

# A comparative study of various screw caps

## Is there any correlation between the results of a target group study and instrumental measurement?

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### Summary

Many consumers, including elderly persons, have difficulty opening packaging. Screw caps are often identified as a type of packaging which is difficult to open. A target group study and an instrumental analysis were carried out to evaluate different screw caps; the results were then compared. The target group study revealed significant differences in the operability of individual bottles. Operability is obviously influenced by a number of different factors: surface feel of the bottle, dimensional stability, size of the bottle and diameter of the cap. The study showed a correlation between the target group study and the instrumental analysis.

**Keywords:** screw caps, bottles, easy opening, ONR CEN/TS 15945:2011, target group study, instrumental measurement, easy operability

TS 15945 [2]. The team also developed a measuring device and a way of measuring the force required to open different screw caps. This device simulated the hand movement required to open screw caps. The study examined whether the force that participants subjectively felt they expended correlated with the results of instrumental measurement.

The process of opening a bottle involves three important levels: cognitive, motor and strength (♦ Figure 1) [3]. The principle of screw caps on drink bottles is widely known. We can therefore assume that cognitive and motor levels play a minor role and that force expended is crucial to the process of opening screw caps. We postulated that there would be a correlation between the results from the target group study and the results from instrumental measurement.

A key concern in food packaging is the conflicting interests of convenience and food safety. A global trend for convenience packaging has been observed. This type of packaging is supposed to be easy to open and to guarantee maximum consumer satisfaction and brand loyalty. This has already been clearly demonstrated by the authors in a study on the operability of packaging for milk and sausage products [4, 5]. However, in terms of food safety, product protection and safety are of primary importance. The risks which may arise from incorrectly opened packaging have already been studied elsewhere [6].

### Introduction

In December 2003, the *Bundesarbeitsgemeinschaft der Senioren-Organisationen e. V.* (BAGSO) (Federal Association of Senior Citizens' Organizations), which represents the interests of elderly persons, published the results of a survey on packaging: 26% of elderly persons stated that they often had difficulty opening drink bottles [1].

People want to live independently for as long as possible. When food and drink packaging is difficult to open, this causes dissatisfaction and a willingness to switch to other products. The target group above 60 years of age should not be subjected to age-related restrictions as a result of packaging and consequently distance themselves from the product.

This study is based on a target group study carried out to evaluate packaging in accordance with CEN/

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## Materials and methods

### Materials

This study looked at six commercial drink bottles (♦ Figure 2). Three reference pairs were formed from the six examples of packaging tested:

Bottles A and B were glass bottles (*Brunneneinheitsflasche*, a standardized type of glass bottle made in Germany) of the same volume (0.7 L). These bottles had different caps. Bottle A had a “rolled-on” aluminum screw cap; a tamper-evident seal was provided by means of a paper strip. Bottle B had a plastic cap.

Specimens C and D were PET water bottles of different sizes; both bottles had an identical cap ( $\varnothing = 28$  mm). Bottle C had a volume of 1.5 L, Bottle D 0.5 L.

Bottles E and F differed in bottle size (volumes: Bottle E = 1 L; Bottle F = 0.33 L) but had the same cap size ( $\varnothing = 38$  mm). The screw caps on Bottles B to F had integrated tamper-evident caps. In these cases, the tamper-evident seal has to be broken when first opened; the band is then detached.

age group [years]	male [%]	female [%]	overall [%]
65–69	10	25	35
70–74	10	25	35
75–80	10	20	30
overall	30	70	100

Tab. 1: Composition of test group according to CEN/TS 15945

### Methods

#### Target group study

The target group study was based on the technical specification CEN/TS 15945:2011 [2]. This specification describes a standard procedure to determine the ease of opening consumer packaging as well as consumer satisfaction. It makes allowance for the fact that increasing age leads to decreasing visual perfor-

mance and motor skills as well as hand strength.

As part of the study, six groups of 20 participants (male and female) aged between 65 and 80 opened the above-mentioned bottles. Each participant opened only one drink bottle, to exclude any potential learning effects. The age distribution of participants is shown in ♦ Table 1. The participants were approached randomly in cafés and at public events. A belief that they led an “independent lifestyle” was a requirement for participation.

The testing situation was particularly important in the target group study; we aimed to reproduce the calm atmosphere of the domestic kitchen table. Requirements of space [7] and sufficient lighting (at least 300 Lux) were taken into account [8]. Participants who needed reading glasses were invited to wear them. The hand movements adopted by the participants in the test were video-recorded, to improve our interpretation of results and analysis of opening behavior. The target group study was divided into three stages in accordance with the requirements of the technical specification CEN/TS 15945:2011:

1. The study firstly determined the effectiveness of the opening process. Here the participants were expected to familiarize themselves with the packaging,

the opening mechanism and the opening instructions and finally open the packaging. The stage was regarded as successful if this occurred within five minutes.

2. The study then tested the efficiency of the opening process. The participants received a new identical packaging. The “efficiency” criterion was regarded as fulfilled if this packaging was opened within one minute.

3. After sampling a portion of the product, e.g. pouring the drink into a glass, the participants stated their satisfaction with the opening process according to a five-tier scale (from +2 “very good” to -2 “very bad”). This stage was regarded as successful if the satisfaction rating was level 0 or higher.

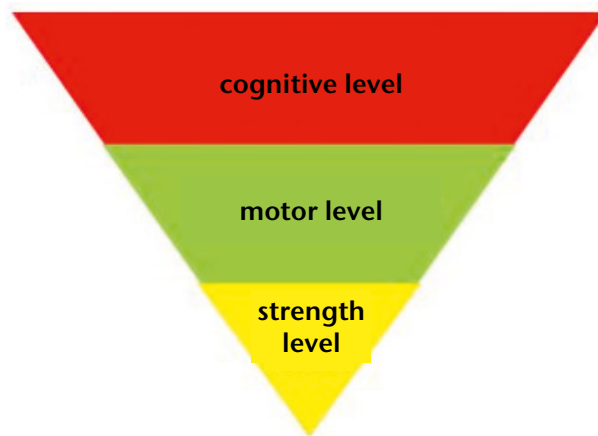


Fig. 1: The levels of action for the process of opening packaging [3]

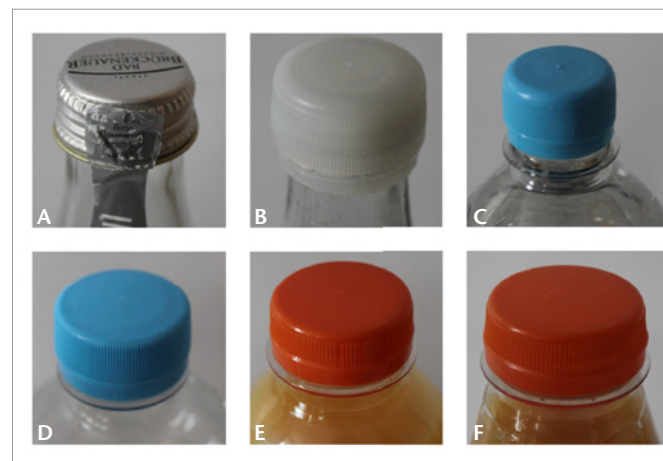


Fig. 2: Packaging studied

### Instrumental measurement

The opening of the screw caps was characterized by the Texture Analyser® (Texture Analyser®.HD Plus) based on the positive surface [in newton meters, NM]. Taking into account the test speed, the data was supplied as force conducted [in Nm]. The device to open the screw caps (♦ Figure 3) was developed by the authors to replicate real conditions. The jaws which surround the lid of the bottle assume the function of fingers in opening the screw caps. The three pairs of jaws are covered with rubber to imitate the structure and characteristics of human skin. The jaws' prism shape produces four main points of contact.

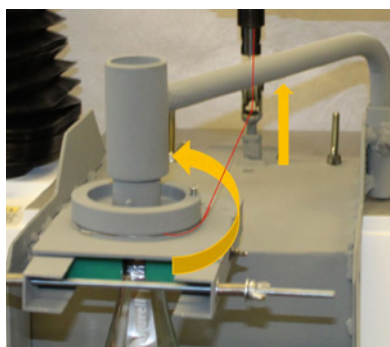


Fig. 3: Device for instrumental measurement of opening force (jaws for clamping the cap are marked green in the foreground; steel wire pulled upwards by the Texture Analyser® is marked red)

The jaws are fixed in a frame made from aluminum U-profile, on which lies a spool. This spool is wrapped twice round with steel wire ( $\varnothing = 0.5$  mm). The jaws are pressed onto the screw cap by a threaded rod and two compression springs, so that the cap is loosened as soon as the Texture Analyser® starts to pull the steel cable upwards. The spool is held in position with an arm. The frame with green jaws and the spool then turn anticlockwise and the Texture Analyser® executes a vertical pull movement until the cap is com-

pletely loosened from the thread of the drinks bottle and rests loosely on top.

The speed of the pull movement of the Texture Analyser® was the same for all bottle types. The so-called pre-speed was determined at 5 mm/s up to the tightly stretched steel wire. The subsequent test speed, the pull movement of the Texture Analyser®, was 20 mm/s. The distance required for the bottle cap to rest loosely on the thread of the bottle differed for each drinks bottle and was a crucial factor in the measurement (♦ Table 2).

The study aimed to ensure that the six different bottles were measured in comparable conditions. The bracket used to clamp the bottle was height adjustable, ensuring that the pulley and spool were on the same level. This produced comparable measuring conditions. Instrumental measurement was performed for 20 opening processes per bottle type.

## Results

### Results of the target group study

#### Effectiveness and efficiency of the opening process

The results for individual bottles in the sub-test on effectiveness are shown in ♦ Figure 4. Opening time percentages are listed in ♦ Table 3 in the time categories of 0–11 seconds and 11–31 seconds.

All 20 participants were able to open the glass bottle with the rolled-on aluminum cap within 11 seconds. The glass bottle with the plastic cap was opened more slowly. One opening process was discontinued for Bottles B, D and E; two opening processes were discontinued for Bottles C and F. The 1.5 L PET water bottle (C) was opened more slowly than Bottles D to F, yet faster than Bottle B. The small PET water bottle (D) and both orange juice bottles (E and F) were opened at a similar speed.

drink bottle	distance [mm]
Bottle A	200
Bottle B	350
Bottle C	240
Bottle D	230
Bottle E	160
Bottle F	160

Tab. 2: Method for instrumental measurement of screw caps using Texture Analyser® (pre-speed = 5 mm/s, test and return speed = 20 mm/s, release value = 0.049 N)

A uniformly moderate learning effect was apparent in the repeated opening of individual bottles (♦ Table 4); only for Bottle C did some participants require significantly longer for repeated opening. The results of the sub-test on efficiency are not represented graphically.

#### Satisfaction with the opening process

Participants' satisfaction with opening the drink bottles is shown in ♦ Figure 5. The participants gave different evaluations for the bottle caps. Discontinued opening processes were rated -2 ("very bad") in accordance with CEN/TS 15945.

Bottle A which was opened successfully by all participants, was graded from "very good" to "neutral" and thus was the only bottle to meet the requirements of CEN/TS 15945. The participants rated Bottle B as "good" to "very bad"; one opening attempt was discontinued and was therefore rated -2. Bottle C was graded from "very good" to "very bad". Like the glass bottle with the rolled-on aluminum cap, Bottle D proved popular with participants. Aside from the discontinued opening process, exclusively positive evaluations were given. Bottles E and F with wide plastic caps received ratings from "very good" to "very bad".

### Results of instrumental measurement

The distributions of the opening force required for individual drink bottle caps are shown in ♦ Figure 6.

There is no standard distribution in the measurements.

20 caps per drink bottle were studied using the Texture Analyser®. As the packaging of Bottle C had meanwhile changed, the study instead measured instrumentally identical bottles of sparkling water. Bottle A was the easiest to open; the arithmetic mean of the force expended was 2.4 Nm. The rolled-on aluminum cap was only secured with a paper strip. The force required to open the screw cap was lower in comparison to the caps with integrated tamper-evident bands (Bottles B to F).

The second glass bottle, Bottle B, required much more force to open. The mean from 20 measurements was 8.8 Nm. The spread of measurements for individual caps was relatively wide; the force required was between 6.0 and 11.0 Nm.

Bottles C and D had the same cap; the mean opening forces were correspondingly similar (mean: Bottle C: 4.4 Nm; Bottle D 4.6 Nm). The instrumentally measured force required to open the juice bottles was also similar (mean: Bottle E 3.4 Nm; Bottle F 3.2 Nm).

drink bottles	effectiveness [%]			efficiency [%]		
	time category 0–11 s	time category 11–31 s	discontinuation	time category 0–11 s	time category 11–31 s	discontinuation
Bottle A	100	0	0	95	5	0
Bottle B	55	40	5	74	26	0
Bottle C	70	20	10	61	39	0
Bottle D	90	5	5	100	0	0
Bottle E	90	5	5	100	0	0
Bottle F	80	10	10	100	0	0

Tab. 3: Results of sub-tests on effectiveness and efficiency

All figures are in percentages, in relation to the number of participants in the respective categories

drink bottle	effectiveness [s]	efficiency [s]	satisfaction [degree of satisfaction]
Bottle A	5.06	4.68	1
Bottle B	11.31	7.23	0
Bottle C	8.66	9.53	0.5
Bottle D	7.56	5.52	1
Bottle E	7.40	6.19	2
Bottle F	5.88	4.38	1

Tab. 4: Median opening times and satisfaction

## Discussion

The bottles differed in terms of material, volume and cap diameter. Almost all participants were familiar with the concept; familiarity with water bottles (Bottles A to D) was

100%. Familiarity with juice bottles was lower: 85% for Bottle E and 90% for Bottle F.

The glass bottle with the aluminum cap was rated positively.

Bottle B was more difficult to open in comparison to Bottle A;

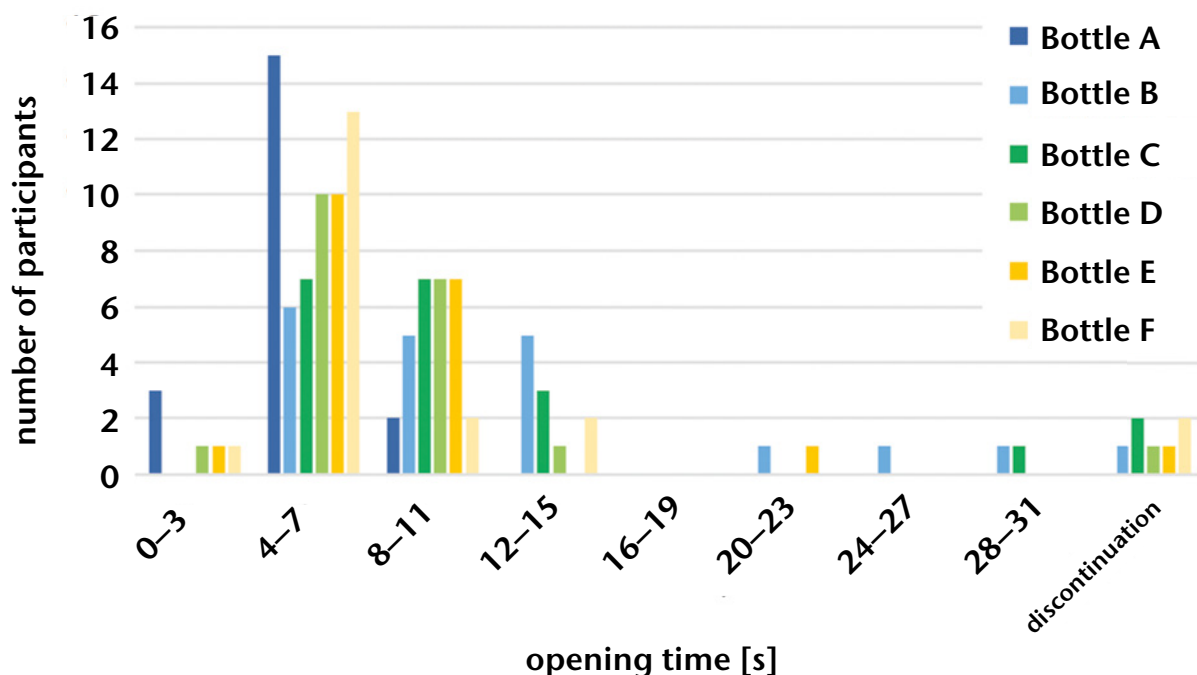


Fig. 4: Time taken to open the bottles (effectiveness test)

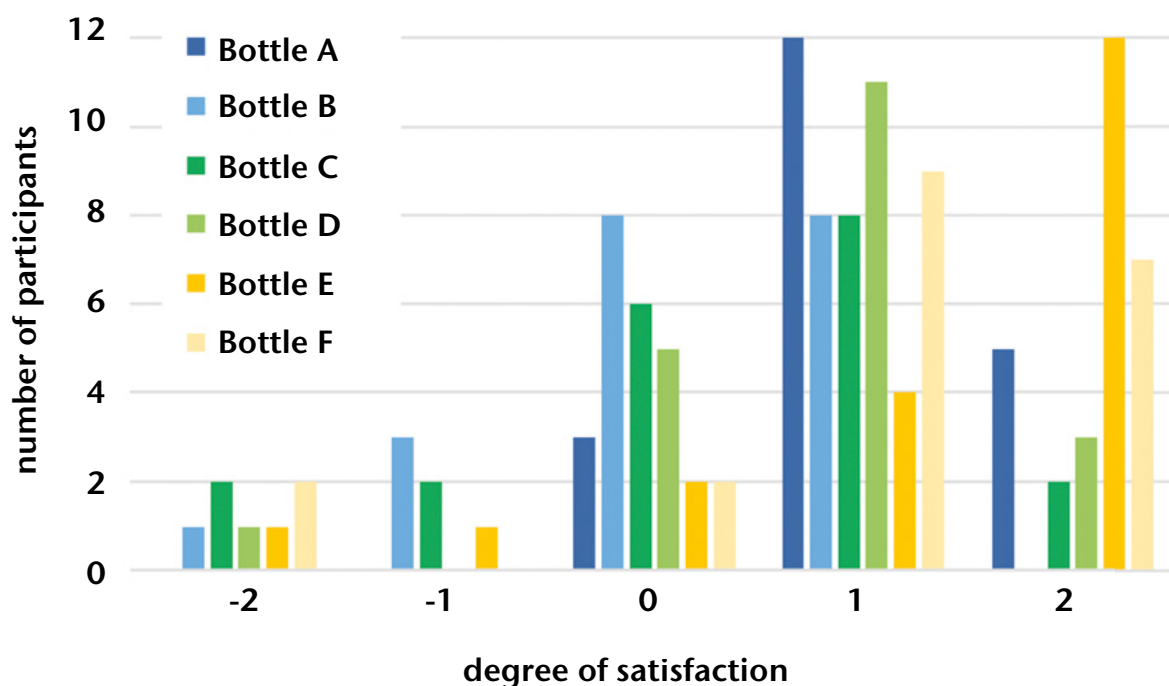


Fig. 5: Satisfaction of participants with the opening process (according to CEN/TS 15945)

the satisfaction of study participants was correspondingly lower. This was due to the integrated tamper-evident cap and the safety band which was difficult to loosen. These difficulties were confirmed by instrumental measurement. The force required to open this cap was particularly high, between 6.0 and 11.0 Nm, five times greater than the force required for the aluminum cap. Bottles C and D were rated positively. Instrumental measurement required a force between 4.0 and 6.0 Nm to open both PET water bottles and to loosen the tamper-evident band. The size and unwieldiness of Bottle C made it

difficult to pour out a portion of water. The dimensional stability of the bottle was low; the bottle often buckled when pouring and the participants spilt water. Bottle D was rated better in the target group study; it was smaller and fitted better in the hand and it was easier to pour.

The screw caps on the juice bottles were larger, the participants were able to grasp them well and the transmission of force was therefore better. The measured force required to open the juice bottles (Bottles E and F) was between 2.0 and 5.0 Nm. In the target group study, the 1 L juice bottle was rated “very good”, and

the 0.33 L only “good”. In comparison to the 1.5 L water bottle, the 1 L juice bottle caused no difficulties when pouring and the participants found no fault with its shape or size.

The median opening times for individual bottles differed (♦ Table 4). Bottle B was opened more slowly overall in comparison with the other bottles.

The participants’ age and gender had no influence on the effectiveness or efficiency of the opening process, or the satisfaction. However, all the study participants who discontinued the opening process were female and aged between 75 and 80 (however, one female participant from the

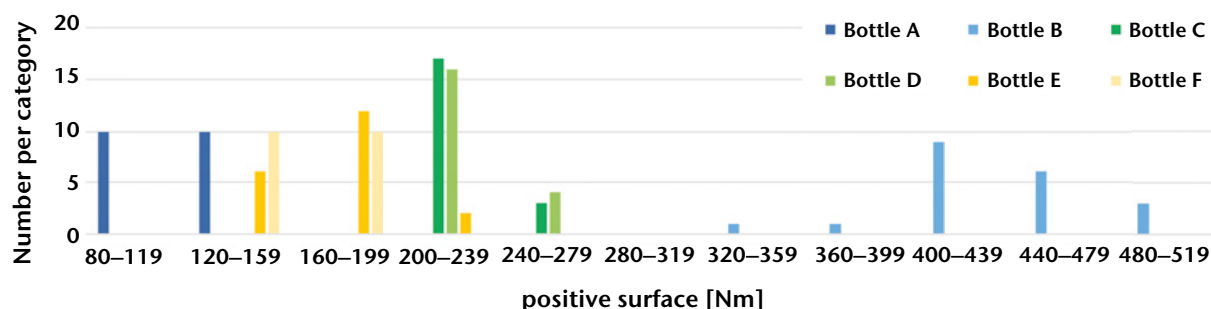


Fig. 6: Results of the force used by the Texture Analyser® to open the bottles  
Nm = Newtonmeter



65–69 age group also discontinued opening Bottle C). They stated that they could not apply enough force and they usually received support from various aids or their husbands in everyday situations.

Only Bottle A fulfilled the requirements of CEN/TS 15945 for easy-to-open packaging in the target group study. Bottles B to F are not easy-to-open packaging according to this standard, as the participants discontinued the opening process or gave a negative evaluation (–1 corresponding to “bad”).

## Conclusion

The 1.5 L water bottle was found to be unwieldy; its poor dimensional stability made it difficult to pour out a portion of water. The aluminum screw cap proved to be an advantage in the target group study. This was also confirmed by instrumental measurement.

The satisfaction results showed that consumers prefer a larger diameter of bottle cap. The participants were better able to grip large bottle caps (motor level, see ♦ Figure 1). The thread lengths of the juice bottles were also shorter in comparison to the PET water bottles. Positive influences on opening behavior should be further discussed.

Pouring out a portion of liquid was also easier with the juice bottles. The dimensional stability of these bottles was better than the 1.5 L water bottle. The size and shape of the 1 L juice bottle also performed well. The small bottles (Bottle D and F) were on average rated positively; instrumental measurement confirmed the satisfaction of participants.

The screw cap on Bottle B demonstrated clear room for improvement in comparison to the other drink bottles. This cap is obviously not suited to elderly persons, who are perhaps able

to apply less force. Furthermore, the two predetermined breaking points on the tamper-evident cap did not work. The tamper-evident band was not detached and the cap stuck when lifted up the bottle thread. This bottle was rated worst in the target group. Instrumental measurement also showed that this bottle required the greatest force to open.

The posited hypothesis was thereby confirmed: the smaller the force required to open, the greater the satisfaction of participants in opening screw caps.

As water and sufficient fluid intake are particularly important in old age, elderly persons should be able to open bottles easily in everyday situations. The above research on drink bottles has demonstrated, in both the target group study and the instrumental analysis, that further action is required.

### Conflict of Interest

The authors declare no conflict of interest.

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