Innofibre
Centre d'innovation
des produits cellulosiques

Assessment of the feasibility of developing a loose-fill insulation material from cartons

Pilot study carried out by
Innofibre – Centre d'innovation de produits cellulosiques
and
SEREX

In collaboration with
Carton Council of Canada

Report prepared by:

Maude Tessier-Parenteau

Maude J. Parenteau, ing.

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Researcher

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1. Introduction

Cartons are a type of food and beverage packaging available in two forms: shelf-stable cartons (also known as aseptic cartons) and refrigerated cartons (gable top cartons). Cartons are primarily composed of paperboard to which fine layers of polyethylene are added. Shelf-stable cartons also contain a thin layer of aluminum.

Aseptic cartons consist, on average, of 74 percent fibre, 22 percent polyethylene and 4 percent aluminum. Products available in aseptic cartons include juice, milk, plant-based beverages, soups and broths, as well as wine. Gable top cartons, meanwhile, contain approximately 80 percent fibre and 20 percent polyethylene. Products available in gable top cartons include milk, juice, cream, egg substitutes and plant-based drinks.

Innofibre and SEREX are both applied research and technology transfer centres in Quebec, specializing in cellulosic products and wood-based products, respectively. Both are part of the college centres for the transfer of technologies (CCTT).

In 2025, Innofibre and SEREX carried out a project funded by the technology innovation arm of the Government of Quebec's *Programme d'aide à la recherche et au transfert* (research and transfer assistance program, known by its French acronym PART). One of the project's objectives was to assess the feasibility of developing a carton-based loose-fill insulation material for use in sustainable building. An insulation manufacturer was recruited to take part in the project[1].

At the invitation of Innofibre, Carton Council of Canada (CCC) joined the project as a partner. CCC is a coalition of carton manufacturers[2] working together and with other stakeholders to deliver long-term solutions that will increase the recovery and recycling of cartons in Canada. This work includes supporting the development of new end markets for end-of-life cartons.

This report details the activities related to this project. It is primarily intended for stakeholders in the cellulose insulation industry who are seeking a new source of quality fibres for their loose-fill insulation products.

[1] For confidentiality reasons, the identity of the partner in question is not disclosed in this report.
[2] The members are Elopak, Novolex, SIG Combibloc and Tetra Pak.

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1.1 Background – The cellulose market

Cellulose insulation is a material traditionally made from recycled newspaper (commonly referred to as old newspaper, ONP). It reduces the transmission of heat and sound, is effective and environmentally friendly, and can help secure LEED credits in construction.

However, in the last decade, there has been a major reduction in the availability of ONP, accompanied by a sharp rise in its cost per tonne. To remain competitive and maintain production, cellulose manufacturers are seeking to partially replace ONP with other fibre sources. Some of them have already begun, for example, to turn to old corrugated containers (commonly referred to as OCC).

Cartons contain long, bleached fibres that are among the best in the recycling supply chain. Currently, four paper mills in North America are transforming cartons into new cellulose-based products, such as tissue and writing paper[3,4]. A number of mills also accept cartons in mixed paper bales. Although the processing of cartons into insulation products is already a reality elsewhere in the world[5], this is not currently the case in North America.

Within that context, cartons could represent an opportunity for cellulose insulation manufacturers, not only to ensure a stable supply, but also to continue contributing to reducing the environmental footprint of the construction sector.

1.2 Project objective

The general aim of the project was to assess the feasibility of incorporating post-consumer cartons into the manufacture of loose-fill cellulose insulation. The specific objectives were as follows:

- assess the feasibility of achieving, with cartons, a density equal to or lower than that obtained with OCC, a substitute for ONP in the manufacture of cellulose insulation (the lower the density of the cellulose, the better its insulating properties);
- investigate the effect of non-fibrous components in cartons (plastic and aluminum) on the performance of the insulation;
- determine the optimum proportion of cartons in the insulation mix and compare the results obtained with the requirements for the current cellulose insulation product.

[3] These are Sustana (mills in Lévis, Québec, and De Pere, Wisconsin), Kimberly-Clark (mill in Ecatepec, Mexico), and Essity (mill in Cherokee, Alabama).
[4] Cartons are also recycled into building materials (mainly roof cover boards) by the company ReCB in Des Moines, Iowa, and in Lodi, California.
[5] See, for example, the company called Insulation Plus (https://www.insulation.plus) which operates in Argentina.

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2. Methodology and results

The project was divided into two main stages: the conditioning of cartons and the development of a loose-fill insulation material. These stages and the corresponding results are described in the following subsections.

2.1 Carton conditioning

Carton conditioning consists of the stages of grinding, refining and drying the cartons in order to achieve the desired physical properties.

2.1.1 Conditioning at the partner facility

Several visits to the loose-fill insulation manufacturing partner helped determine the appropriate conditioning for cartons. The aim was to replicate an industrial process as closely as possible in order to obtain a product that most closely matched real-world factory operating conditions.

The partner currently has one conditioning line for ONP and two lines for OCC.

The material currently used by the partner is quickly sorted by operators and is then fed into a series of grinders to reduce its size. All the ground material, including the flame-retardant additives, then passes through a dry refiner.

The partner explained that the additives must be incorporated at the same time as the material is refined, as it is the heat generated in this equipment that enables the flame-retardant additives to bind to the material.

The partner also explained that the main challenge was the product's density (or bulk density), which had to remain as low as possible. Given that Innofibre would be unable to replicate the process with the addition of the flame retardant, it was agreed with the partner that the aim of the study was to determine whether it was possible to achieve, with the cartons, a density equal to or lower than that obtained with containerboard.

2.1.2 Conditioning and dry refining trial

To do this, Innofibre separately conditioned and dry refined the three materials: OCC, ONP and cartons. OCC was easy to source, but acquiring 50 kg of ONP proved somewhat of a challenge. Innofibre was eventually able to obtain a significant quantity of old books printed on newsprint-type paper. As for the cartons, a bale was obtained from a material recovery facility (MRF) in Québec (Figure 1) and then unpacked by hand. All straws and caps were removed from this material sourced from the MRF to prevent contamination by plastics, which could have resulted in a higher density.

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Figure 1: Bale of recycled cartons



To reduce the size, each material was slowly ground in the WEIMA slow-speed grinder (Figure 2), fitted with a screen with 30 mm openings. A high-speed hammermill grinder (Figure 3), fitted with a screen with 22 mm openings, was then used.

Figure 2: Slow-speed grinder



Figure 3: High-speed hammermill grinder



For the dry refining stage, Innofibre's low-consistency (wet) pulp refiner was adapted as a dry refiner by adding a cyclonic separator and a fan to extract the material collected in a drum (Figure 4). By way of comparison, the diameter of the discs in the Innofibre refiner is 24 inches, while those in an industrial refiner are larger. This is a significant difference and may result in outcomes that are difficult to compare between the material produced at Innofibre and a commercial product. However, a comparison between materials refined at Innofibre makes it possible to determine whether cartons can produce insulation similar to that manufactured commercially from OCC.

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Figure 4: Refiner and cyclonic separator





Table 1 shows the operating parameters used for the dry refining trials.

Table 1: Operating parameters used for dry refining trials

Trial	Air gap (mm)	RPM (rev/min)
OCC	5	600
OCC	3.5	
OCC	2	1000
ONP	2	
Cartons	2	
Cartons	1.5	

Figure 5 shows photographs of the materials obtained under the various refining conditions.

The materials produced under the operating conditions that yielded the finest particle size, and which had an appearance comparable to that of the commercial product, were sent to SEREX so that the

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necessary analyses could be conducted to determine their properties as loose-fill cellulose insulation, in accordance with the applicable requirements of the CAN/ULC-S703 standard.

Figure 5: Photographs of the materials obtained under different refining conditions



Refined OCC, 5 mm air gap, 600 rpm



Refined OCC, 3.5 mm air gap, 600 rpm



Refined OCC, 3.5 mm air gap, 1000 rpm



Refined OCC, 2 mm air gap, 1000 rpm



Refined OCC, no high-speed grinding, 2 mm air gap, 1000 rpm



Refined ONP, 2 mm air gap, 1000 rpm

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Refined cartons, 2 mm air gap, 1000 rpm



Refined cartons, 1.5 mm air gap, 1000 rpm



Loose-fill cellulose — reference commercial insulation

2.2 Material properties and insulation performance of blends incorporating cartons

The following section outlines the properties of the materials under study: commercial cellulose insulation used as reference — referred to hereafter as "cellulose" — cartons, OCC and ONP; as well as the results of the assessment of the insulating performance of blends incorporating cartons.

The reference cellulose contains a mixture of ONP and OCC.

2.2.1 Density

Density (also known as bulk density) was determined in accordance with the CAN/ULC-S703 standard and is defined as the ratio of the mass of the insulation to the volume it occupies after installation, including interstitial air gaps. It was measured using representative samples placed in containers of known volume. Table 2 shows the results obtained for the various materials studied. It also shows the limiting design density, a term that takes into account the method of application (blowing into attics, into walls, etc.) and the settling phenomena that can be expected over the lifetime of the product. It thus enables the setting of a safety threshold, below which the thermal performance and homogeneity of the insulation cannot be guaranteed. The limiting design density value was calculated from the measured bulk density by multiplying it by a factor of 1.21 in accordance with the CAN/ULC-S703 standard.

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Table 2: Bulk density and limiting design density

ID	Theoretical bulk density (kg/m^3)	Standard deviation (kg/m^3)	Coefficient of variation (%)	Limiting design density (kg/m^3)
Cellulose	25.9	1.80	6.96	31.3
Cartons	31.5	1.82	5.78	38.1
OCC	31.2	2.47	7.94	37.7
ONP	29.7	1.25	4.20	35.9

The bulk density obtained for cellulose is relatively lower than that of the other materials, as this is the commercial product, refined in the partner's refiner, whereas the one at Innofibre is half the size.

When comparing the three materials conditioned at Innofibre, it appears that cartons have a bulk density very similar to that of OCC.

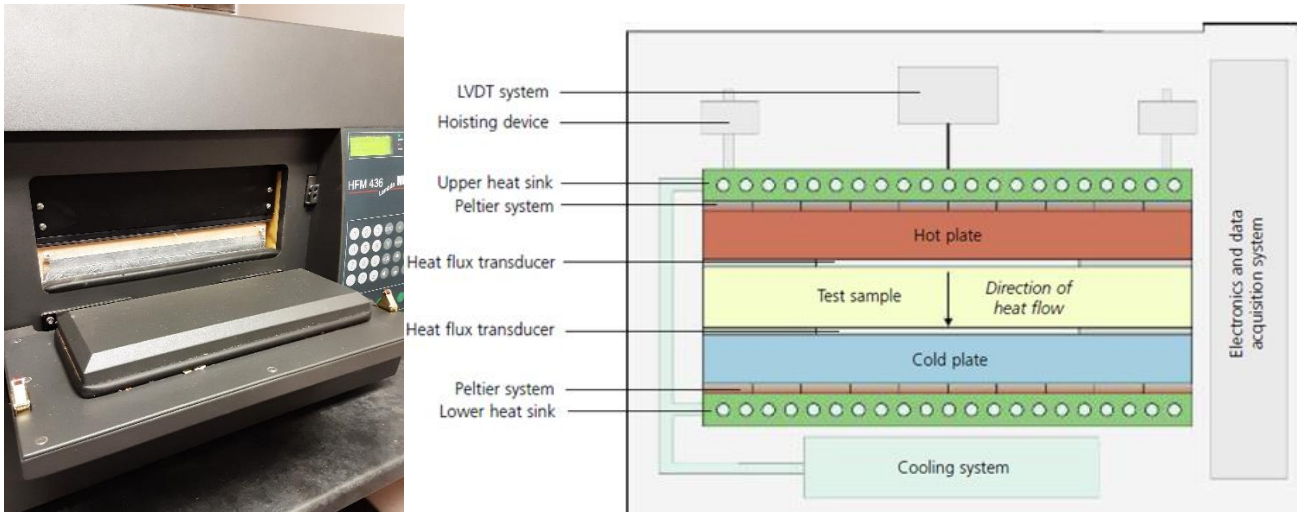
2.2.2 Thermal conductivity and specific heat

Six samples per material type were tested at this stage to determine their thermal conductivity and specific heat in accordance with the ASTM C508 standard (Figure 6). The trial involves placing the sample in a frame (300 x 300 x 45 mm) so that it has a density of 50 kg/m^3. The frame is then inserted between the device's two heated plates, with a temperature difference of 20 °C. The sample is at room temperature at the start of the trial.

Heat transfer then begins from the hot zone to the cold zone until thermal equilibrium is reached. This allows thermal conductivity to be calculated, which is also related to the insulation value R — a measure of thermal resistance — and specific heat. The latter is used to determine a material's ability to store or release heat when it is heated or cooled. The higher the specific heat, the more energy is required to raise the temperature of a set mass of the material.

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Figure 6: Thermal conductivity analyzer and test principle for measuring thermal conductivity and specific heat



Good loose-fill insulation will therefore have low thermal conductivity, high thermal resistance (or a high R-value), and a high specific heat capacity to optimize energy performance and thermal comfort.

Table 3 shows the results obtained. The comparative analysis, based on a constant density of 50 kg/m³, reveals significant differences in performance.

The refined ONP at Innofibre and the partner's cellulose show similar thermal conductivity values (0.0405 and 0.0407 W/m·K respectively) and, consequently, the highest R-values per inch (3.56 and 3.54), indicating that the conditioning conducted at Innofibre yielded a relatively comparable result.

OCC exhibits a slightly higher thermal conductivity (0.0429 W/m·K), but a similar specific heat. The partner had actually mentioned that OCC generally exhibited less favourable thermal properties, but that the final product met the market's thermal requirements.

Cartons exhibit higher thermal conductivity (0.0499 W/m·K) and a lower R-value per inch (2.89), indicating that their insulating performances are relatively inferior to that of other materials. These results show that the conditioning would probably need to be optimized in order to use this raw material in the process.

Table 3: Thermal conductivity, thermal resistance and specific heat of the materials studied

ID	Bulk density (kg/m³)	Thermal conductivity (W/(m·K))	R value (h·ft²·°F/Btu)	Specific heat (MJ/m³K)
Cellulose	50	0.0407	3.54	0.080
Cartons	50	0.0499	2.89	0.084
OCC	50	0.0429	3.36	0.088
ONP	50	0.0405	3.56	0.088

2.2.3 Insulation performance of cartons/cellulose blends

The initial objective at this stage was to optimize the proportion of the substitute in the insulation blend and to compare the results obtained with the specified requirements. Two cartons/cellulose blends were studied, namely 25/75 and 50/50. Thermal performance was assessed in terms of thermal conductivity and specific heat, based on a constant density of 50 kg/m³.

Analysis of the results shown in Table 4 and Figure 7 reveals that the thermal conductivity of cartons is higher than that of cellulose. An increase in thermal conductivity was to be expected when the cartons were incorporated into the cellulose. The results confirm this tendency, but show that the increase remains relatively small, around 10 to 13 percent depending on the proportions, as illustrated in Figure 7.

Similar observations apply to the R-value per inch, which is more commonly used in industry, where the addition of the cartons results in a slight decrease in thermal resistance, without, however, significantly compromising the overall performance of the blend. The observed values for specific heat show no significant variation.

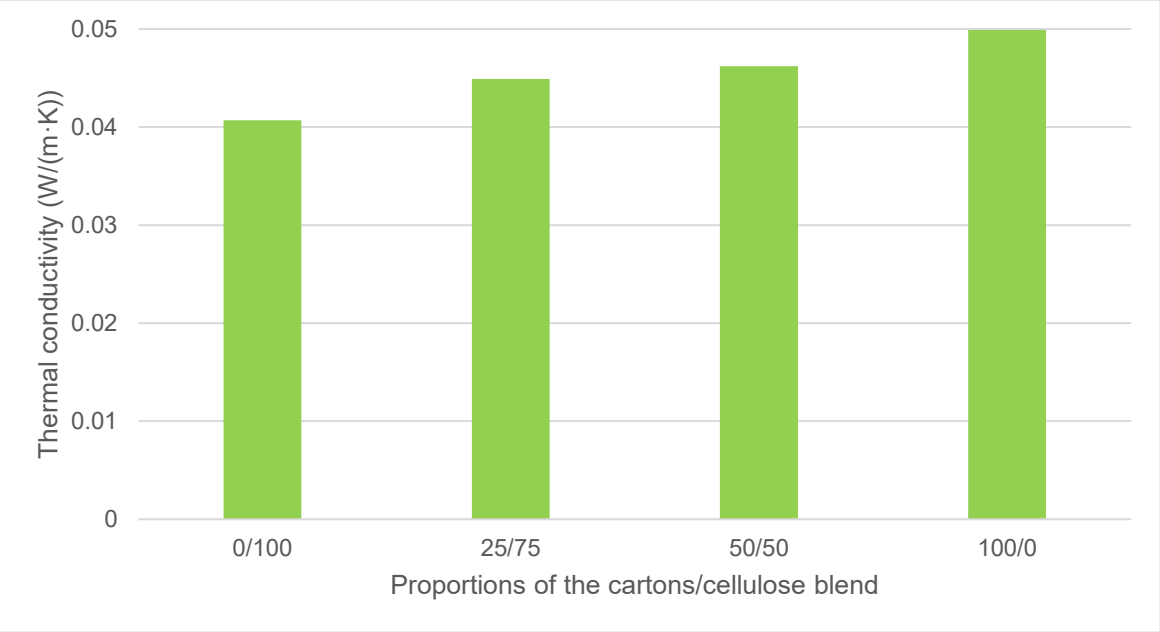
In light of these results and discussions with the partner, in any subsequent project it would be appropriate to blend the materials prior to the dry refining stage in order to align more closely with the commercial process.

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Table 4: Thermal conductivity, thermal resistance and specific heat of the blends

ID	Bulk density (kg/m^3)	Thermal conductivity (W/(m·K))	R value ($h·ft^2·°F/Btu$)	Specific heat (MJ/m^3K)
Cellulose	50	0.0407	3.54	0.0799
Cartons	50	0.0499	2.89	0.0836
Cartons/cellulose (25/75)	50	0.0449	3.21	0.0768
Cartons/cellulose (50/50)	50	0.0462	3.12	0.0775

Figure 7: Thermal conductivity based on the proportions of the cartons-cellulose blends



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2.2.4 Fire behaviour and resistance

At this stage, the cartons and other materials studied were first treated with a powdered fire-retardant agent containing boric acid, a product commonly used in industry. The laboratory application method involved spraying, whereas in industry, this stage is carried out simultaneously with the refining of the material, so that the heat generated in the refining equipment (approximately 50 °C) allows the flame-retardant additives to bond with the material. At SEREX, the blend was tumbled in a drum coater which helped to ensure a uniform treatment (Figure 8), with the aim of maximizing the dispersion of the treatment agent throughout the material.

Figure 8: Fire-retardant treatment of loose-fill insulation



The assessment of the fire behaviour of cartons and other materials studied was carried out using the cigarette test as per the CAN/ULC-S130–M87 standard (Figure 9). This test is designed to assess the ignition resistance of insulating materials when exposed to a small heat source. The principle involves placing a standard burning cigarette in contact with the sample, under controlled conditions of temperature and air circulation. The test observes whether contact results in ignition, smouldering or flame spread. According to the standard, the test is considered successful when the mass loss of the insulation is less than 15 percent.

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Figure 9: Principle of the cigarette test in accordance with the CAN/ULC-S130–M87 standard



The test was conducted on two samples per material type (cellulose, cartons, OCC and ONP). The results are shown in Table 5. First, it can be seen that the mass loss of the treated cartons following the cigarette test is well below the 15 percent threshold. These results indicate that the treatment used by the partner could potentially be effective in improving cartons' resistance to this ignition source, under the test conditions. However, this test alone does not suffice to conclude that the material is fully compliant with the CAN/ULC-S703 standard, which also includes other fire behaviour requirements, in particular those relating to critical radiant flux.

On the other hand, the results for the other materials studied were mixed: one sample burned (mass loss > 15 percent) while the other did not (mass loss < 15 percent). This variability can be explained largely by the fact that the flame-retardant agent was added cold, after the material had been refined. Thus,

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although particular care was taken during the use of the coating machine, the lack of synergy between the treatment agent and the refining stage prevented the agent from performing to its full potential. It is highly likely that the measurement area of the cigarette test was not representative of the treated sample.

Table 5: Mass loss caused by the cigarette test in accordance with CAN/ULC-S130–M87

ID	Mass loss (%)
Cellulose #1	0.56
Cellulose #2	0.47
Cartons #1	0.01
Cartons #2	0.04
OCC #1	0.23
OCC #2	24.36
ONP #1	1.72
ONP #2	29.51

3. Conclusions

The results of this project have demonstrated, on the scale of a pilot laboratory study, the technical feasibility of a process for recycling post-consumer cartons into loose-fill insulation for use in eco-friendly construction applications. The direct recycling of cartons, without prior separation of their constituents (apart from the removal of caps), made it possible to assess their potential as a raw material, when mixed with ONP and OCC, in the manufacture of cellulose insulation.

The results show that, when conditioned in a manner similar to that applied to ONP and OCC in industrial settings, cartons offer a density comparable to that of OCC. This suggests that a cellulose insulation blend incorporating cartons would have thermal properties comparable to those of cellulose insulation made exclusively from ONP and OCC, and that it could be used in the same way as the latter.

Although cartons themselves offer slightly inferior thermal performance, incorporating them in small proportions into the process remains a viable option. The increase in thermal conductivity observed in the blends remains moderate (10 to 13 percent), which, following optimization of the proportion of cartons, would ensure acceptable insulation performance for everyday applications.

Furthermore, the fire resistance tests carried out indicate that, once treated with a conventional boric acid-based flame retardant, cartons exhibit a mass loss below the 15 percent threshold in the cigarette burn test. This behaviour suggests good compatibility with existing treatments, such as those used in industry. However, to validate overall compliance with the CAN/ULC-S703 standard governing loose-fill insulation, these results should be supplemented by the radiant panel test, a crucial step in assessing surface flame spread.

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In summary, this project confirms that post-consumer cartons have the potential to serve as an attractive, low-cost complementary raw material for the manufacture of eco-friendly insulation, provided that their conditioning and processing are properly managed. The adoption of this approach by cellulose insulation manufacturers would help to increase the number of end markets for this material.

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