water could be artificially carbonated, and from this knowledge came the industry of carbonated beverage [7].

This type of beverage is widely consumed nowadays, commonly bottled in PET (Polyethylene Terephthalate) bottles. In 2004, Brazil was the third largest consumer of PET resin for bottle production [12]. The PET resin for packaging has been mainly used for carbonated beverages (60%), soy oil (24%) and mineral water (6%) [1].

Some advantages of PET bottles are: their supposed ease of opening; the possibility of repointing; bursts resistance and absence of shrapnel; the possibility of using different sizes and smaller space on the shelves (10% lower than the corresponding in glass) [5].

In 2006, according to data supplied by the Brazilian Manufacturers Association of Soft Drinks - AFREBRAS, Brazil was the third market of soft drinks worldwide. In 2005, 12.42 billion liters were consumed, a total consumption of 67 liters per capita. Thus, it is only behind the United States (198 liters per capita) and Mexico (147 liters per capita) [11]. However, studies involving usability and accessibility of such products are still incipient.

1.3. Strength data

As mentioned before, assessments on the maximum torque forces in packagings are rare, but general data tables can provide a guide to predict and highlight issues related to opening forces. Hence, data tables as those provided by Peebles and Norris [8], who conducted a broad survey with several types of handles and different tasks, might be helpful.

That study includes torque tasks with corrugated and smooth cylinders (45, 65 and 85 mm of diameter). The maximum torque of the preferred hand was evaluated in 144 subjects ageing from 2 – 90 years old. The subjects adopted a free posture and exerted their forces for about 5 seconds in each aluminum jar.

A study involving different cylinders diameters (25, 30, 35, 40, 45 and 50 mm) and two handle orientations (vertical or horizontal) was also conducted by Kong and Lowe [14]. Twenty-four young subjects (26.6 ± 4.24 years) of both genders have participated in a set of maximum voluntary torque tasks. The results showed that, in general, the maximum torque increased as the handle diameter increased for both handle orientations. There were no differences between males and females subjects.

In order to compare data from biomechanical analysis and the necessary forces to open a packaging, some tests could be done, such as those done to determine the necessary force to open of a vacuum jar [2]. For that purpose a rig (Figure 1) was developed by Yoxall and Janson [2], which consisted in a base with a torque sensor, where a jar was coupled, and the opening was performed.

Figure 1. Rig to assess the vacuum jar opening torque [2, p.141].

That study obtained reasonable expectations about the accessibility of vacuum jars by people from different genders and ages. Hence, this approach can be applied to others packagings, like PET bottles. The aim of this study is to evaluate the moment of force necessary to open soft drinks PET bottles, and to compare the values obtained with biomechanical data from different age groups and both genders. At the moment, another study that has evaluated torque forces in soft drinks packaging is unknown.

2. Methods

2.1. Apparatus and procedures

The materials used in this study were:

- 48 PET bottles of several brands, flavors and capacities (ranging from 2L to 3,3L) available in local stores (Bauru – SP – Brazil);

Figure 2. Different PET bottles used in the study.

- Static Torque Transducer (STT – Mecmesin Ltd. – Figure 3);

Figure 3. Static Torque Transducer (Mecmesin Ltd.).

- Advanced Force Gauge (AFG 500 – Mecmesin Ltd. – Figure 4);

Figure 4. Advanced Force Gauge (AFG500 – Mecmesin Ltd.)

- Infrared thermometer (model DT320 - range -50 – 320ºC, accuracy 0.1ºC – Figure 5);

Figure 5. Infrared thermometer with laser pointer (model DT320).

- A rig made of stainless steel. The structure consists in a circular plate which has two rods with

tabs that hold the bottle in the center of the plate. The base of the structure was attached to the STT, which was connected to the AFG500, used to display the exerted torque force needed to open the packaging (Figure 6).

Figure 6. Apparatus to evaluate opening forces of PET bottles.

Each model was refrigerated to a temperature near 10ºC (mean 10.42ºC and s.d. 0.75ºC). A measurement area of 30 X 30 mm was covered with electrical black tape and the temperature was assessed by the IR thermometer at a 50 mm distance. After the temperature measurement, each bottle was fixed to the base and opened as usual (manually). The value for moment of force was recorded in N.m. for all the 48 PET bottles.

2.2. Data analysis

The data from the test was tabulated in electronic spreadsheets, and then basics statistics were applied to obtain mean and standard deviation values. A one-sample *t-Test* was applied for differences among the bottles, despite their capacity, flavor or vendor. Additionally, correlations among that aspects and the opening force were evaluated.

The tables of Peebles and Norris [8] were used for data comparison; specifically the 45 mm jar with corrugated lid, which represents the closest settings to a PET bottle lid. The data of Kong and Lowe [14], from the 30 mm cylinder in vertical orientation, was also used.

The values from the tables were inserted in Probability Calculator of *Statistica 8* software (StatSoft, Inc.). Hence, assuming the data fit a normal distribution; all the mean subject's forces, standard deviations and opening force were inserted, so the software could create the graphics and compute the probabilities.

3. Results

The average opening moment for all 48 PET bottles was 1.37 N.m. (s.d. 0.25 N.m.). Additionally, there were no correlations among force-capacity, brand, or flavor on the products evaluated. The moment of force required to open the packages seem to be more related to the internal pressure of the liquid and the closure system (similar in all bottles).

When that value is compared to the maximum forces data collected by Peebles and Norris [8], most of subjects groups show no considerable amount of individuals below the necessary force. This is true for both females and males which age lies between 11-20 years old (0.62% and 1.08% respectively); and males of 21-60 (0.38%) and 61-90 years old (0.18%). Nevertheless, it can be expected that 2.8% of women in 21-60 group have difficulties to open the bottles (Figure 7).

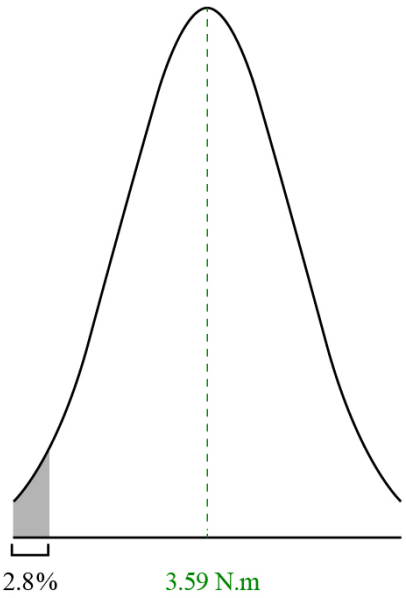

Figure 7. Mean subject's force and percentage of subjects that would have difficulties to open a PET bottle (females 21-60 years old).

On the other hand, the strength of females over 61 is 1.21 N.m lower than the previous one, which might create some difficulties for them. In this sense, 5.45 % of women older than 61 years old would not be able to open a bottle (Figure 8).

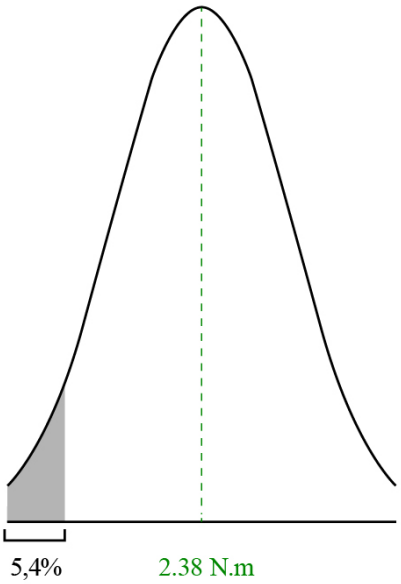

Figure 8. Mean subject's force and percentage of subjects that would have difficulties to open a PET bottle (females 61-90 years old).

Nevertheless, for the study of Kong and Lowe [14], and the data for the 30 mm diameter cylinder, approximately 18% of participants in that study (both genders) would not be able to open these packagings. It is noteworthy that this study evaluated a cylinder with a diameter close to the bottle caps (31 mm on average), but they used a smooth cylinder, while the first presents the data on a knurled one.

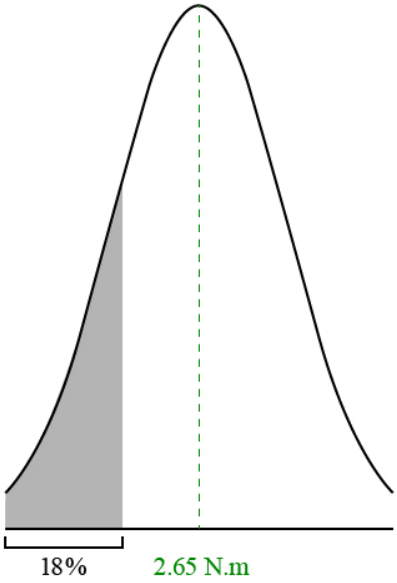

Figure 9. Mean subject's force and percentage of subjects that would have difficulties to open a bottle (around 26 years, both genders).

4. Discussion

The test results showed no differences among the several types of bottles, their capacity, brand or flavor. Hence, the moment of force seems to be more related to the closure of the product, since most of them are similar. It must be added that all products were cooled to a temperature near 10°C, which contributes to dissolve the gas and lower the internal pressure. Besides this aspect, the 1.37 N.m force necessary to open the product could represent a challenge to several users.

The data analysis shows that a considerable amount of individuals might have some difficulties to open soft drinks PET bottles. On the first data source compared [8], the percentage of users is relatively low, and within the female subjects. The issue becomes clearer in the female elderly group, which presents almost twice as many individuals below the necessary force to open a typical PET bottle.

The second data source is more restrict [14]. There are only young subjects and, since the authors couldn't find differences between genders, the data were mixed together. Still, the analysis shows about 18% of individuals that would not be able to perform the opening. Despite being only estimates, this find-

ing suggests that a great number of users might not access the product they have paid for.

The results of this study show that gender and the age are determinants to a good design. The interface of soft drinks PET packagings have signs of serious problems, which might exclude representative portions of economically active population. In this sense, it should be emphasized the importance of a deepest research on this product, which can provide parameters for improving its usability by the design.

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