The Effect of Old Corrugated Container (OCC) Pulp Addition on the Properties of Paper Made with Virgin Softwood Kraft Pulps

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In this study, old corrugated container (OCC) pulp was added in different ratios (5%, 10%, 15%, 20%, and 25% w/w) to unbleached virgin pulps of both European black pine and Scots pine, and its effects on paper properties were investigated. As a control, OCC pulp-free handsheets were separately produced from European black pine and Scots pine pulps. The results indicated that the addition of OCC pulp decreased the strength properties, except for the tear index, of the handsheets. In addition, compared to the control handsheets, the paper containing the OCC pulp displayed higher air permeability. The results showed that up to 10% of the virgin softwood kraft pulp could be replaced with OCC pulp without bringing about considerable loss of strength. Also, this ratio of OCC addition could be suitable for production of wrapping papers.

Keywords: Black pine; Kraft; OCC; Scots pine; Strength properties; Virgin pulp

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INTRODUCTION

Even though forest resources of the world have been decreasing, paper production has been increasing. The utilization of recycled fibers instead of virgin fibers in paper production has been a significant factor in meeting the raw material needs of the paper industry. In 2011, world pulp and paper production reached about 403 million metric tons, about 53% of which was obtained from recycled fibers (FAO 2011). Paper made from recycled fibers is cost-competitive due to its lower production costs in comparison to virgin fibers (Göttsching 1998). Moreover, paper recycling reduces unnecessary landfilling (Luo and Zhu 2011) as well as the amount of water (Čabalová *et al*. 2011), chemicals (Čabalová *et al.* 2011), and energy (Schmidt *et al.* 2007) used in paper production. Therefore, even though the use of recycled fibers results in a loss in paper strength, paper production in some countries is being conducted using recycled fibers (Nazhad 2005). The main source of recycled fibers is OCC, which represents about 40% of total wastepaper (Guo *et al*. 2011).

The differences between recycled fibers and virgin fibers in terms of morphology and surface properties can be ascribed to treatments during the papermaking process, such as refining and drying (Hubbe *et al.* 2007). Such processes result in reduced swelling capability of recycled fibers due to the fiber stiffening that occurs. This causes a reduction in the bonding areas of the fibers (Nazhad 2005). The loss in swelling ability during the rewetting of recycled fibers has been attributed to hornification (Hubbe *et al*. 2007; Wanrosli *et al*. 2005), which refers to the physical change that takes place in papermaking fibers upon drying. Moreover, recycling also causes the semi-irreversible closure of nano-sized pore spaces (Hubbe *et al*. 2007), loss of specific volume and external surface area of the fibers (Klungness and Caufield 1982), loss of the flexibility and conformability of the fibers (Wanrosli *et al*. 2005), and fiber shortening (Abubakr *et al*. 1995). Eventually, the changes occurring in the fiber properties result in inferior strength properties (Oksanen *et al*. 2000).

The fiber sources of paper mills commonly consist of either 100% recycled or 100% virgin fibers. Some mills are blending both fiber sources. In the blending of virgin and recycled fibers, the primary issue is usually the amount of recycled fibers that can be adapted to virgin fibers rather than the amount of virgin fibers required to improve the inferior properties of recycled fibers (Minor *et al.* 1993). It has been noted that 20 to 40% recycled fibers can be used in papermaking, and that the number of times a fiber can undergo recycling is approximately 10 to 12 (Grozdits *et al.* 2006). Although many studies have been carried out in relation with the use of OCC fiber as a substitute for virgin fiber (Ghasemian *et al.* 2012; Van Tran 2002; Wistara and Hidayah 2010), limited studies have been reported to evaluate the effects of OCC fiber addition on the paper properties of virgin kraft softwood pulp (Fišerová *et al.* 2013).

The aim of this study was to investigate the effects of different ratios of OCC pulp to virgin kraft pulp of European black pine and Scots pine and to determine the resulting paper properties.

EXPERIMENTAL

Preparation of Raw Materials

Logs of European black pine and Scots pine were collected from the Bartin province of Turkey. Wood discs 10 cm in thickness were taken from each log at breast height. These discs were debarked, and each was subdivided into four discs of 25 mm in height. A chisel was used to manually chip each disc as homogeneously as possible to the size of 25 × 15 × 5 mm for pulping. The wood chips were air-dried and stored in dry conditions. The OCC used in this study was obtained from a local recycling company. The morphological characteristics of the OCC, European black pine, and Scots pine fibers were measured as follows: fiber lengths of 1.7, 3.0, and 2.4 mm; fiber widths of 33.6, 46.3, and 39.2 μm; lumen widths of 24.6, 23.4, and 28.6 μm; and double-wall thicknesses of 9, 22.9, and 10.6 μm, respectively.

Preparation of Virgin and Recycled Pulps

The virgin pulps of the European black pine and the Scots pine used in this study were prepared under the following conditions: 20% active alkali as Na_2O, sulfidity 30%, liquor/wood ratio 4:1, cooking temperature 170 °C, time until cooking temperature 90 min, and time at cooking temperature 75 min. Air-dried chips, corresponding to 800 g of oven-dried chips, were cooked in a 15-L electrically-heated laboratory cylindrical-type rotary digester. After cooking, the pulps were washed to remove the black liquor and were disintegrated in a laboratory disintegrator. The kappa numbers (TAPPI T 236) of the resulting pulps were determined to be 37.3 and 38.3 for the European black pine and Scots pine, respectively. The kappa number of the OCC pulp was found to be 88. The OCC was manually cut into 30 × 30 mm fractions for further processing. These samples were soaked in water for 24 h and were then repulped in a laboratory disintegrator. The

OCC and virgin pulps were screened using a Somerville-type pulp screen with a 0.15-mm slotted plate (TAPPI T 275).

Handsheet Making and Testing

The freeness levels of the OCC pulp and the virgin pulps of the European black pine and Scots pine were measured as 19 °SR, 12 °SR, and 15 °SR, respectively (ISO 5267-1). For comparison at the same freeness, all pulps were beaten to 25 °SR in a Valley Beater according to TAPPI T 200. The OCC pulp was added to the virgin pulps of both the European black pine and the Scots pine at ratios of 5%, 10%, 15%, 20%, and 25% (w/w) in a pulp distributor. Then, the OCC pulp-free (controls) and the OCC pulp-containing handsheets (75 g/m^2) were formed with a Rapid-Kothen Sheet Former (ISO 5269-2). The handsheets were conditioned according to TAPPI T 402. The tensile index (TAPPI T 494), burst index (TAPPI T 403), tear index (TAPPI T 414), air permeability (ISO 5636-3), and bulk (TAPPI T 220) of the handsheets were measured using the relevant standard methods.

The handsheet property data for each pulp-blending ratio were statistically analyzed using ANOVA and Tukey’s test at a 95% confidence level. In all the figures, the same lower case letter on the same colored bars denotes that the difference in the mean values of the properties among the compared groups was not statistically significant ($P > 0.05$).

RESULTS AND DISCUSSION

One of the important strength properties of paper is its tensile strength, which depends on the strength, flexibility, and length of individual fibers in the network (Nazhad 2005). As can be seen in Fig. 1, the addition of OCC pulp significantly decreased the tensile index ($P < 0.05$). OCC additions of 25% to the European black pine and Scots pine virgin pulps decreased the tensile indices by 10.17% and 14.66%, respectively. Tensile index losses were not statistically significant in the case of OCC additions of 10% to the European black pine. In the case of OCC additions of 15% to the Scots pine, a sudden decline in tensile index was observed. Similar tensile index losses were also found in previous studies (Wanrosli *et al*. 2005; Latifah *et al.* 2009; Sarkosh and Talaeipoor 2011; Fišerová *et al.* 2013). The losses in tensile index could be explained by the shorter fibers (Scott *et al.* 1995) of the OCC pulp. On the other hand, swollen fibers are more flexible (Wanrosli *et al.* 2005) and more suitable for papermaking. The swelling capacity (Oksanen *et al.* 2000) and water retention value (WRV) (Howard 1995) of dried fibers are lower as a result of hornification. The inter-fiber bonding of flexible fibers is stronger than that of hornified fibers (Hubbe *et al.* 2007). Furthermore, fiber shortness contributes to tensile index losses because of a lower ability to overlap and conform (Abubakr *et al.* 1995). Conversely, Wistara and Hidayah (2010) noted that an addition of 30% OCC pulp to virgin soda bamboo pulp improved the tensile index by 5.53%. Ghasemian *et al.* (2012) showed that OCC pulp additions of 20%, 30%, and 40% to neutral sulfite semi-chemical (NSSC) pulp increased the tensile indices by 9.02%, 32.79%, and 32.79%, respectively.

The burst index was significantly ($P < 0.05$) decreased with the addition of OCC pulp (Fig. 2). After additions of 25% OCC pulp to the virgin European black pine and Scots pine pulps, the burst indices decreased by 17.26% and 17.18%, respectively.

Similar results were reported by several other authors (Latifah *et al.* 2009; Sarkosh and Talaeipoor 2011; Horn *et al.* 1992). These losses could be ascribed to the lower bonding potential (Scott *et al*. 1995) and lower flexibility (Scallan and Tydeman 1992) of the OCC fibers. Moreover, the short length of the OCC fibers in comparison to the European black pine and Scots pine fibers could be another reason for the lower burst index (Abubakr *et al*. 1995). In contrast, Wistara and Hidayah (2010) noted that an OCC pulp addition of 30% to bamboo virgin soda pulp increased the burst index by 13.39%. Ghasemian *et al*. (2012) showed that OCC pulp additions of 20%, 30%, and 40% to NSSC pulp increased the burst indices by 30.85%, 53.19%, and 63.83%, respectively. These conflicting results could be ascribed to morphological differences between OCC and virgin fibers.

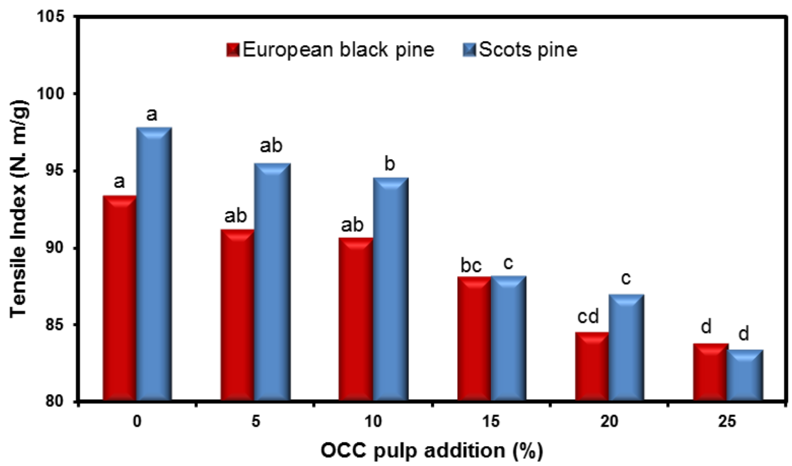

Fig. 1. The effects of OCC pulp addition on the tensile index

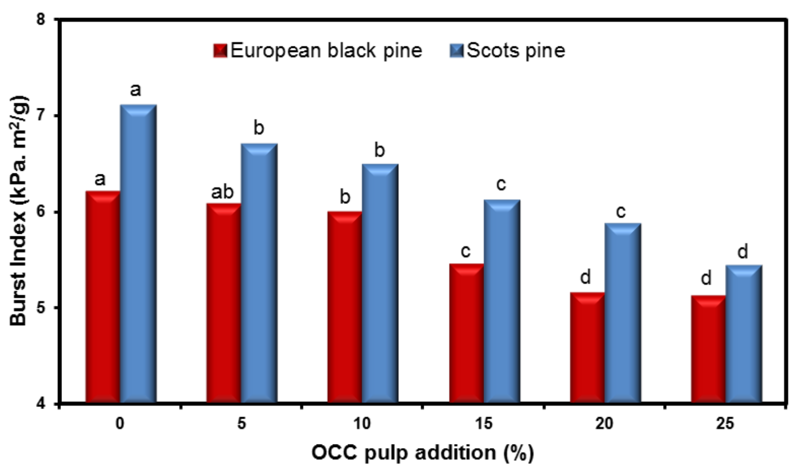

Fig. 2. The effects of OCC pulp addition on the burst index

The tear index increased slightly with higher percentages of OCC pulp in the mixture (Fig. 3). However, this trend was not statistically significant ($P > 0.05$) for both virgin pulp types. OCC pulp additions of 20%, 30%, and 40% to NSSC pulp were shown to increase the tear indices by 14.52%, 20.97%, and 24.19%, respectively (Ghasemian *et al*. 2012). Conversely, a recent study (Wistara and Hidayah 2010) showed that adding 30% OCC pulp to bamboo virgin soda pulp decreased the tear index by 16.67%. Similar tear index losses were reported by several other authors (Wanrosli *et al*. 2005; Latifah *et al*. 2009).

The relationships between the addition of OCC pulp to virgin pulp of the European black pine and Scots pine and the stretch ratio of the handsheets are presented in Fig. 4. The stretch ratio of the handsheets decreased when the OCC pulp in the mixture was increased ($P < 0.05$). Additions of 25% OCC pulp to the European black pine and Scots pine virgin pulps decreased the stretch ratios by 14.85% and 15.64%, respectively. Stretch losses were not statistically significant in case of OCC additions of 10% to the Scots pine. However, stretch of handsheets statistically significant decreased with OCC additions of 5% to the European black pine. The losses in the stretch could be explained by the lower bonding potential and lower flexibility of the OCC fibers (Nazhad 2005). In addition, the decrease in the stretch ratio with increasing percentage of OCC pulp in the mixture could be ascribed to the comparative shortness of the OCC fibers (Horn 1978). Another study indicated that OCC pulp additions of 20%, 30%, and 40% to NSSC pulp increased the stretch ratio by 1.22%, 28.05%, and 34.15%, respectively (Ghasemian *et al*. 2012). These conflicting results could be explained by morphological differences between OCC and virgin fibers.

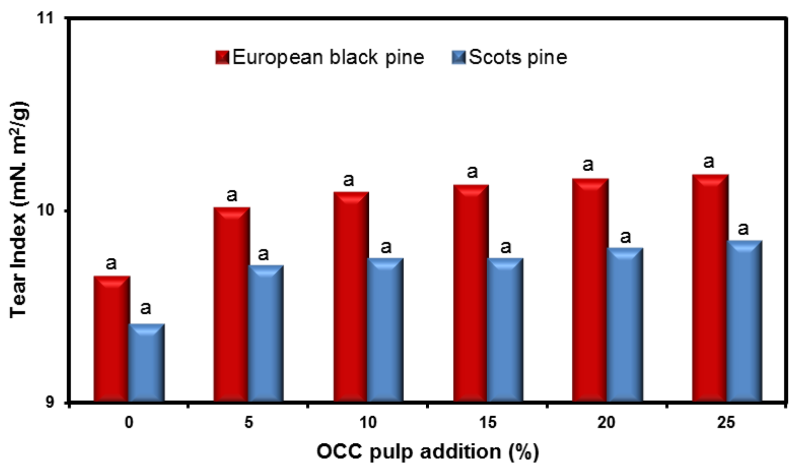

Fig. 3. The effects of OCC pulp addition on the tear index

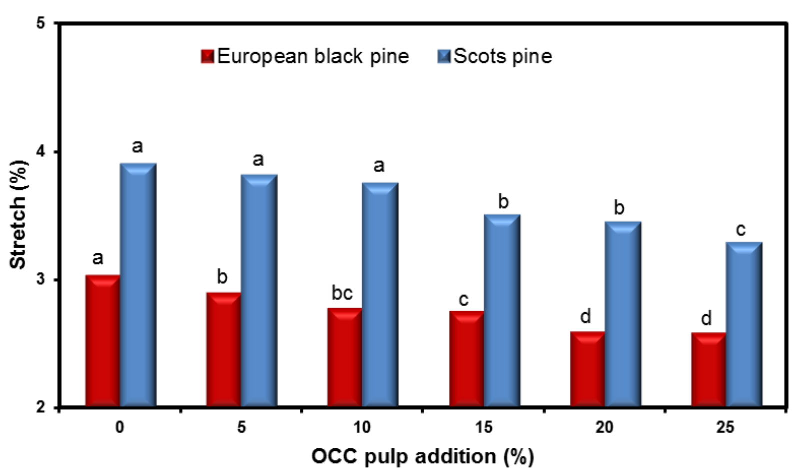

Fig. 4. The effects of OCC pulp addition on the stretch

In Fig. 5, the effect of OCC pulp addition on the air permeability of the handsheets is shown. It was observed that air permeability increased significantly ($P < 0.05$) with an increasing ratio of OCC pulp in the mixture. This was probably due to the longer and more flexible fibers of the European black pine and Scots pine in comparison to the OCC fibers (Scott *et al*. 1995). Additions of 25% OCC pulp to the European black pine and Scots pine virgin pulp led to increases in the air permeability by 54.76% and 196.18%, respectively. Similar results were also reported by Sarkosh and Talaeipoor (2011) and Fišerová *et al.* (2013). OCC-added handsheets having higher air permeability could be suitable for production of sack papers because of the fast escape of air during filling of sacks.

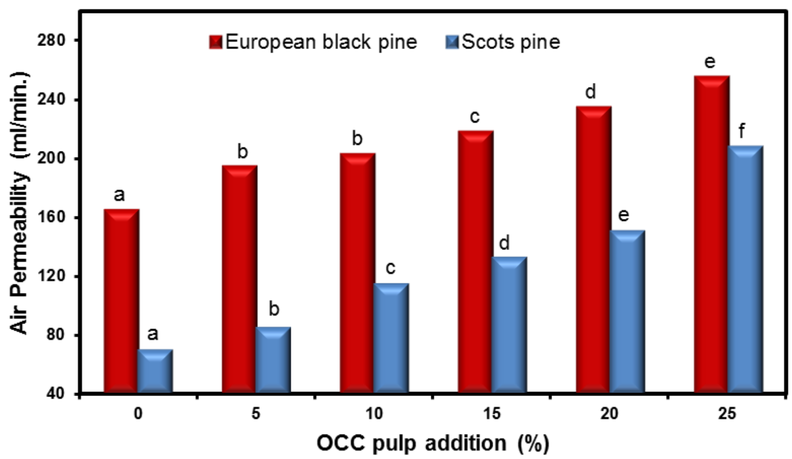

Fig. 5. The effects of OCC pulp addition on air permeability

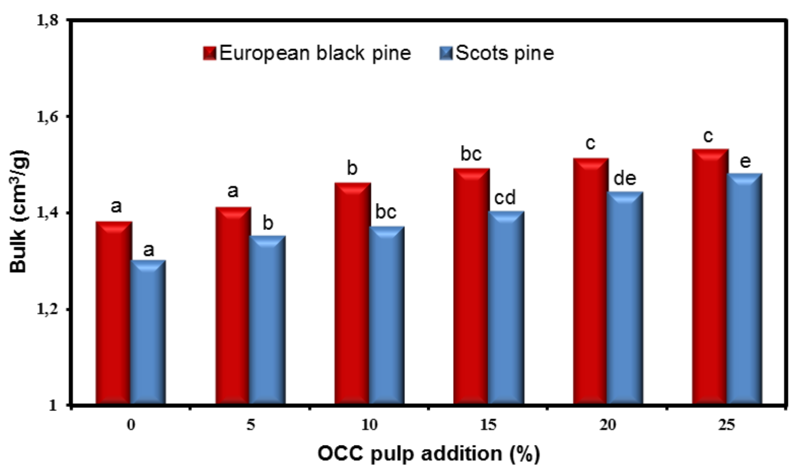

Fig. 6. The effects of OCC pulp addition on bulk

The bulk of the handsheets showed a linear correlation ($P < 0.05$) with the addition of OCC pulp (Fig. 6). Additions of 25% OCC pulp to the European black pine and Scots pine virgin pulps increased the bulk values by 10.87% and 13.87%, respectively. This could be ascribed to the longer fibers of European black pine and Scots pine in comparison to those of the OCC fibers (Scott *et al*. 1995). Sarkosh and Talaeipoor (2011) revealed that an increase in the OCC pulp ratio in a mixture of soda-AQ wheat straw pulp and OCC pulp increased the bulk of the paper. The bulk of paper containing recycled fiber has been found in previous studies to be higher than that of virgin fiber for the same beating time (Bhat *et al*. 1991; Howard 1995; Nazhad 2005; Oksanen *et al*. 2000). The flexibility of recycled fibers decreases due to hornification (Minor *et al*. 1993). Inflexible (stiff) fibers do not form close contact with one another fiber in a paper sheet (Yan *et al*. 2008). Therefore, recycled fibers tend to form a bulky sheet.

CONCLUSIONS

1. With the exception of the tear index, the strength properties of handsheets decreased gradually with the increase in the proportion of OCC fibers in the mixture.
2. The results showed that up to 10% of the virgin softwood kraft pulps could be replaced with OCC pulp without bringing about considerable loss of strength. This ratio of OCC addition could be suitable for production of wrapping papers. Also, OCC-added handsheets can be used in the production of sack papers due to their higher air permeability.

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