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STUDY OF THE MECHANICAL PROPERTIES OF CARDBOARD WITH BARRIER PROPERTIES

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Abstract
The aim of this study is to test and compare the mechanical properties of the cardboard selected for the tests and to determine the best type of material. As cardboard is used in a wide range of industries for the packaging of goods, it is important to determine which of the types of cardboard tested is the most resistant to wear and the least deformable under changing environmental conditions. It is also important to compare and identify what improvements could be made to existing materials to make the board durable and environmentally friendly. To conduct the experiment of this study, four types of cardboard with barrier properties were used. For all the tests sample groups of different cardboards with different barrier properties were prepared and the specimens were stored and acclimatised under the same conditions before the tests. Specific software and devices were used to determine the final results. Selected types of tests were chosen to compare the types of cardboard as they are close to the real-life use of the packaging. After obtaining results of selected tests, compared values have shown that there were no significant changes, but there were some differences in the strength properties, which could be mainly due to the different mechanical properties of each type of paperboard. As a result, one type of paperboard was superior in both resistance and wetting tests. To conclude, this study, which was carried out to compare the strength properties of four different types of cardboard and their behaviour caused by changed surroundings demonstrates that all the types of tested cardboards are proper for use but need to be protected from direct wetting or wearing and tearing. Furthermore, this study helped to obtain new directions and ideas on how cardboard could be improved and made an even more resilient but environmentally friendly material and how it could be improved and applied in industrial companies in the future.

Keywords: *cardboard packages, cardboard improvements, barrier properties*

Introduction

In our fast-paced environment where we are used to get all needed goods immediately, packages represent and service a very important role. Usually, different kind of packaging is met in almost every area of food industry, pharmaceuticals or hygiene products, non the less including all the huge variety of items used every day that come in packaged. The package itself not only serves as a protection of a product, but may be used as a way of delivering additional information or advertise brand or other products (Gunaratne, N. M. et al., 2019). Packages are used as primary or secondary depending on the packaged product that is why the chosen materials shall be safe, not to contaminate the product, be sustainable and recyclable, easy producible and durable for the required period (Deshwal, G.K. et al., 2019). It is important not only to pack a product, but make it as accessible as possible, e. g. for people with visual impairments. Braille is one way of presenting the most important information, but it is very important to choose right materials and printing techniques (in this study, embossed Braille was used) to ensure minimal damage for written text that might be caused by environment factors (Havenko, S. et al., 2016). Furthermore, packaging should be well thought through and made as environmentally friendly as possible. According to Eurostats and comparing numbers of years 2021 and 2020, plastic packaging waste generation increased by 4 % per capita followed by an increased recycling rate by 9.5% (Eurostat, 2023). The rising numbers of recycled materials are encouraging but the part, which is left, usually is buried or burnt (Cheng, H. et al., 2021). That is a very important reason why materials, which incorporate great qualities and offer additional moisture and grease barrier keeping recyclability option instead of additional layer of different material, could be explored and adapted even more. For this study cardboard with additional barrier properties (MM Group, 2014) and Braille printed on top was chosen with an aim of checking cardboards' reaction to environmental changes and Braille resistance to some of possible damaging factors.

Methodology and equipment

For this study of cardboards and their properties, four types of cardboards suitable for contact with food where chosen with different grease and moisture barrier properties. The materials that were chosen are listed: 'Accurate', 'Accurate Freeze', 'Accurate Freeze Grease KIT 7-9', 'Accurate Freeze Grease KIT 9-11'. These cardboards were prepared in the production line, so each sample was already enhanced with a short Braille lettering executed by embossing it on each type of cardboard sheet. The main characteristics of all used cardboards are summarized and presented in Table 1 below.

Table 1. Characteristics of four types of cardboard with barrier properties

Cardboard type	Accurate	Accurate Freeze	Accurate Freeze Grease KIT 7-9	Accurate Freeze Grease KIT 9-11
Grammage g/m^2	305 +/- 2%	305 +/- 2%	305 +/- 2%	305 +/- 2%
Thickness, µm	520 +/- 5%	520 +/- 5%	520 +/- 5%	520 +/- 5%
Gloss 75°, %	> 45	> 45	> 45	> 45
Smoothness top, µm	1,0	1,0	1,0	1,0
Brightness top (% Elrepho)	90 %	90 %	90 %	90 %
Stiffness L&W, mNm	29,8	29,8	29,8	29,8
Additional properties	Cardboard with a high visual impression, neutral in odour and taste.	With additional moisture barrier (freeze barrier) and resistant to temperature fluctuations	With combined moisture barrier and grease barrier (freeze-grease barrier)	With combined moisture barrier and grease barrier (freeze-grease barrier)
Applications	Cosmetics and personal care, Pharma and health care, dry, fast food	Fruit and vegetable, Frozen food, Chocolate and confectionary, Fast food	Dry food, Frozen food, Chocolate and confectionary, Fast food	Dry food, Frozen food, Chocolate and confectionary, Fast food

To make sure, that every cardboard is prepared for the testing in the same way, all sheets were kept in the same environment for a few days. The conditions for preparing the specimens were room temperature of around 21±1 ºC and moisture 50±1 %. Samples of different types of cardboard were prepared and tested using Braille dots checking device and software to measure the parameters of Braille dots for the first test and pocket goniometer to measure the contact angle between the surfaces of the samples and water droplets for the second test.

For the first test specimens were prepared using the part of each cardboard with embossed text. Six samples were cut out of each cardboard type making sure that each specimen includes Braille lettering. All Braille dots on the samples were measured using ‘Brai3’ device and ‘Peret’ software. As Braille is embossed as a three dots marking in the column, this device takes an image of every three dots and analyses their characteristics. Using the ‘Peret’ software each dot can be selected and according to chosen settings for measuring and analyzing, information of every dot is shown in the image. The gained information is height of selected dot, base diameter and information if size of a dot passes the normal values based on selected settings. An example of measured dot is given in Fig 1.

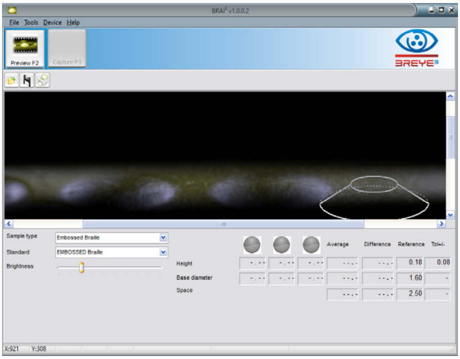
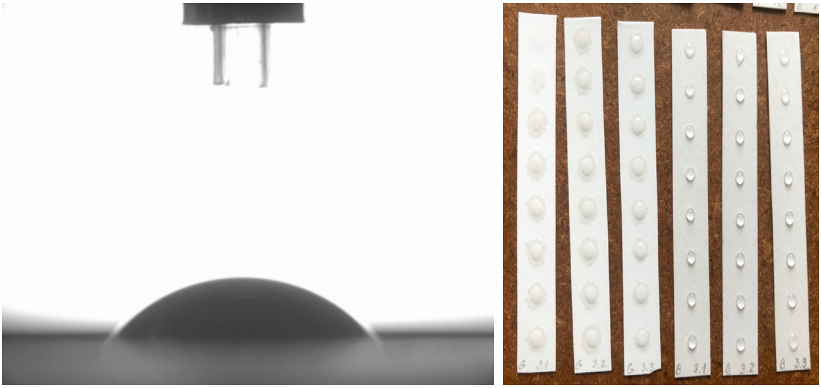


Fig 1. Example of Braille dot measuring and image on the screen

All dots on the specimens were measured and thirty dots were marked specifically on the cardboard for further investigation. The measurements of all dots were saved for analysis. To check if environmental changes makes an impact on cardboard surface and effects Braille dots, all prepared samples were stored in a freezer in a surrounding temperature of around –18±1 ºC and moisture of 68±2 % for 60 days. The samples were visually inspected regularly to ensure no changes in appearance. After 60 days the specimens were taken out and all dots that were marked before were measured again. Obtained results were compared to the ones received before changing the environment of samples storage.

For the second test, wetting angle test, specimens were prepared using the same sheets of cardboard that were used for sampling in the first test. Six sample strips of size 100x15 mm were cut out of every type of cardboard and marked accordingly. For this test three strips were used for each side of cardboard. This test was chosen to identify and monitor the differences between both sides of cardboard with barrier properties by investigating the contact angle of each side. To perform this test 'The Pocket Goniometer PG2' device for capturing and measuring the droplets and 'PG program 3.1' software for evaluating were used. The captured image of droplet and image of tested samples are presented in Fig. 2.



a *b*

Fig 2. Image of droplet captured using goniometer (a) and example of tested samples (b)

Using distilled water and device, eight droplets were dripped on each sample and measured. The measurements of each droplet were taken after dripping the droplet and letting it settle for a few seconds; after each drip the photo using goniometer was taken and data such as contact angle, base diameter, volume and height was collected. After measuring all samples, collected data was used to compare results between both sides and all used types of cardboard.

Presentation of research results

After the first test samples of cardboard with Braille dots were visually evaluated and no impact or change of form was noticed, measurement results of Braille dots on 'Accurate', 'Accurate Freeze', 'Accurate Freeze Grease KIT 7-9', 'Accurate Freeze Grease KIT 9-11' cardboards with different barrier properties were compared to the previous results of the same dots and average values confirmed minimal changes. The compared average results are displayed in Figures 3 and 4 below, showcasing minor changes in dot height and base diameter.

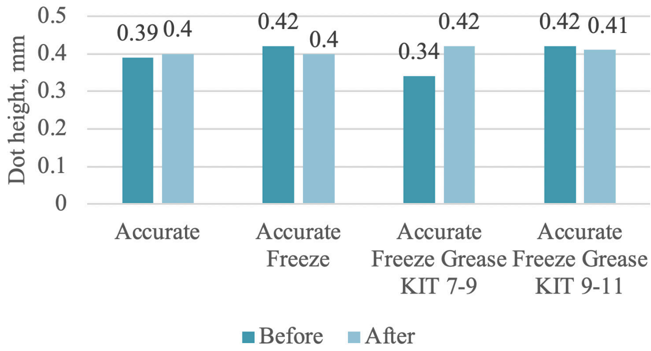


Fig 3. The changes of Braille dot height

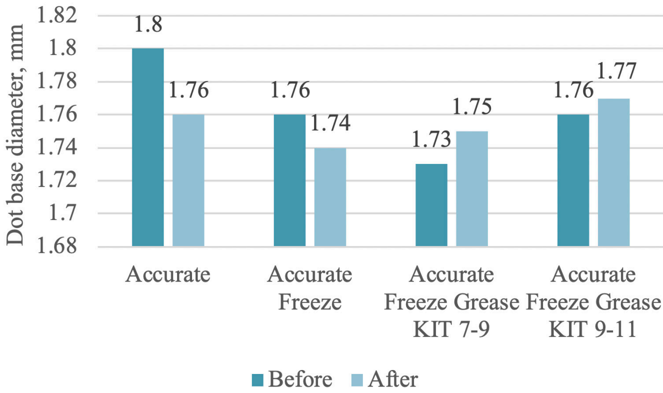


Fig 4. The changes of Braille dot base diameter

The changed conditions of samples storage have not made any major impact on Braille dots and it is possible to consider that barrier properties made an impact on preserving cardboard and Braille dots in the same state. Results demonstrate minor changes in measurements, but these changes have no major impact on dots measurements that would deviate from the standard dimensions and could reduce the possibility to read the embossed text.

Taking into consideration results of the wetting angle test, the measured values have shown that the reverse side of the cardboard tends to absorb fewer liquids than the upper side (Fig. 5).

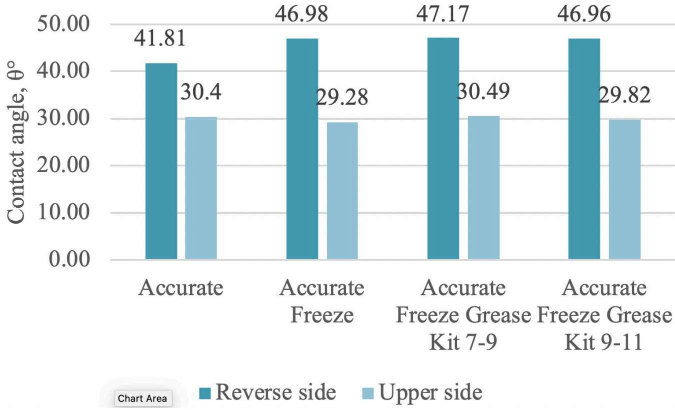


Fig 5. The compared contact angle of both cardboard sides

According to the results, the best performance on not-absorbing liquid was shown by 'Accurate Freeze Grease KIT 7-9' with a contact angle of 30.49 º on the upper side and 47.17 º on the reverse side. Cardboard 'Accurate', which has the lowest barrier properties according to the producer listed specifics, demonstrated better results on the upper side compared to moisture-resistant and grease-proof 'Accurate Freeze' and 'Accurate Freeze Grease 9-11' cardboards even if the difference is not major. On the other hand, results of the reverse side measured values have shown that 'Accurate' has the greatest absorbing capacity from all four tested cardboards.

Conclusions

- This study was carried out to check the properties and possible changes of four different types of cardboard designed with different levels of moisture and grease barrier properties and their behaviour caused by changed keeping environment. The results of test of Braille dots shows that cardboard with additional barrier properties manages to stay in the same state keeping the dimensions and visual appearance the same.
- Braille dots maintained almost the same dimensions after exposing the cardboard to freezing temperatures and moisture (an average change of the height of Braille dot was 0.03 and of base diameter 0.02 mm). Therefore, it follows that cardboard might be used for various food products and pharmaceutical packages and environmental changes should not impact suitability.

- The contact angle test has shown that upper side of all four cardboards is likely to absorb liquid almost 1.5 times more than the reverse side (the least absorbing 'Accurate Freeze Grease Kit 7-9' demonstrated results of 30.49 º on upper side and 47.17 º on reverse side) and even to change the cardboard look after applying water. This means that cardboard packages with barrier properties should be kept away from the direct contact with liquids.

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