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Upgrading of Old Corrugated Container Board with Aseptic Packaging Container for Paper Board Applications - A Laboratory Handsheet Study

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

In the recent past packaging material is on high demand. The use of environmentally friendly packaging materials requires that more recycled material is utilized in the manufacturing chain. Fiber material from liquid container board packaging which may contain over 75% virgin bleached fiber material may be used to offset and or upgrade existing board products.
In this laboratory handsheet study the use of presently not utilized liquid containerboard packaging material together with currently used recycled fibers from old corrugated containers was investigated.

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The recycled fiber material was repulped for 30 minutes at a pH of 10, a temperature of 150°F (65.6°C), and 1% Oxone addition based on fiber content under laboratory conditions.
Repulping results indicate that repulping of old corrugated container fiber material and liquid container board fiber material together might require a higher energy input for repulping and processing afterward due to a higher Canadian standard freeness level, and flake content compared to old corrugated container fiber material alone, whereas repulping of liquid container board fiber material only resulted in slightly higher energy consumption and slightly higher Canadian standard freeness level.
Handsheets containing repulped liquid container board showed a significant improvement in the short compression test strength, an important mechanical paper property for the evaluation of cardboard box material.
Increasing the liquid containerboard fiber content resulted in increased brightness and color of the manufactured handsheets compared to old corrugated container fiber material with similar opacity levels.
It can be concluded that LCB fibers can be used as a valuable source of recycled fiber material with the potential to upgrade board paper products regarding mechanical and optical requirements if additional deflaking and refining processes are considered.

Keywords: Aseptic packaging materials; beverage carton; liquid container board; milk carton; paper board; paper properties; recycling; repulping.

1. INTRODUCTION

Liquid Packaging board (LCB) is used to produce aseptic packaging container (APC) and or Gable-Top Cartons (GTC), or Polymer Coated Paperboard (PCPB) [1]. It is a paper product used in the food industry to package and store liquids that prevents microorganisms from entering the product [2]. Packaging made from LCB can extend the shelf life of liquid food products, especially when refrigerated. Dairy and fruit juice are some of the most notable products that are often packaged in liquid container boards, but many producers of liquid food products are beginning to use APC [3]. APC extend the shelf life of liquid products substantially for over 6 months [4]. In addition, APC allows many products that typically would need refrigeration to be stored on shelves. This greatly reduces energy consumption and costs, as it removes the need for large scale refrigeration [5,6]. Fig. 1 shows a typical composition of LCB used in the North American market containing paperboard as a based material coated with multiple layers of Polyethylene (PE).

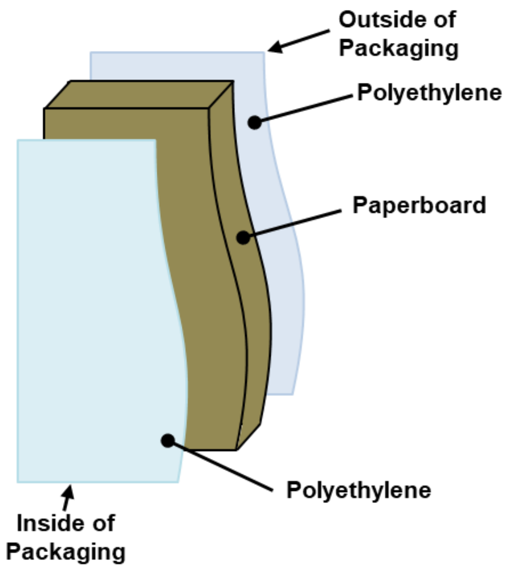

Fig. 1. Illustration of North American moister resistant liquid packaging board [7]

The recycled APC, GTC, is defined by the Industry of Scrap Recycling Industries (ISRI) 2021 Scrap Specification Circular (SSC) as Grade N0. 52 [8,9]. This material can be considered a composite material, and according to the ISRI-SSC includes generally no less than 70% bleached chemical fibers, up to 24% Polyethylene (PE) film, up to 6% Aluminum, and prohibitive material and outthrows may not exceed 2% and 5% respectively [1-6, 8-10].

With liquid food product producers increasingly using of APC, GTC due to environmental it is estimated that the world market volume grows to $ 716.70 billion by 2030 [11] with an expected growth potential of 5.7% in North America [12].

LCB used to manufacture APC/GTC In North America contains virgin bleached chemical fibers used to manufacture the base paperboard layer, which represents the most valuable material for recycling. The PE layer at present time cannot be used as raw material for new food packaging and in most cases is downcycled and or used as byproduct for various composite materials [1,8].

With the increased use of sustainable packaging such as APC/GTC, it can be assumed more APC/GTC material is collected through the recycling stream and is made available for reuse in paper and board manufacturing processes, and solution are needed to utilize the fiber material that composes over 75% [1,10] of the APC/GTC packaging material.

Recovery processes using APC/GTC raw material need to take in consideration already implemented processes in the fiber preparation are, called stock preparation, of paper manufacturing process. Fig. 2a), illustrates as an example a commercial continuous repulping processes for Old Corrugated Container (OCC) board at Low Consistency (LC) with Solids Contents (SC) of up to 5% to 8% [13,14], as well as the laboratory process, Fig. 2b), used for the laboratory research project.

In the commercial OCC repulping processes friction, centrifugal and gravity forces are used to disintegrate the fiber material and are designed to process of over 3000 metric tons of dry material per day [15]. These LC processing systems can be arranged in different ways to use the available fiber

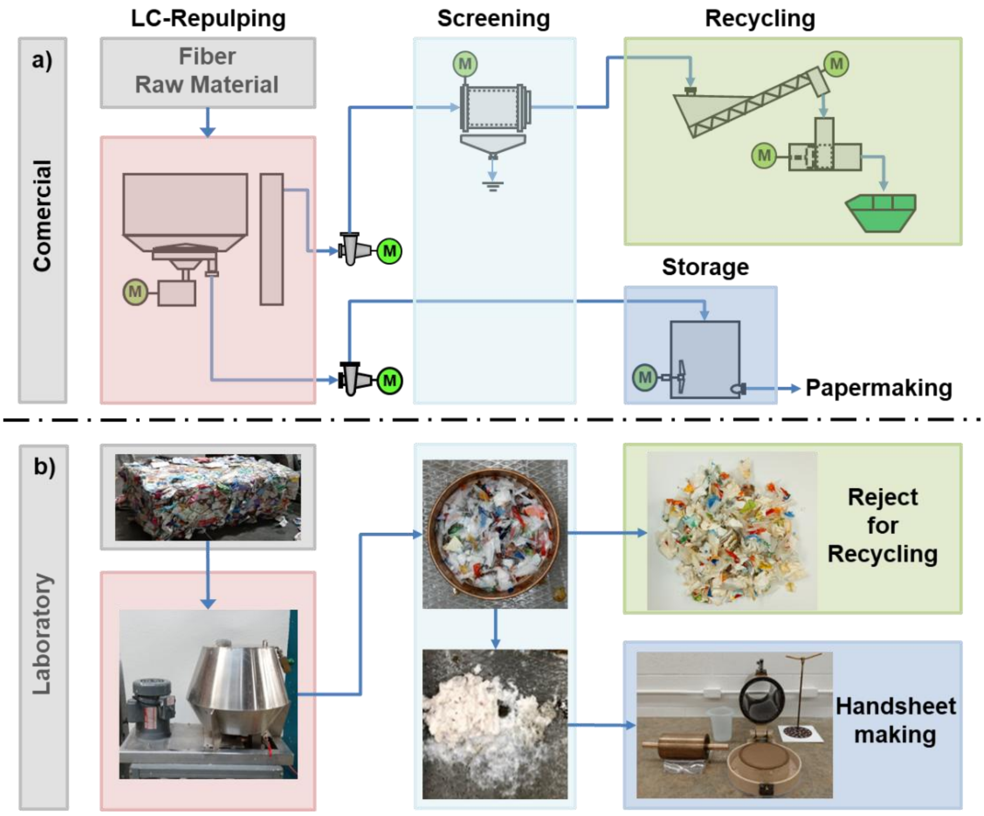

Fig. 2. Repulping process: a) Commercial, b) Laboratory [16]

material and for the product manufactured. Internal screen devices during repulping and or external screening machines are employed based on the type of recovered material processed. After the repulping the pulp is diluted to approximately 4% to better remove unwanted material. Metal, sand, plastic and hard to process recycled material that has been removed from the repulped fiber slurry. Recycled material is thickened and or baled and then feed into the recycled industries material stream for the manufacture of new recycled metal and plastic materials [17]. The cleaned fiber slurry is processed further and utilized for papermaking.

The following manuscript describes research work executed for the recovery of fiber material from APC/GTC packaging material containing LCB in combination with and without OCC board material, using a laboratory repulping procedure for the recovery of the virgin fiber material and or OCC fiber material to investigate if mechanical and optical paper properties are affected by the addition of virgin fiber material from LCB.

2. MATERIALS AND METHODS

The following materials and methods were used for the laboratory evaluation on recycling LCB for board paper applications.

2.1 Materials and Equipment

For this laboratory study LCB material from recycled orange juice containers containing 64 fluidounces (fl. oz.). (1.89 l) were used. As OCC material shipping boxes from Amazon were used. Both materials were collected by the researchers in their respective households.

As pulping chemical Oxone ($2KHSO_5$ $KHSO_4K_2SO_4$) was used acquired from Beantown Chemicals in granular form based on Oven Dry (OD) content.

The pH for repulping was adjusted with Sodium Hydroxide (NaOH) pellets acquired from Sigma Aldrich.

The temperature of the laboratory repulping was with low pressure steam at a pressure of 100 psi (689.48 kPa).

Temperature and pH were measured with a portable Milwaukee MW102 pH/temperature meter as well as a Therm-Pro handheld temperature probe.

For repulping a 1 hp (0.75 kW) Laboratory Pulper was used able to repulp 3 gallons (11.35 liter) of liquid.

The repulper power consumption was measured with a PN2000 Electronic monitor.
For screening of the repulped LCB material a No. 5 mesh (4 mm) 200 mm diameter screen pan was used. To recover usable fiber material a large screening box with a No. 150 mesh (105 μm) screen lining was utilized.

2.2 Testing Methods

For this research project the following testing methods of the Technical Association of the Pulp and Paper Industry (TAPPI) were used:

Handsheets were prepared according to TAPPI T 205 sp-12, “Forming handsheets for physical tests of pulp” [18]. Physical testing of handsheets was performed in accordance with T 220 sp-06, “Physical testing of pulp handsheets” [19]. The Zero span breaking length was measured using T 231 cm-96, ‘Zero-span breaking strength of pulp (dry zero-span tensile)” [20] Consistency of the pulp suspensions was measured with TAPPI T 240 om-07 “Consistency (concentration) of pulp suspensions” [21]. Freeness of pulp was measured as Canadian Standard Freeness (CSF) according to T 227 om-09 “Freeness of pulp (Canadian standard method)” [22]. Conditioning of the paper samples was done according to T 402 sp-08, “Standard conditioning and testing atmospheres for paper, board, pulp handsheets, and related products” [23]. Burst Strength was measured in accordance with T 403 om-02 :Bursting strength of paper” [24]. Basis weight was measured with T 410 om-08. “Grammage of Paper and Paperboard (weight per unit area)” [25]. Thickness/Caliper of paper was measured in accordance with T 411 om-10, “Thickness (caliper) of paper, paperboard, and combined board” [26]. Moisture content of pulp was determined by T 412 om-06 “Moisture in pulp, paper and paperboard” [27]. The hand sheets tear resistance was measured with T-414 om-98, “Internal tearing resistance of paper (Elmendorf-type method)” [28].

Air resistance was measured with T 460 om-02 “Air resistance of paper (Gurly method)” [29].

Tensile strength properties were measured according to T-494 om-01. Tensile properties of paper and paperboard (using constant rate of elongation apparatus) [30].

Short span compressive strength was measured according to T 826 pm-92 "Short span compression strength of containerboard" [31].

Brightness was measured according to ISO 2470 "Paper, board and pulps - Measurement of diffuse blue reflectance factor – Part 1: Indoor daylight conditions (ISO Brightness) [32]. Opacity was determined according to ISO 2471:2008 Paper and Board: Determination of Opacity (Paper Backing) – Diffuse Reflectance Method [33].

Whiteness/Color was measured according to ISO 11476:2016 "Paper and Board – determination of CIE Whiteness, C/2° (Indoor Illumination Conditions)" [34].

2.3 Repulping Development Procedure

The laboratories projects repulping procedure, as shown in Fig. 3 was based on an earlier 2022 study by Dölle, Jeva and Iribarne where repulping under a pH of 10, a temperature of 150°F (65.6°C), and an 1% Oxone addition achieved optimum results [8]. First, the collected LCB and OCC material was cut with scissors it into approximately 1-to-2-inch (25 to 50 mm) pieces prior to the five performed repulping runs containing: (i) 100% OCC containing 450.0 g OCC material, (ii) 75% OCC/25% LCB containing 337.5 g OCC and 112.5 g LCB material, (iii) 50% OCCC and LCB containing 225.0 g of both materials, (iv) 25% OCC/25% LCB material containing 112.5 g OCC and 337.5g LCB, and (v) 100% LCB (450.0g) material. For repulping 10 l (2.64 gal.) of water were heated to an initial temperature of 150°F (65.6°C). Then 450.0 g of the prepared cut raw material on an Oven Dry (OD) bases were added to achieve a 4.5% Solids Content (SC). 1% Oxone addition followed based on Oven Dry (OD) fiber content. The repulping pH was adjusted to a pH of 10 using Sodium Hydroxide pellets.

Temperature and pH were measured with a portable Milwaukee MW102 pH/temperature meter as well as a Therm-Pro handheld temperature probe.

After repulping the pulp suspension had a temperature between 140°F to 145°F (60.0°C to 62.8°C) and was filled in a 5-gallon (18.9 l) PVC pail and cooled down to room temperature of 68°F (20°C). The repulped content of each pail was screened with a No. 5 mesh (4 mm) 200 mm diameter screen pan and the usable fiber material was collected with large screening box lined with a No. 150 mesh (105 µm) screen. The recovered fiber material from each repulping trial was collected in 2-gallon (7.6 l) plastic bags. Prior to handsheet making the plastic bag content was diluted and prepared according to TAPPI method T 205 sp-12 [XX].

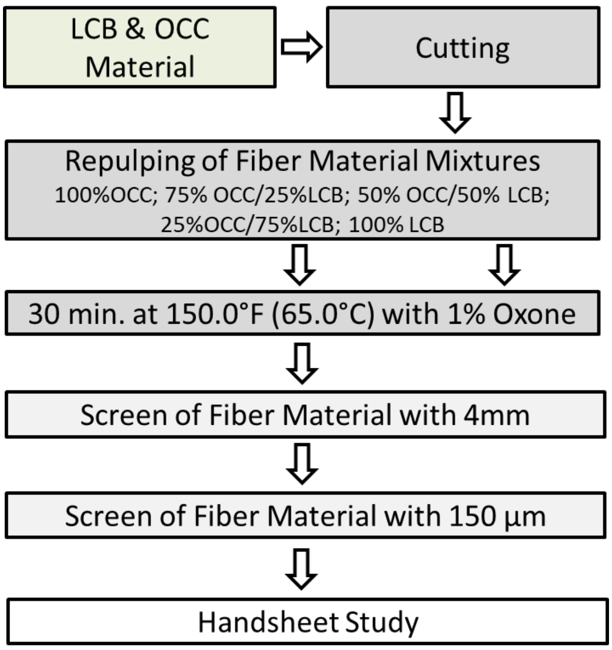

Fig. 3. Repulping development procedure

2.4 Repulping if Aseptic Packaging Materials

Repulping of OCC/LCB material was carried out to simulate an industrial process. Fig. 2a), shows a simplified process sketch of such a process utilizing a repulper machine as continuous process. In general, a commercial continuous pulper has an internal screen device for presorting and an external screening machine for secondary screening based on the type of recovered material processed.

The repulping consistency of a commercial continuous process is around 4.5% with a theoretical retention time of approximately 30 minutes based on material OD content. During continuous repulping operation unwanted material such as metal, sand, plastic and hard to process recycled material is removed from the fiber slurry with screening processes [13]. The fiber slurry containing the recycled fiber material is forwarded to the papermaking operation. The recovered material is thickened and baled and then feed into recycling industries recovered material stream for the manufacture of new recycled metal and plastic materials [17].

The chosen laboratory operation, based on Fig. 2b), simulates a continuous repulping of the OCC & LCB recycled fiber material at a solids content of 4.5% in a 0.75 kW (1.0 hp), 3 gallons (11.35 liter) laboratory pulper, shown in Fig. 4 using 400 g of the OCC/LCB material, and 10 l (2.64 gal.) of water. The repulping procedure for each repulping sequence as explained in Section 2.3. was used. During laboratory repulping centrifugal and mechanical forces separate the individual fibers and unwanted materials from the 1-to-2-inch (25 to 50 mm) cut OCC/LCB material pieces and bring them in suspension. Fibrous material as well as unwanted material such as polyethylene components in the suspension can be recovered by using a screening process.

2.5 Screening

Screening out usable fiber material from the individual repulping runs done, as described by Dölle et.al. (2022), by filling a portion of the repulped slurry into a No. 5 mesh (4 mm) screen pan and washing out the usable fiber material with water at a temperature of 40°C applied with a water hose [8]. Unusable material such as polyethylene, and wet strength material, etc. was retained on the screen, see Fig. 2b), collected, and moved into a 4-liter plastic beaker and discarded later. The usable fiber material passing the screen was collected in a larger scree box with a 150 mesh (105 µm) screen lining. The retained fibers, see Fig. 2b), in the screen box were double checked for contamination before they were moved in a 2-gallon (7.6 l) plastic bags. The collected rejects were diluted again and screened a second and third time to recover all usable fibers, which were put in the plastic bag thereafter.

2.5 Paper Handsheet Making

Handsheets with a target basis weight of 70 g/m² instead of 60 g/m² were prepared from the recovered OCC and LCB fiber material by following TAPPI test method T 205 sp-06 [18]. However, handsheet making pre-trials showed it was easier to produce 70 g/m² handsheets without defects as using the test methods 60 g/m² basis weight handsheets.

Fig. 4. Low consistency laboratory repulper [35]

Prior to handsheet making the recovered fiber material was diluted to 1.2% consistency and processed in a TAPPI style disintegrator to disperse the fibers. To prepare the handsheets, a 0.3% pulp solution was prepared and added to the handsheet forming apparatus to produce 70 g/m² handsheets for later optical and mechanical evaluation.

The produced handhseets were labeled and placed in a climate-controlled room with 50% relative humidity and a temperature of 23°C for conditioning, according to TAPPI T-402 sp-06 test method [23]. These steps were repeated for all repulping runs.

3. RESULTS AND DISCUSSION

3.1 Repulping

3.1.1 Energy consumption

Fig. 5. shows the energy consumption of the five repulping mixtures at pH 10, a repulping temperature of 150°F (65.6°C), 1% Oxone addition, and repulping time of 30 minutes. Each pulp mixture has a slightly varying power consumption for operating just under water and with and with the various pulp mixtures. The resulting power consumption in kWh measured with a PN2000 electronic power monitoring device showed that the 100% OCCC and 75% OCC and 25% LCB mixture resulted in a power consumption of 0.21kWh or 466.66 kWh/mt, whereas the 75% LCB and 25% OCCC and 100% LCB mixture power consumption was at 0.22 kWh or 488.88 kWh/mt. the Highest Power consumption was measured for the 50% split of OCC and LCB at 0.23 kWh or 511.11 kWh/mt.

3.1.2 Freeness evaluation

After repulping, cooling down the repulped fiber suspension, and screening as described in section 2.4 and 2.5, each pulp suspension was diluted to a 0.3% consistency applying TAPPI Testing methods T 205 sp-12 and T 240 om-07 [18,21], followed by Freeness testing of the different pulp suspensions according to TAPPI to T 227 om-09 [22].

Fig. 6 shows the freeness testing results. The pulp suspension containing OCC and LCB only had a CSF of 651 ml and 629 ml respectively. The 75% OCC and 25% LCB split resulted in a CSF of 688 ml, whereas the 75% LCB and 25% OCC split resulted in a 11-point lower freeness of 677 ml. The highest CSF level was measured for the 50% OCC/LCB spit with 715 ml.

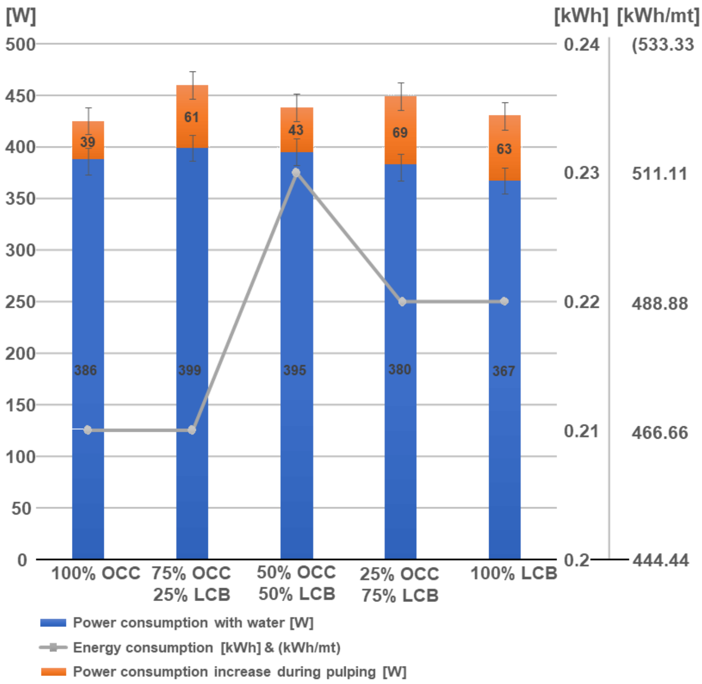

Fig. 5. Energy consumption of OCC and LCB mixtures

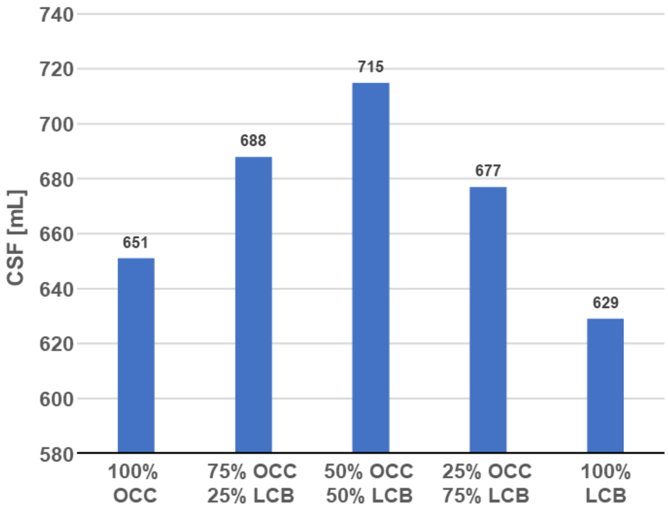

Fig. 6. CSF level of OCC and LCB mixtures

3.1.3 Visual hansheet evaluation

The visual handsheet evaluation inf Fig. 7 shows, that OCC and LCB only have a very low flake content, indicating that a repulping time of 30 minutes is sufficient. Handsheets prepared with the OCC and LCB split show a higher flake content that is visualized by the dark and light dots on the hansheets. This indicates that the pulping time was to short and/or an additional deflaking process step might be needed.

The repulping results indicates that repulping of OCC and LCB together might require a higher energy input for repulping then OCC material alone, whereas repulping LCB only resulted in slightly higher energy consumption. Measuring the CSF level of the resulting pulp suspension indicates that a mix of OCC and LCB fibers might need more refining and energy to achieve a CSF level, for instance CSF of 450 ml, that is suitable for a paper making operation. Repulping and processing the OCC and LCB material separately including refining might be more economical, because the LCB material requires more repulping energy, but less refining due to the lower CSF compared to the OCC/LCB split repulping tests. In addition, a separate process line might give more versatility regarding the composition of the pulp suspension before papermaking.

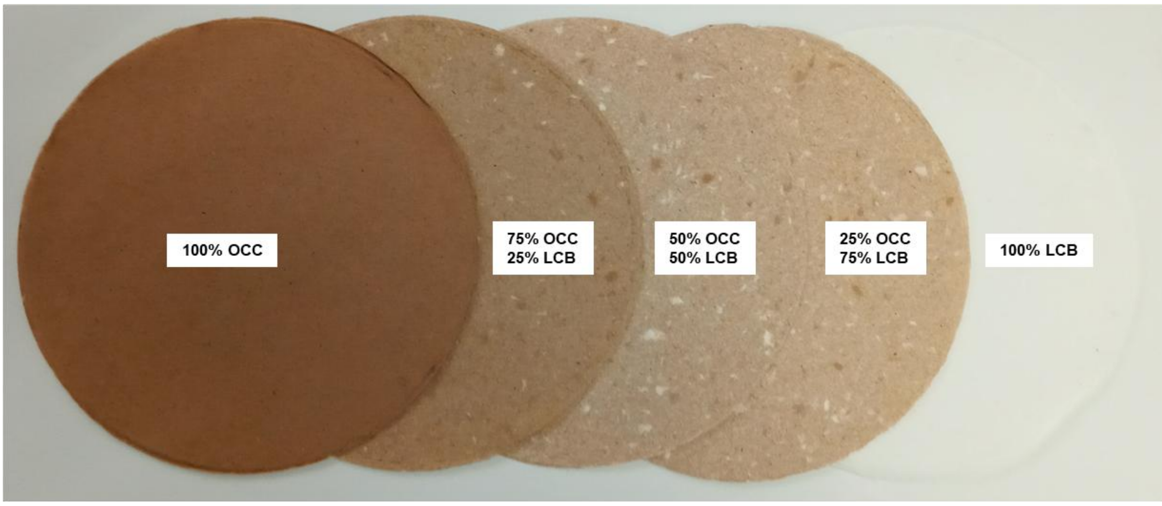

Fig. 7. Handsheets of OCC and LCB mixtures [36]

3.2 Handsheet Properties

Handsheets were made from each repulping run with a target basis weight of 70 g/m² according to T 205-sp-12 [18] and tested to the in Section 2.2. listed TAPPI testing standards for mechanical and optical properties. All tests were performed in the standard conditioning and testing atmospheres according to T 402 sp-08 at a temperature of 23°C ± 1°C and a humidity of 50% ± 2%. All results stayed in the precision statements for the referenced TAPPI and ISO methods.

Values of the measured paper properties are shown in the radar diagram Fig. 8 on a 0% to 100% value with actual testing results with the actual numerical value.

All mechanical paper testing values are shown as an index based on the basis weight of the paper handsheets tested, except for Porosity, Elongation, Tensile Energy Absorption (TEA) and 0-Span which is corrected to a 60 g/m² value.

3.2.1 Burst index

The Burst Index (BI) of the manufactured handsheets is measured according to T 403 om-02 [24]. Handsheets with recycled and repulped OCC material had the highest BI of 1.09 kPa*m²/g followed by the handsheets containing LCB fibers only with a BI of 0.84 kPa*m²/g.
Handsheets containing a 75% OCC/25% LCB, 50%OCCand LCB split, and 25% OCC/75% LCB split had a BI of 0.84 mNm²/g, 1.05 mNm²/g, and 0.81 mNm²/g.

3.2.2 Tear index

The Tear Index (TI) of the manufactured handsheets is measured according to T-414 om-98 [28]. Handsheets with recycled and repulped OCC material had the highest TI of 13.42 mNm²/g followed by the handsheets containing LCB fibers only with a BI of 13.42 mNm²/g.

Handsheets containing a 75% OCC/25% LCB, 50%OCCand LCB split, and 25% OCC/75% LCB split had a TI of 12.14 mNm²/g, 12.56 mNm²/g, and 11.85 mNm²/g.

3.2.3 Short compression test strength index

The Short Compression Test Strength (SCTS) index was measured according to T 826 pm-92 [31]. The SCTS index for handsheets containing repulped OCC material only was at the lowest SCTS index of 11.40 kNm/g. The highest SCTS index was at 13.36 kNm/g for the handsheets containing a 25% OCC/ 75% LCB split, followed by handsheets containing a 75%OCC/25% LCB with a SCTS index of 13.24 kNm/g. Handsheets with a 50% split of OCCC & LCB and 100% LCB fibers only had a SCTS of 12.56 kNm/g and 13.08 kNm/g respectively.

3.2.4 Zero span

Zero-Span (ZS) data measured with T 231 cm-07 [20] and normalized to a 60 g/m² basis weight. Handsheets containing only recycled and repulped OCC material had the highest ZS of 10.13 kg/15mm followed by the handsheets containing a split of 50% OCC and LCB fibers and 100% LCB fibers only with a ZS of 9.18 kg/15mm. Handsheets containing a split of 75% OCC and 25% LCB fibers had a ZS of 8.23 kg/15mm. the lowest ZS value was measured for handsheets having a 25% OCC and 75% LCB split at a value of 7.50kg/15 mm.

3.2.5 Tensile index

Tensile strength of handsheets was measured according to T 494 om-06 [30] and reported as Tensile Index (TI). For handsheets made from 100% recycled and repulped OCC material had the highest TI o 29.20 Nm/g followed by handsheets containing a fiber split of 75% OCC and 25% LCB with a TI value of 25.26 Nm/g and handsheets containing 100 LCB fibers at a value of 23.08 Nm/g. Handsheets with a fiber split of 25% OCC and 75% LCB has a value of 22.30 Nm/g and handsheets with a fiber split of 50% OCC and LCB resulted in the lowest TI value of 21.92 Nm/g.

3.2.6 Elongation

Elongation of the handsheets was measured according to T 494 om-06 [30]. Handsheets made from 100% recycled and repulped OCC and 100% LCB material had the highest elongation of 1.43% and 1.29% respectively. Elongation of Handsheets made with a fiber split of 50% OCC and LCB resulted in a value of 1.22%. Handsheets with a fiber split of 75% OCC and 25% LCB and 25% OCC and 75% LCB had an measured elongation of 1.02 and 1.04 respectively.

3.2.7 Tensile energy absorption

Tensile Energy Absorption (TEA) was measured according to T 494 om-06 [30]. Handsheets made from 100% recycled and repulped OCC and 100% LCB material had the highest TEA of 19.26 J/m² and 16.04 J/m² respectively. Elongation of Handsheets made with a fiber split of 50% OCC and LCB resulted in a TEA value of 11.66 J/m². Handsheets with a fiber split of 75% OCC and 25% LCB and 25% OCC and 75% LCB had an measured TEA of 11.66 J/m² and 11.43 J/m² respectively.

3.2.8 Porosity

Porosity was measured according to T 460 om-02, which tests the air resistance of paper according to the Gurly method which measures the time it takes to flow 100 ml of air through paper handsheet [29]. Handsheets made from 100% recycled and repulped OCC and 100% LCB material had the highest value of 1.00 s/100 ml and 0.9 s/100 ml respectively. Handsheets made with a fiber split of 50% OCC and LCB resulted in a time value of 0.4 s/100 ml. Handsheets with a fiber split of 75% OCC and 25% LCB and 25% OCC and 75% LCB had an measured time value of 0.6 s/100 ml and 0.7 s/100 ml respectively.

3.2.9 Optical handsheet properties

Optical properties of the produced handsheets from the five repulping runs, shown in Fig. 9 were measured according to ISO standards. Color (L, a, b) and CIE was measured according to ISO 11476 [34], Opacity was measured according to ISO 2471 [33], Brightness was measured according to ISO 2470 [32].

Color: L, a, b - Color measured for the 100% OCC conganging paper handsheets was at 57.35, 5.50, 19.06 respectively being the darkest brown color. The paper handsheets containing 100% LCB the L, a, b color was 85.28, -0.65, 0.47. respectively, being the color most closely to white.

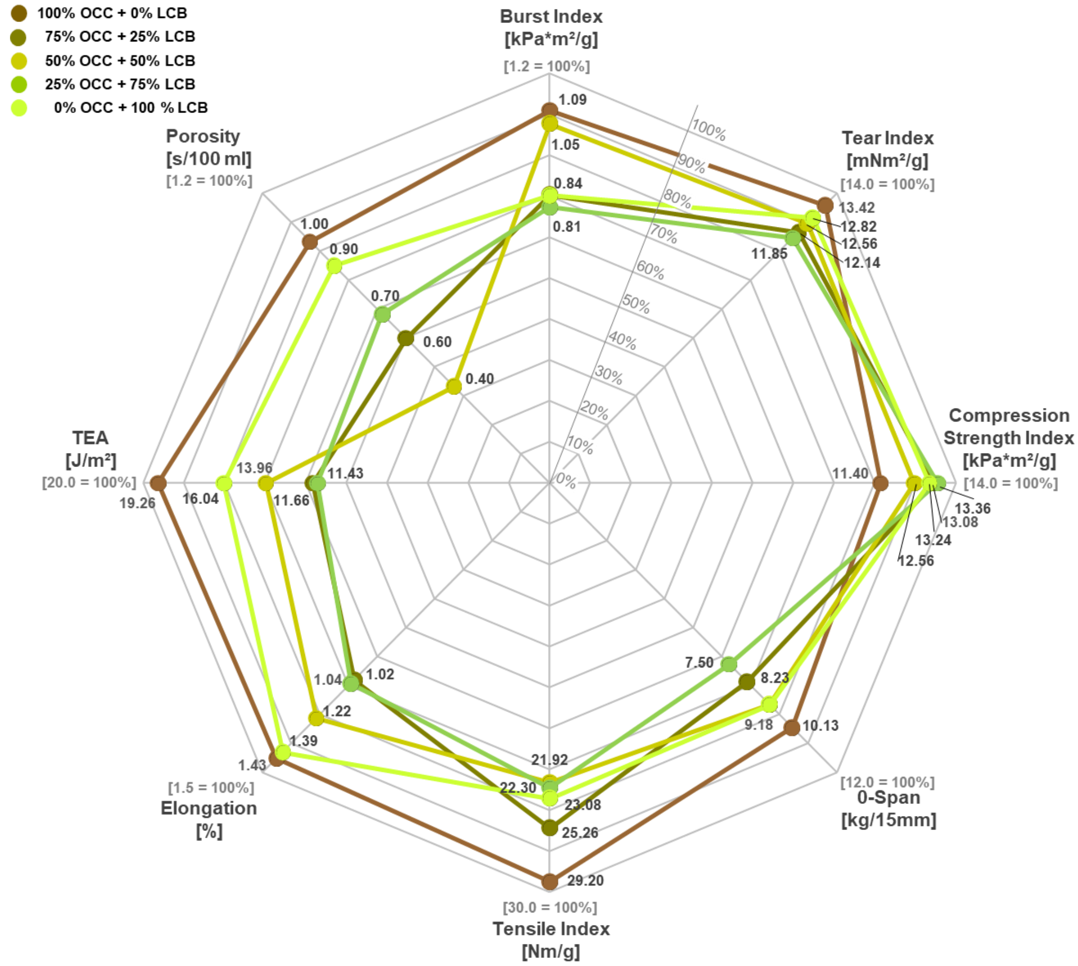

Fig. 8. Mechanical handsheet paper properties of OCC and LCB mixtures

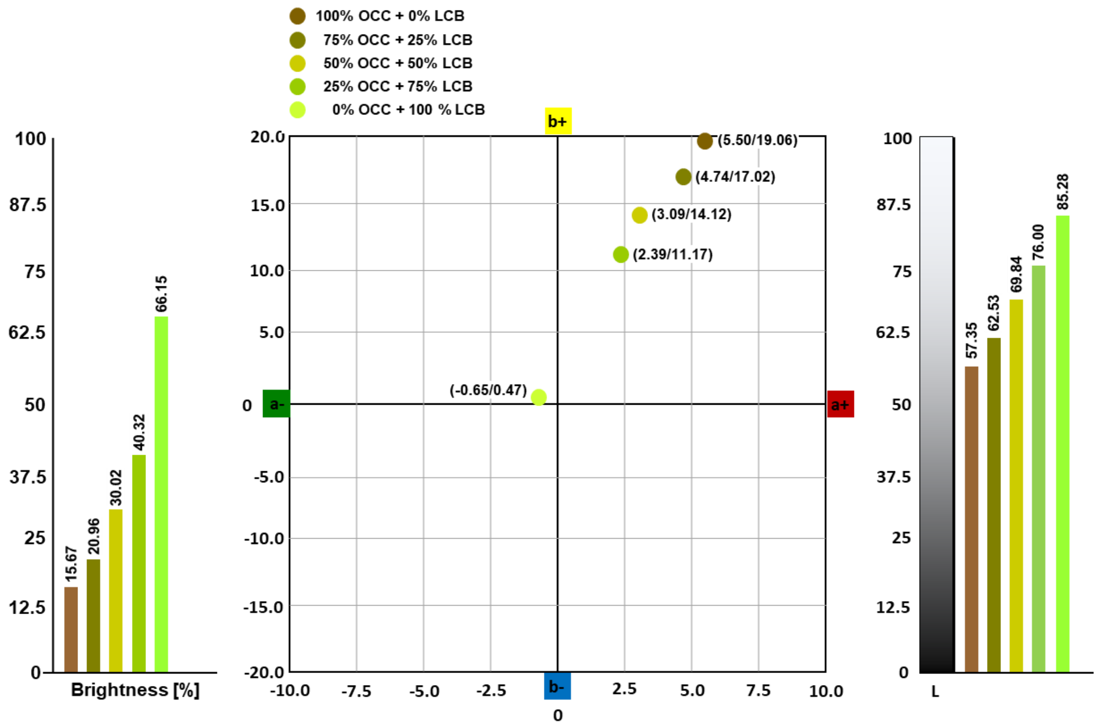

Fig. 9. Optical handsheet paper properties of OCC and LCB mixtures

Handsheets produced with a 75% OCC and 25% LCB fiber split had a L, a, b – color of 62.53, 4.74, 17.02 respectively. The 50% OCC and LCB fiber containing handsheets had a L, a, b – color of 69.84, 3.09, 14.12 respectively. Handsheets with a 15% OCC and 75% LCB composition showed a L, a, b – color value of 76.00, 2.39, 11.17 respectively.

The color of handsheets increased from a dark brow color to a white color based on increasing LCB fiber content, because of the virgin bleached softwood fibers used to manufacture the LCB paper product [Reference raw material].

Brightness: The resulting Brightness was measured on a 100% scale for the produced handsheets manufactured from the five different repulping mixtures.

The handsheet containing only LCB fiber had the highest brightness of 66.15.%. Increasing OCC fiber content in the repulping mixture resulted in a decrease of the brightness value, whereas a OCC fiber content of 25%, 50% and 75% resulted in a brightness value of 40.32, 30.02, 20.96 respectively. Handsheets manufactured with 100% OCC fiber resulted in the darkest brightness value of 15.67%.

Opacity: The resulting opacity measured for the produced 70 g/m² handsheets with the different OCC and LCB fiber compositions showed a value of 100% for all handsheets.

4. CONCLUSION

In the recent past internet sales increased, customer behavior and legislature actions require more environmentally friendly packaging materials and the utilization of recycled material, such as fiber material from LCB packaging material.

LCB packaging materials may contains over 75% virgin bleached fiber material that can be used to offset and or upgrade existing board products.

In this laboratory handsheet study, repulping of currently used OCC material, and presently not utilized LCB recycled material was investigated to produce fibrous material for board paper production. All tests conducted were done according to TAPPI and ISO testing standards.

OCC and LCB recycled fiber material was repulped for 30 minutes at a pH of 10, a temperature of 150°F (65.6°C), and 1% Oxone addition based on fiber content under laboratory conditions.

Repulping results indicates that repulping of OCC and LCB together might require a higher energy input for repulping and processing afterwards due to a higher CSF level compared to OCC material alone, whereas repulping LCB only resulted in slightly higher energy consumption and slightly higher CSF level.

Repulping at various OCC and LCB contents resulted in a higher visible flake content, whereas repulping OCCC and LCB material alone showed good disintegration of the material.

Handsheets made from repulped material containing OCC fiber material only showed higher paper properties for the BI, TI ZS, TI, elongation, TEA and Porosity except for SCTS which in comparison to the OCC/LCB mixtures. However, paper handsheets containing an OCC/LCB had a higher flake content that might have influenced mechanical properties. Handheets made from repulped LCB fiber materials showed good properties for the TI, SCTS ZS, elongation and TEA in comparison to OCC fiber material only handsheests. It can be expected if to OCC/LCB fiber mixtures a deflaking process is added higher mechanical paper properties values are achieved.

Increased LCB fiber content increased the brightness and color of the manufactured handsheet from OCC only containing handsheets from 16.67 to 66.15.

Opacity values were at the 100% level for all handsheets produced containing different amounts of OCC and LCB fiber.

LCB fibers can be used as a valuable source of recycled fiber material with the potential to upgrade board paper products regarding mechanical an optical requirement. However, more research is needed to assess the optimum LCB fiber addition and processing condition such as applying deflaking and refining regarding improvement of mechanical and optical properties of the resulting board paper product.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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