RECYCLABILITY OF CARTONBOARD AND CARTON

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Introduction

According to Eurostat, paper, board and cartonboard have by far the highest recycling rate of all packaging materials, reaching around 85% in 2019. Metal comes in second at 81%, glass at 76%, with plastic at only about 40%. The European paper industry is even aiming to increase the recycling rate for fibre based packaging to 90% by 2030.

Recovered paper, is the most important raw material for the production of paper, board and cartonboard in Europe. Taking all types into consideration, its share is over 54%. Recovered paper is mainly used in newsprint and packaging materials such as corrugated base paper, folding boxes and packaging paper.

While newspapers and corrugated board are produced from almost 100% recovered paper, the amount of recovered paper in folding boxes is significantly lower at around 35%. Due to product requirements and food regulations, the range of grades is divided into products that are largely produced from recovered paper (GT, GD cartonboard) and those based on virgin fibre (GC and GZ cartonboard).

Cartonboard packaging is preferred by consumers because of its environmental credentials and its easy and well-established recyclability. The advantages of fibre-based packaging are seen in the use of renewable natural fibres, which are obtained from renewable raw materials from sustainable forestry and can be recovered from the waste stream after use.

Recycling as much as possible has a significant positive effect on the eco-balance of the packaging, as it can reduce the specific water consumption in fibre production and also significantly reduces CO2 production thanks to the lower energy input. The more often the same item of packaging can be recycled, the more positive its impact on the environment.

When it comes to producing GT/GD cartonboard based on recovered paper, mainly mixed recovered paper from household collections is used, with varying proportions of newspapers and magazines, and packaging materials such as corrugated board boxes and folding boxes. Decisive factors when selecting the different types of recovered paper include not only price, availability, and cleanliness, but above all the quality characteristics. While the properties of folding cartons made of virgin fibre are very clearly defined by the grade classification, this is much more difficult when it comes to packaging made from recovered paper. It is no longer possible to determine whether the material used has ever been recycled or whether it has already passed through the recovered paper cycle many times. And depending on seasonal or local variations in the types of material collected, there are additional factors that influence the fibre mix.

When using recovered paper for cartonboard packaging in general and specifically with the aim of increasing recovered paper collection rates, it is therefore important to understand whether and how the fibre properties change as a result of repeated recycling and how frequently recovered paper fibres are recycled in order to keep them suitable for cartonboard production.

What we know already

In the paper industry and in numerous sources, many people persistently believe the myth that the maximum number of possible recycling cycles for paper fibres ranges between 4 and 7. A closer look at what has already been published on this issue shows that the number of recycling cycles that can be carried out in a test setup is often less limited by the fibre or the quality of the fibre than it is by fibre losses that occur during the recycling process [1]. It is often difficult to compare the results since the boundary conditions (pre-dried/initially wet fibre, sheet formation, drying) are different every time. As far as the technological development of fibre is concerned, the key points are that fibre changes mainly in the first two to four recycling cycles in terms of water retention capacity and strength potential, while the additional changes are marginal. The current study by Putz and Schabel [2], on which this paper is largely based, also addresses this issue with a suitable setup for recycling. The study deals with a mixture of fibres of different ages as a starting material, which is based on the paper grade structure for the production of corrugated board in Germany (40% testliner 3, 40% recycled fluting, 20% kraftliner), which corresponds to a mixture of 80% secondary fibres of different ages and 20% primary fibres. The defibration was carried out in an LC pulper with a material density of 4%. The handsheet was prepared using white water circulation and sheets of 120 g/m² were produced. 25 cycles were performed and no primary fibres or minerals were added over these cycles. Over the 25 cycles, there was a decrease in water retention of 14.5%, a slight decrease in the grinding degree of 4 points, and a slight decrease in ash content, which is associated with unavoidable losses of fine materials during sheet formation. Losses in mechanical properties (breaking length, CMT, SCT etc.) over the 25 cycles ranged from 5.1 to 11.6%. The reason cited for the low decrease is the low primary fibre content of 20%, since, as already mentioned, fibres undergo a change mainly in the first 2-4 cycles. Based on this study, this paper examines the development of a fibre blend used for the production of white lined folding box board over 25 cycles. In contrast to the above-mentioned study, the primary fibre content in this blend is somewhat lower and is represented exclusively by mechanically produced fibre, which according to Stürmer and Göttsching [3] loses hardly any strength potential during recycling. Moreover, the ash content in the blend used here is significantly higher at 21% than in the corrugated board mixture at 7.9%. On the one hand, the significantly lower primary fibre content leads to the expectation that the changes over the recycling cycles will be even smaller; on the other hand, it is necessary to take into account the high ash content in the test setup, as losses are to be expected during sheet formation which would subsequently distort the development of the technological properties.

Carrying out the recycling study on folding box board

The folding box board used in this study is constructed as follows:

• Top liner: 30 g/m², white files and shavings

• Underliner: 35 g/m², mixed recovered paper and packaging

• Filler ply: 213 g/m², 75% mixed recovered paper and packaging, 25% RMP

• Back ply: 40 g/m², 50% mixed recovered paper and corrugated board, 50% own waste

Uncoated unfinished cartonboard was used to make the experiment easier to carry out. For this reason, the primary fibre content represented by the refiner mechanical pulp (RMP) used in the filler ply is just under 18% (waste taken into account). The ash content is 21%, as already described above. This high ash content would make it impossible to interpret the development of the technological properties of the fibre, as the ongoing loss of ash during the course of repeated sheet formation would inevitably have a positive influence on the mechanical properties. This situation is taken into account during the study by largely removing the mineral components from the raw material in a laboratory pressure screen which is equipped with a perforated screen basket with a 250 µm hole diameter. Inevitably, a significant amount of the fine fibre material is also lost in this step. However, since the development of the fibre fraction is of primary interest in the study, this loss of fine material was consciously accepted and has no influence on the statements to be made. The ash content is reduced from 21% to 5.9% during this grading process, and the grinding degree is reduced from almost 40 SR° to 17 SR° due to the reduction in fibre fines. The mechanical properties are positively influenced by the reduction of mineral components that interfere with the fiber-fiber bonding. The change in the length distribution of the fibre due to the grading is shown in Fig. 1 in the results section. Starting from this sorted raw material, 25 recycling cycles were simulated. The sheet formation was done on a Rapid-Köthen handsheet formation with white water circulation. Any white water that goes towards the drain during sheet formation is collected and then used to suspend the sheets during recycling. In this way, virtually no fresh water was used over the recycling cycles, thus minimizing the loss of fibre material during sheet formation. Despite this, a certain loss of fibre material via the water ring vacuum pump is unavoidable. This amounts to an average of 0.98% per cycle over the cycles. A beater according to DIN EN ISO 5263-1 was used to redisperse the formed handsheets. Redispersion was carried out for 25 minutes at a material density of 2%. Even though this laboratory disintegration can be described as gentle, it is known from the literature [4] that fine material is removed from the fibre surface during this process step. This manifested itself in an increase in the degree of grinding (in contrast to the study by Putz and Schabel [4] in which a decrease in the degree of grinding was recorded) over the 25 cycles. Grinding degree (EN ISO 5267-1), water retention (ISO 23714) and fibre morphology (ISO 16065-2) were determined after cycles 1, 3, 5, 7, 10, 15, 20, and 25. Sheet tests for thickness/density/volume (EN ISO 534), tensile strength (EN ISO 1924-2), bending stiffness (ISO 2493-1), and Scott Bond splitting work (ISO 16260) were carried out on every cycle up to cycle 10 and on every second cycle from cycle 10 onwards. In addition, the ash content (DIN 54370) was determined after cycles 1, 5, 12, and 25.

<u>Results of the recycling study on folding box board</u>

As already mentioned, the disintegration of the sheets in the laboratory beater during the recycling cycles leads to a production of fines, as fines are detached from the fibre wall. This can be seen both in the fibre morphology (Fig. 1) and in an increase in the degree of grinding (Fig. 2). The length-weighted fibre length distribution shown in Fig. 1 shows the effect of the grading of the raw material for the present study on the one hand and the development over the recycling cycles on the other.

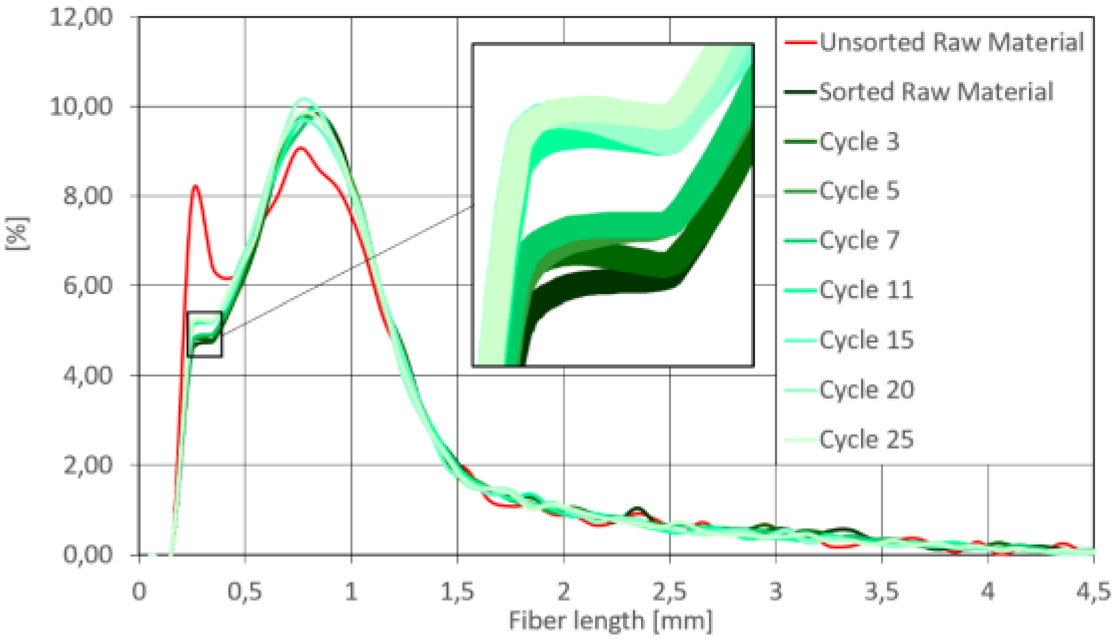

Fig. 1: Length-weighted fibre length distribution of the raw material before grading (red), after grading, and after the individual recycling cycles. The detail shows the area of very fine material (200-400 µm).

It is clearly evident that although recycling produces fine material (see also the detail in the diagram), there is essentially no change in the length distribution, i.e. no shortening of the fibre material. However, a large part of the fine material produced does not appear in this diagram, as only objects with a length of 200 µm or more are included in the length distribution. Similar effects can also be expected in the context of stock preparation on a production line. The extent of this will depend on the aggregates used, the process steps, and the energy input. The increase in the grinding degree and the development of the water retention capacity can be seen in Fig. 2.

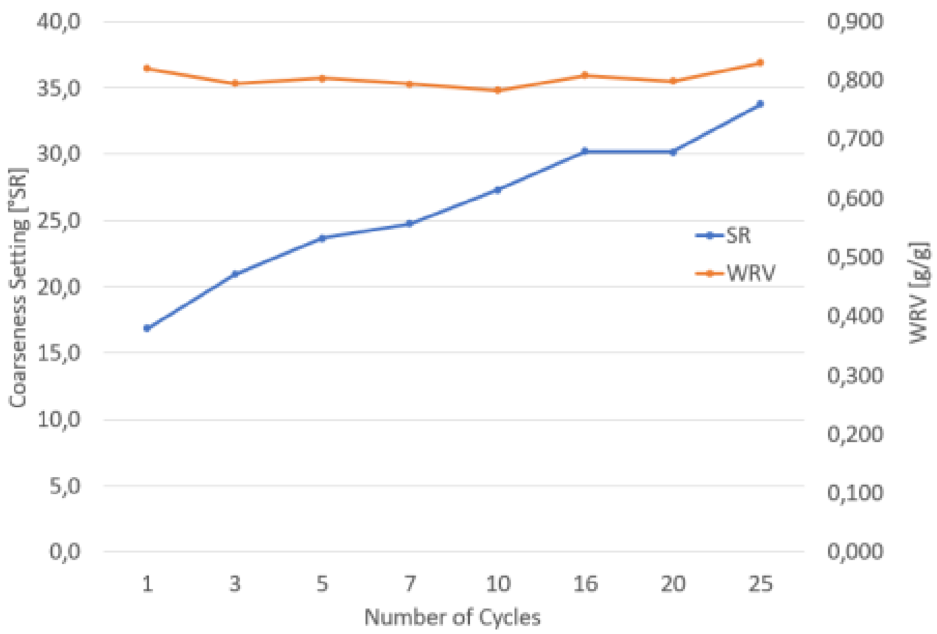

Fig. 2: Development of grinding degree and water retention capacity over the 25 recycling cycles.

A decrease was to be expected for the development of the water retention capacity due to the hornification of the fibre after repeated drying. There is also a slight decrease in water retention value at the beginning (up to cycle 10), but this is followed by a slight increase again. Apparently, two effects overlap here. On the one hand, we have the increasing hornification, which was not to be expected to be very pronounced anyway for this fibre, which consists primarily of secondary fibres and a proportion of wood fibre, and on the other hand, we have the increase in the degree of grinding due to the production of fines, which in turn increases the water retention capacity of the fibre. This production of fines during recycling also affects the sheet density and tensile strength (Fig. 3) of the handsheets. The increased content of fines causes compaction of the sheet, which increases the bonded area and subsequently also the tensile strength. At least at the beginning, the ash content may also have an influence, as it drops from an initial 5.8% to 3.8% by cycle 5. Over the additional cycles up to cycle 25, the ash content then remains constant, so that no further influence on the mechanical properties is to be expected. Other mechanical properties considered were the bending index relevant for this product group, as well as the Scott Bond splitting work (Fig. 4). These two parameters show no significant development over the 25 cycles. Either the fibre is not affected at all by recycling with regard to these two properties, or the negative development of the fibre is more or less compensated for by the production of fines and the associated increase in binding capacity.

Conclusion

Unlike in the case of the study on the corrugated board mixture [4], in which a decline in the mechanical properties of between approx. 5 and 10% was recorded over the 25 cycles, no negative effect on the mechanical properties in question can be demonstrated in this study. The swelling capacity of the fibre (represented here by the water retention capacity) also shows no clear negative trend. A less pronounced effect was to be entirely expected for the present folding box board blend due to the lower primary fibre content, which was limited to refiner wood fibre. Especially in the case of the swelling capacity, but also in the case of the mechanical properties, it can be assumed that the effect of stock preparation (in the case of this study, redispersion of the sheets in a laboratory beater for 25 minutes at a density of 2%) compensates for any negative effects of hornification. This influence of redispersion and stock preparation will vary depending on the aggregates used, process steps, and energy input, and will naturally be reflected in the mechanical properties. In principle, however, it can be clearly stated on the basis of this study that the fibre itself allows recycling over 25 cycles without further difficulty and that no limiting trend can be foreseen in this study. Therefore, limiting factors for the recycling of the fibre will primarily be unavoidable losses of fibre together with waste in the waste paper grading process, as well as the stress on the fibre in the preparation process, which leads to the production of fibre fines and possibly also to significant damage to the fibre. The results show that folding boxes represent a highly sustainable packaging solution that can seemingly be recycled any number of times and whose number of recycling cycles is limited mainly due to the waste paper collection rate and the losses that occur during cleaning of the fibre material.

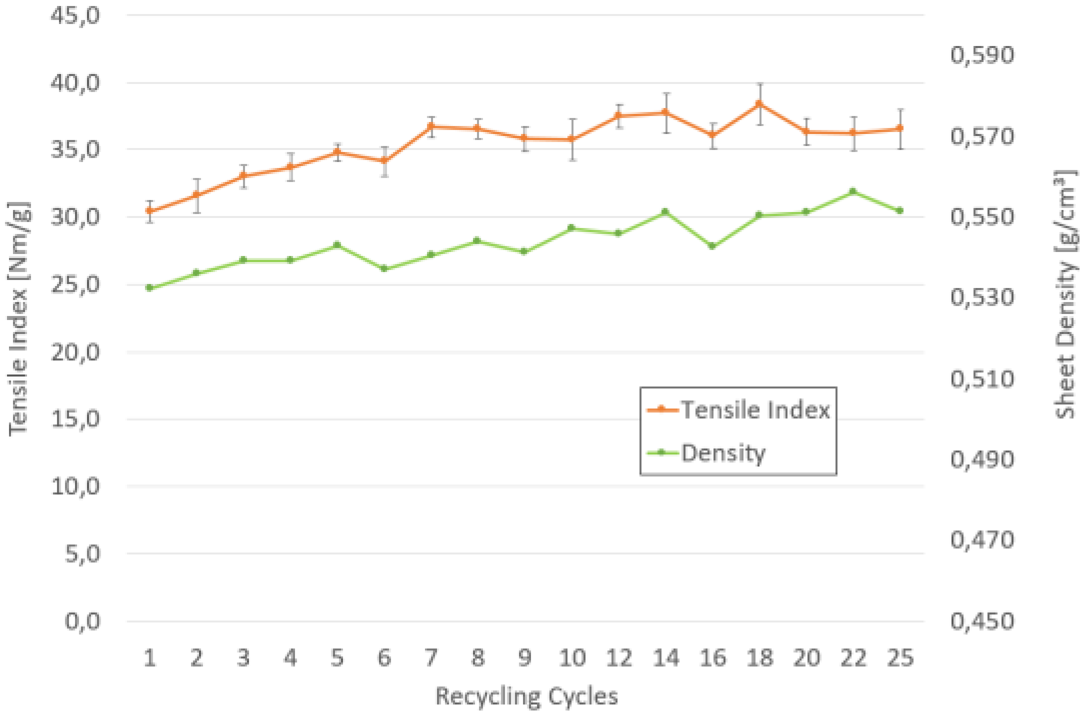

Fig. 3: Development of the tensile index and the sheet density over the 25 recycling cycles.

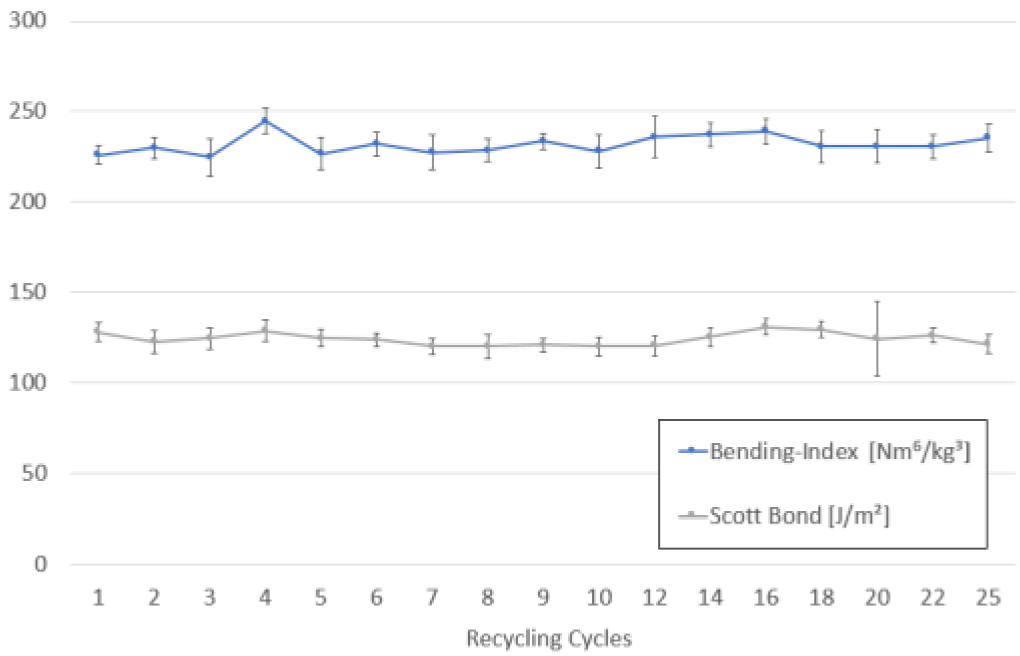

Fig. 4: Development of the bending index and the Scott Bond splitting work over the 25 recycling cycles.

[1] Eriksson, I., Lunabba P., Petterson A., Carlsson G.; Recycling Potential of thermomechanical fibres for newsprint; Tappi Journal, 80(1997), No. 7, p. 151 ff.

[2] Putz H.J., Schabl S.; Der Mythos begrenzter Faserlebenszyklen; Wochenblatt für Papierfabrikation 6(2018), p. 350 ff.

[3] Göttsching L., Stürmer L.; Physikalische Eigenschaften von Sekundärfaserstoffen unter dem Einfluss ihrer Vorgeschichte, Teil II: Einfluß des mehrfachen Recycling; Wochenblatt für Papierfabrikation, 106(1978) No. 23/24, p. 909 ff.

[4] Heijnesson A., Simonson R., Westermark U.; Metal Ion Content of Material Removed from the Surface of Unbleached kraft Fibres; Holzforschung 49(1995), p. 75 ff