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# UTILIZATION OF CARTONS WASTE CHIPS IN MANUFACTURING OF FIBER COMPOSITE BOARDS

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**ABSTRACT**

This experiment was implemented to study the physical and mechanical properties of Medium Density Fiberboard (MDF) manufactured from Old Corrugated Containers OCCs using three variables including density of board (0.6 g/cm3 and 0.7 g/cm3), resin content of urea-formaldehyde (8 %, 10 % and 12 %) and pressing time (25, 30 and 35 minutes). Results showed that board density proved to be an important factor affecting MDF manufacturing, board density showed significant effects on both Modulus Of Elasticity (MOE) and Modulus Of Rapture (MOR), while it had no significant effect on Internal Bonding (IB), higher board density (0.7 g/cm3) surpass low board density (0.6 g/cm3). The percent resin content and press time gave a significant effect on mechanical properties except IB. Also, it was noticed a perfection of boards combined at 12% resin contents and 30 minutes of mechanical properties. The triple intercourse between main effects showed to be significant for MOR, MOE and IB, generally boards made of higher density (0.7 g/cm3) with 12% resin content at pressing time 30 minutes developed better mechanical properties than other boards. According to the physical properties, board density showed a significant effect on Water Absorption (WA), Thickness Swelling (TS) and Linear Expansion (LE) after 2 and 24 hours of submersion in water. The resin content at 12 % and pressing time at 30 minutes showed better mechanical and physical properties.



## INTRODUCTION

Fiberboard is an industrial product made by drying or wet process from vegetative and waste paper(Eroglu,1988), and medium density fiberboards (MDF) are completely used in furniture, packaging, decoration, construction, and other industries due to it adjust density, low cost, superior physical and mechanical features (Myers and Holmes,1977).

The utilization of recovered paper as a raw material for MDF goods is a substantial means for decreasing waste and essential using resources (DE Alda and Torrea, 2006) .Thus, waste paper like OCCs can be transformed into variant design, that admits it to be enough for multiple usage implying composite boards manufactured throughout the process of (MDF) (Muehl *et al.*,2004 and Ayrilmis *et al.*, 2008 )The process utilizes all the package of waste without remaining any



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OCCs residue are scraped into particles and produced in a layer to obtain a required thickness, then the mat is pressed under the heat and pressure (Buelens *et al.,* 2001) .When fibers from recovered OCCs and *Pinus contorta* are utilized to manufacture fiberboard at range densities of 300 to 1100 kg/m$^3$, (Hunt *et al.,* 2008) found that increase density was associated with the increasing Internal Bonding (IB), Modulus Of Rapture (MOR) and Modulus Of Elasticity (MOE).

Also, resin percentage influenced positively the mechanical and physical properties, (Eroglu *et al.,* 2000) reported that 12 % resin ratio gave favorable results than did 8 or 10 %. The increase of temperature and pressing time is critically able to improve the internal bonding (Nemli,2002 and Iswanto *et al.,* 2014)

The objective of this study is to analyses the possibility of consuming old corrugated containers (OCCs) as an alternative of virgin wood fibers in manufacturing of Fiber Composite Board (FCB), applying process of dry way without taking any pre-treatment like refining or de-fiberation that was the first time to be used for producing easier and cheaper FCB in Kurdistan, compared to the process of wet method.

## MATERIALS AND METHODS

### The experimental design

To study the mechanical properties and physical properties of fiber composite boards manufactured from Old Corrugated Containers, a factorial design of 2 density (0.6, 0.7 g/cm$^3$) × 3 resin content (8, 10, 12 %) and 3 pressing time (25, 30, 35 minute) was used to manufacturing 18 compositions and three replications were taken from each panel (30×30×1 cm) for studying their properties. The mechanical properties (internal bonding, modulus of rapture and modulus of elasticity) and physical properties (water absorption, thickness swelling and linear expansion) testing of panels were taken based on ASTM E8 (Astm,2001).

### Raw material preparation

The OCC was obtained from Istikbal brand in (Mazi Super Market) in Duhok Province. The OCCs was breakdown to a pattern of small chips ranging from 1cm to 1cm, and later separation for every single layer of OCC from each other, then air dried the resultant chips had a finale moisture content about 4 percent, and afterward it was divided into two board densities (0.6 and 0.7 g/cm$^3$).

Urea–formaldehyde (UF) was utilized as a glue binder with OCCs in this study. Before the MDF manufacturing (8, 10, 12 %) of (UF) resin on the base of oven dry weight were added, and then adding a hardener with (NH4CL) at a concentration of (14 %) at a rate of (1 %) was mixed with water and (UF) by blender (Terentiev *et al* ., 1986).

### Mat Forming

For making FCB mat a wooden mold with dimensions of (36 cm × 36 cm with 36 cm deep) was utilized towards lower the height of and also to density the mat, then the mat was placed in the wooden mold over an aluminum foil (2 mm) and pressed manually at a board of 70 kg/cm$^3$ pressure. This procedure lower the mat height to about 50 to 100 mm that facilitate insertion into the press (Krzy *et al.,* 1977) .

**Board Pressing**

The mat was stocked into a hot hydraulic press (AS METAL – Ayhan Necipoglu, model SSP-140) which was available at (Zewa mill for the purpose of wood industrial / in Duhok). The time of pressing were (25, 30 and 35 minutes) at press temperature of (100 c°) to provide an accurate strength and density, the hot-pressing operation was carried out with pressure at 5 kg/cm$^2$ according to the method described by Winandy and Krzysik (2007). After pressing the boards generally were cooled prior to stacking.

**Preparation of Specimen for Testing**

After pressing the panels were edged by trimmer in the mill to achieve panels with a particular size (30 × 30 cm), later all boards were placed in conditioning room until the panels reached the moisture content of (10 %). Two samples from different positions of each panel were taken for all testes.

Afterward the plastic bags used for storing samples to keep them in the stable condition (with 30 C$^o$ temperature and 41 % relative humidity).

**The statistical analysis:**

The statistical analysis was carrying out as for assessing the impacts of these elements on the physical and mechanical properties of the board, a factorial totally randomized block design was used, by using SAS program version 0.9 (Anonymous, 2002). Differences between treatments were tested by Duncan Multiple Range test at 5 % level (Al-Rawi and Khalafalah, 2000).

## RESULTS AND DISCUSSIONS

**Mechanical Properties**

**Modulus of Rupture (MOR):**

Results of analysis of variance revealed that all studied factors together with their interactions had a significant effect on MOR (Table 1). It can be observed that the upper value of MOR (231.0 kg/cm$^2$) was obtained in panels made of higher density (0.7 g/cm$^3$). Similarly, Wu [17] showed that an improvement in MOR with raising the density of board. Such result is in agreement with others (Ganev *et al.,* 2005; Hunt *et al.,* 2008 and Santos *et al.,* 2014) Also, it was noticed that the higher MOR value (234.6 kg/cm$^2$) was attained in panels manufactured of 12 % resin. Such increase could be due an increase in bonded surface of OCCs and possibly due to OCCs surface coverage ratio increase with the resin (Young and Kim, 2007; Aryilmi and ara,2012 and Malanit *et al.,* 2009).

Table (1): Effect of studied factors on the Modulus of Rupture of the produced Fiber Composite Boards FCBs.

| Modulus of Elasticity MOR (kg/cm$^2$) | | | | | |
|---|---|---|---|---|---|
| **Resin Content (%)** | **Press Time (minutes)** | **Board Density** | | **Resin content × Press Time** | **Resin Content** |
| | | **Lower Density (D1) (0.6 g/cm$^3$)** | **Higher Density (D2) (0.7 g/cm$^3$)** | | |
| **8%** | **25** | 192.2f -h | 202.9d-h | 197.5de | **8%** |
| | **30** | 222. 7c -f | 229.8-e | 226.3bc | |
| | **35** | 199. 0e -h | 169.2h | 184.1e | |
| **10%** | **25** | 192. 2f -h | 214.1c-g | 203.1de | **10%** |
| | **30** | 192. 0f -h | 236.1b-d | 214.1cd | |
| | **35** | 196. 4e -h | 266.5ab | 231.5bc | |
| **12%** | **25** | 187. 0gh | 292.4a | 239.7b | **12%** |
| | **30** | 245. 3bc | 280.1a | 262.7a | |
| | **35** | 215. 3c -g | 187.5gh | 201.4de | |
| **Board Density × Resin Content** | **8%** | 204.6bc | 200.6bc | **Press Time** | |
| | **10%** | 193.5c | 238.9a | | |
| | **12%** | 215.8b | 253.3a | | |
| **Board Density × Press Time** | **25** | 190.4d | 236.5ab | 213.5b | |
| | **30** | 220.0bc | 248.7a | 234.3a | |
| | **35** | 203.6cd | 207.7cd | 205.6b | |
| **Board Density** | | 204.7b | 231.0a | | |

-Means with the same letters are not significantly different.

It appears that the higher value (234.3 kg/cm²) of pressing time on MOR was recorded in boards produced by pressing time at 30 minutes, the cause of this result can be clarified in term of the combination the both time and temperature of pressing. Rosili *et al.(*2006) raising the temperature press at a stable time and prolonging time of press at a stable temperature, will improving the mechanical properties of MDFs, in the same time at the short pressing time and low temperature will induce the adhesive pre-curing, while at the longer time of pressing with higher temperature will lead over-curing the adhesive. Pre and over-curing of adhesive will reduce the strength of bonding of fiberboard. These results are in accordance with other workers (Kargarfard *et al.*,2010 and Hunt,2001)

The combination effects of the three main factors (Table 1) showed that the higher value (292.4 kg/cm²) was noted in panels manufactured from density of 0.7 g/cm$^3$ at 12 % resin content with time of pressing at 25 minutes. This result agreed with other investigators (James et al., 1999 and Hunt *et al.,* 2008)

**Modulus of Elasticity (MOE):**

Results of the analyses of difference for modulus of elasticity (Table 2) indicates which there is a significant effect (5 %) for the three main factors, together with their interactions of the main factors, except between board density and pressing time. It can be observed that the panels with density of 0.7

g/cm$^3$ observed a higher value (8353.1 kg/cm²). As it was resolved before in case of MOR the higher density observed the higher MOE. This result correspond with other workers (Yang *et al.*,2003;Izran *et al.,* 2009 and Maloney,1989).

On the effects of resin content levels on MOE (Table 2), It appears that the higher MOE (8146.8 kg/cm²) achieved in all treatment combinations manufactured at 12 % resin content. However, the lower value (6172.9 kg/cm²) was in boards made at 8% resin content. When it clarified before if there should be MOR that would be growing in the content of resin will increase the values of MOE of the boards, that is due to OCCs surface coverage ratio increasing with the resin. Same results were reported by others (Hunt *et al.*,2008;Ayrilmis and Kara,2012 and Kalaycioglu *et al*.,2005).

Table (2): Effect of studied factors on the Modulus of Elasticity (MOE) of the manufactured Fiber Composite Boards FCBs.

| MOE (kg/cm$^2$) | | | | | |
|---|---|---|---|---|---|
| Resin Content (%) | Press Time (minutes) | Board Density | | **Resin content × Press Time** | **Resin Content** |
| | | Lower Density (D1) (0.6 g/cm$^3$) | **Higher Density (D2) (0.7 g/cm$^3$)** | | |
| 8% | 25 | 4678.0h | 6488.9def | 5583.5f | 6172.9c |
| | 30 | 5948.1fg | 7962.0bc | 6955.0de | |
| | 35 | 5100.3gh | 6860.4de | 5980.3f | |
| 10% | 25 | 5918.8fg | 7200.2cd | 6559.5e | 7271.6b |
| | 30 | 6382.3d-f | 8589.3b | 7485.8cd | |
| | 35 | 5805.3fg | 9733.6a | 7769.4bc | |
| 12% | 25 | 6276.9ef | 10038.1a | 8157.5b | 8146.8a |
| | 30 | 7732.5bc | 10033.0a | 8882.7a | |
| | 35 | 6527.7d-f | 8272.4b | 7400.1cd | |
| Board Density × Resin Content | 8% | 5242.1e | 7103.7c | **Press Time** | |
| | 10% | 6035.5d | 8507.7b | | |
| | 12% | 6845.7c | 9447.8a | | |
| Board Density × Press Time | 25 | 5624.6d | 7909.1b | 6766.8b | |
| | **30** | 6687.6c | 8861.4a | 7774.5a | |
| | **35** | 5811.1d | 8288.8b | 7049.9b | |
| **Board Density** | | 6041.1b | 8353.1a | | |

-Means with the same letters are not significantly different.

With the regard of the effect of press time on MOE, it was shown that the highest value (7774.5 kg/cm²) was recorded in panels build of time pressing at 30 minutes, and the lowest value of MOE (6766.8 kg/cm²) was observed in panels made of time pressing at 25 minutes. The cause of this alteration may be due to press temperature increasing at a stable time will raise the mechanical properties of MDFs. This result concede with other researchers (Ayrilmis and Kara, 2012;Rosilei *et al.,* 2006 and C.P.A, 2002).

The combination effects of three main factors showed a significant (5%) effect on MOE. Table (2) revealed that, the highest value (10038.1 kg/cm²) was recorded in panels manufactured with density of 0.7 g/cm$^3$ at time pressing 25 minutes and 12% resin content, which was in accordance with standard American association for internal applications (Cai *et al.,* 2006).

**Internal Bond (IB):**

With the exception of the effect of board density and their interaction with press time all others are not significant ($p < 0.05$) as shown in Table (3). it was shown that the greatest rate of IB was achieved in boards made at 10 and 12 % resin content manufactured from either density of 0.6 g/cm$^3$ or 0.7 g/cm$^3$ and pressing time at 30. The proportion of such boards were 1.28 and 1.27 kg/cm² respectively, the effect of high density on IB mainly was when temperature of press machine reached to 100 during different pressing time leads to for solidifying the resin and produce high IB, which agreed with others (Kalaycoglu *et al.,*2005 ana Heinemann *et al.,* 2002)

From the above results, it is revealed that there was no significant difference between the mean values of IB, and agreed with Nemli, Heinemann et al. (Young and Kim,2007 and Jani and Izran, 2013) the raising the temperature and time of pressing this condition was caused by over-curing of resin, which resulted in increase in IB rate, while a higher temperature and pressing duration caused a drop in IB. and corresponding to Jani and Izran (Ashori and Nourbakhsh,2008) such result is expected due to the presence of more voids in the panels, the voids induced inefficacy of the inter-fiber bonding. The result resembles those of others researchers (Ashori *et al.,* 2012 and Loh *et al.,*2010).

**Physical Properties**

**Water Absorption (WA) after 2 hours of submersion in Water:**

It appears from Table (4) that all studied factors as well as their interaction had a significant ($p < 0.05$) effect on WA. Also, it was observed that the maximum values (111.63 %) and boards made of density 0.6 g/cm$^3$ and at 8% resin content and 111.77 % when the press time was 35 minutes.

According to the combination effects of the three main factors, the minimum value (98.79 %) was noticed in boards manufactured from density 0.6 g/cm$^3$ with time of pressing 30 minutes and 12 % resin content. Such result was similar with those reported by Loh et al. (Khedari *et al.,* 2003) who noted that with increasing density of board, will decrease the physical properties. This result agrees with others (Halvarsson *et al.,* 2004 and Eshragi and Khademieslam, 2012). It was also founded that WA decreased by increasing the resin content. This result agrees with other workers ( Ashori and Nourbakhsh, 2008 and young *et al.,* 2011). The press time at 30 minutes was suitable for hardening the resin also provides larger surface area between the OCC with the resin, and this led to reducing water absorption of boards (Hunt *et al.,* 2008and Heinemann *et al.,* 2002).

Table (3): Effect of studied factors on Internal bond of the produced Fiber Composite Boards FCBs.

| Modulus of Elasticity IB (kg/cm$^2$) | | | | | |
|---|---|---|---|---|---|
| Resin Content (%) | Press Time (minutes) | Board Density | | Resin content × Press Time | Resin Content |
| | | Lower Density (D1) (0.6 g/cm$^3$) | Higher Density (D2) (0.7 g/cm$^3$) | | |
| **8%** | **25** | 0.89cd | 1.05a -d | 0.97bc | 1.15a |
| | **30** | 1.28ab | 1.22a -c | 1.25a | |
| | **35** | 1.35a | 1.08a- d | 1.22ab | |
| **10%** | **25** | 1.16a- d | 0.98a- d | 1.06a- c | 1.02a |
| | **30** | 1.27ab | 0.87cd | 1.07a -c | |
| | **35** | 0.81d | 1.00a- d | 0.93c | |
| **12%** | **25** | 1.01a- d | 1.11a -d | 1.06a -c | 1.07a |
| | **30** | 0.94b- d | 1.28ab | 1.11a- c | |
| | **35** | 1.07a- d | 1.02a -d | 1.05a -c | |
| **Board Density × Resin Content** | **8%** | 1. 17a | 1.12a | **Press Time** | |
| | **10%** | 1.08a | 0.97a | | |
| | **12%** | 1.01a | 1.13a | | |
| **Board Density × Press Time** | **25** | 1.02a | 1.04a | 1.03a | |
| | **30** | 1.16a | 1.12a | 1.14a | |
| | **35** | 1.07a | 1.05a | 1.06a | |
| **Board Density** | | 1.08a | 1.07a | | |

-Means with the similar letters significantly are not different.

**Water Absorption (WA) after 24 Hours of submersion in Water:**

In the current work, results revealed that the affecting studied factors except press time along with their interaction had a significant effect ($p < 0.05$) on WA. The results of multiple range test of Duncan's (Table 5) revealed that the highest value of WA was observed in panels manufactured of density 0.6 g/cm$^3$ (115.49 %). Also, it can be noted that there exist is a light extending inside the rate of when water is absorbed the properties are contrasted together with them achieved following that 2 hour of submersion for the similar models, and the maximum value of WA was (117.93) noticed in boards made at 8% resin content, and press time on WA was considerable.

Table (4): Effects of studied factors on the water absorption (%) of the manufactured FCBs after 2 hours of submersion in water.

| Water Absorption after 2 hours | | | | | |
|---|---|---|---|---|---|
| Resin Content (%) | Press Time (minutes) | Board Density | | Resin content × Press Time | Resin Content |
| | | Lower Density (D1) (0.6 $g/cm^3$) | Higher Density (D2) (0.7 $g/cm^3$) | | |
| 8% | 25 | 117. 55ab | 117.57ab | 117.56a | 112.43a |
| | 30 | 104. 19c-e | 116.19a-d | 110.19a | |
| | 35 | 112. 71a-d | 106.39b-e | 109.55a | |
| 10% | 25 | 116. 54a-c | 108.29a-e | 112.42a | 112.28a |
| | 30 | 115. 81a-d | 106.06b-e | 110.93a | |
| | 35 | 120. 36a | 106.60b-e | 113.48a | |
| 12% | 25 | 103.60de | 99.65e | 101.62b | 104.42b |
| | 30 | 98.79e | 99.93e | 99.36b | |
| | 35 | 115.14a-d | 109.42a-e | 112.28a | |
| Board Density × Resin Content | 8% | 111.48a-c | 113.38ab | Press Time | |
| | 10% | 117.57a | 106.98bcd | | |
| | 12% | 105.84cd | 103.00d | | |
| Board Density × Press Time | 25 | 112.56ab | 108.50b | 110.53ab | |
| | 30 | 106.26b | 107.39b | 106.83b | |
| | 35 | 116.07a | 107.47b | 111.77a | |
| Board Density | | 111.63a | 107.79b | | |

- Means with the similar letters significantly are not different.

It has been shown from Table (5) that the minimum value (103.39 %) was recorded in panels manufactured from density 0.7 $g/cm^3$ with time of pressing 30 minutes and at 12 % resin content. These results agreed with some researchers who also found that a similar tendency of the factors on water absorption (Winandy and Lebow, 2001 and Ashori and Nourbakhsh,2008). Also, the water absorption value increased by increasing the press time to 35 minutes which caused by accumulation of heating, also lead to change the resin structure and its decomposition that cause an increase the water absorption of boards (Li *et al.*, 2009 and AHA,1995).

Table (5): Effect of studied factors on the water absorption (%) of the manufactured FCBs after 24 hours of submersion in water.

| Water Absorption after 24 hours | | | | | |
|---|---|---|---|---|---|
| Resin Content (%) | Press Time (minutes) | Board Density | | Resin content × Press Time | Resin Content |
| | | Lower Density (D1) (0.6 g/cm$^3$) | Higher Density (D2) (0.7 g/cm$^3$) | | |
| 8% | 25 | 121.26ab | 120.62a-c | 120.94a | 117.93a |
| | 30 | 110.57b-f | 126.19a | 118.38ab | |
| | 35 | 115.60a-e | 113.34b-f | 114.47ab | |
| 10% | 25 | 120. 05a-d | 111.62b-f | 115.83ab | 114.78a |
| | 30 | 117. 12a-d | 108.98d-f | 113.05bc | |
| | 35 | 121. 60ab | 109.29d-f | 115.44ab | |
| 12% | 25 | 109. 78c-f | 103.73f | 106.76cd | 108.25b |
| | 30 | 104.56ef | 103.39f | 103.98d | |
| | 35 | 118.88a-d | 109.13d-f | 114.00ab | |
| Board Density × Resin Content | 8% | 115.81ab | 120.05a | Press Time | |
| | 10% | 119.59a | 109.96c | | |
| | 12% | 111.07bc | 105.42c | | |
| Board Density × Press Time | 25 | 117.03ab | 111.99bc | 114.51a | |
| | 30 | 110.75c | 112.85bc | 111.80a | |
| | 35 | 118.69a | 110.58c | 114.64a | |
| Board Density | | 115.49a | 111.81b | | |

-Means with the same letters are not significantly different.

**Thickness Swelling (TS) after 2 hours of submersion in Water:**

It has been shown that only density of board as main factors had a significant effect (5 %) on thickness swelling (TS), According to Duncan' s test it appears that there was a significant difference among the higher rate of density 0.7 g/cm$^3$ and lower rate of density 0.6 g/cm$^3$, which were 31.9 and 28.29 % respectively. Also, there was no significant difference among the averages of the levels of resin content and levels of time of press on thickness swelling.

Moreover the three factors combinations observed a significant (5 %) effect on the thickness swelling after 2 hours of submersion in water, furthermore Duncan's test (Table 6) showed that the minimum TS (22.37 %) was observed in the panels produced from intensity of 0.6 g/cm$^3$ with time of imperative 30 minutes at 10 % resin content, this was in the line of American National Standard Institute (Guler *et al.,* 2008). Results revealed that thickness swelling increased by increasing the amount of density and this result agreed with others (Ganev *et al.,* 2005 and Eshragi and Khademislam,2012). Also, by increasing the resin content in the boards the amount of TS reduced. These results resemble those of some researchers (Ergulo *et al.,*2000;Young *et al.,* 2011 and Iswanto *et al.,* 2014) in their studies on various kinds of MDFs.

Table (6): Effects of studied factors on the thickness swellings (%) of the manufactured FCBs after 2 hours of submersion in water.

| Thickness Swelling after 2 hours | | | | | |
|---|---|---|---|---|---|
| Resin Content (%) | Press Time (minutes) | Board Density | | Resin content × Press Time | Resin Content |
| | | Lower Density (D1) (0.6 g/cm$^3$) | Higher Density (D2) (0.7 g/cm$^3$) | | |
| 8% | 25 | 25.61f-h | 33.11a-c | 29.36bc | 30.64a |
| | 30 | 23.14gh | 34.35ab | 28.74bc | |
| | 35 | 32.62a-d | 35.00a | 33.81a | |
| 10% | 25 | 28.78b-g | 29.25b-f | 29.02bc | 29.86a |
| | 30 | 22.37h | 33.99ab | 28.18c | |
| | 35 | 36.81a | 27.97c-g | 32.39ab | |
| 12% | 25 | 31.67a-e | 28.00c-g | 29.83bc | 29.88a |
| | 30 | 27.22d-h | 37.20a | 32.21ab | |
| | 35 | 26.39f-h | 28.79b-g | 27.59c | |
| Board Density × Resin Content | 8% | 27.12c | 34.15a | Press Time | |
| | 10% | 29.32bc | 30.40b | | |
| | 12% | 28.43bc | 31.33ab | | |
| Board Density × Press Time | 25 | 28.69c | 30.12bc | 29.40a | |
| | 30 | 24.24d | 35.18a | 29.71a | |
| | 35 | 31.94b | 30.58bc | 31.26a | |
| Board Density | | 28.29b | 31.96a | | |

-Means with the same letters are not different significantly.

**Thickness Swelling (TS) after 24 hours of submersion in Water:**

From results presented Table (7) it appears that density and percent resin content of board as a main factor along with three and two factors interactions observed a significant effect (5 %) on thickness swelling, but no significant effects of press time were noticed on this trait.

Results indicated that, the uppermost mean of TS was attained in panels manufactured of density 0.7 g/cm$^3$ (78.33 %), when comparing with them obtained once 2 hours of immersion to the similar examples which may be noticed that there is a little increase in the rate of TS. Also, it was observed that the highest TS (59.88 %) found in the panels manufactured of 10 % resin content. The increasing of TS values as resembles with the sample of 2 hours submersion in water is rely on the rate of resin in panels. These results were in accordance with other investigators (Ayrilmis,2007 and Eroglu *et al.,* 2000) On the other hand, no significant effect of time of press was observed on TS, the pressing time at 30 minutes was superior for hardening the resin on all over the surface of OCCs which leads to limiting thickness swelling. Similar results have been reported (Kalaycioglu *et al.,* 2005 and Heinemann *et al.,* 2002). Though, in situation of the effect of the combination of the three factors (Table 7) it observed from the results that the most endurance boards to TS are those that manufactured with intensity 0.6 g/cm$^3$ with period of pressing 25 minutes at 8 % resin content.

Table (7): Effect of studied factors on the TS (%) of the manufactured FCBs after 24 hours of submersion in water.

| Thickness Swelling after 24 hours | | | | | |
|---|---|---|---|---|---|
| Resin Content (%) | Press Time (minutes) | Board Density | | Resin content × Press Time | Resin Content |
| | | Lower Density (D1) (0.6 g/cm$^3$) | Higher Density (D2) (0.7 g/cm$^3$) | | |
| 8% | 25 | 31.77j | 82.50bc | 57.13bc | 58.62ab |
| | 30 | 34.96h-j | 70.99de | 52.98cd | |
| | 35 | 40.40f-i | 91.12a | 65.76a | |
| 10% | 25 | 43.73fg | 76.13cd | 59.93b | 59.88a |
| | 30 | 33.49ij | 84.80ab | 59.14b | |
| | 35 | 47.39f | 73.76d | 60.57ab | |
| 12% | 25 | 42.17f-h | 75.94cd | 59.06b | 56.29b |
| | 30 | 36.71g-j | 85.21ab | 60.96ab | |
| | 35 | 33.16ij | 64.53e | 48.84d | |
| Board Density × Resin Content | 8% | 35.71d | 81.54a | Press Time | |
| | 10% | 41.53c | 78.23ab | | |
| | 12% | 37.34d | 75.23b | | |
| Board Density × Press Time | 25 | 39.22b | 78.19a | 58.71a | |
| | 30 | 35.05c | 80.34a | 57.69a | |
| | 35 | 40.31b | 76.47a | 58.39a | |
| Board Density | | 38.20b | 78.33a | | |

-Means with the same letters are not significantly different.

**Linear Expansion (LE) after 2 hours submersion in Water:**

In the present work, it was noticed that the effect of density of panel had a significant effect (5 %) on linear expansion (Table 8). The results observed that the density 0.7 g/cm$^3$ gave highest value of LE (2.32 %), while panels manufactured from density 0.6g/cm$^3$ were superior in its resistance to expand linearly (2.02 %). This result confirmed the others (Ganev *et al.*, 2005 and Ramli *et al.*, 2002) who also observed that the physical properties of MDFs such as LE was affected detrimentally by density of board.

The combination effects of the three main factors appeared that the minimum LE (1.49 %) observed in all panels manufactured of density of 0.6 g/cm$^3$ with time of pressing at 35 minutes and 10 % resin content. This result indicates that using 10 % of resin content was adequate to reduce the LE to the minimum.

**Linear Expansion (LE) after 24 hours of submersion in Water:**

With regard to LE next 24 hours of submersion in water, the results showed that the three factors with the interactions of two and three factors significantly effected (5 %) on percent linear expansion (Table 9). Also, the results revealed that, the highest LE obtained in panels manufactured of density 0.7 g/cm$^3$ (6.82 %), and the maximum of percent LE (5.08 %) was obtained in panels manufactured at 10 % resin content, and the minimum rate (4.04 %) was observed in panels manufactured at 12% resin content, and the highest value of LE was time of press at 25 minutes average (4.83 %).

Table (8): Effect of studied factors on the LE (%) of the manufactured FCBs after 2 hours of submersion in water.

<table>
<tr><th colspan="6">Linear Expansion after 2 hours</th></tr>
<tr><th rowspan="2">Resin Content (%)</th><th rowspan="2">Press Time (minutes)</th><th colspan="2">Board Density</th><th rowspan="2">Resin content × Press Time</th><th rowspan="2">Resin Content</th></tr>
<tr><th>Lower Density (D1) (0.6 g/cm$^3$)</th><th>Higher Density (D2) (0.7 g/cm$^3$)</th></tr>
<tr><td rowspan="3">8%</td><td>25</td><td>1.74cd</td><td>2.46a-c</td><td>2.10ab</td><td rowspan="3">2.10a</td></tr>
<tr><td>30</td><td>1.94b-d</td><td>2.31a-c</td><td>2.12ab</td></tr>
<tr><td>35</td><td>1.94b-d</td><td>2.23a-d</td><td>2.08ab</td></tr>
<tr><td rowspan="3">10%</td><td>25</td><td>1.98b-d</td><td>2.87a</td><td>2.42a</td><td rowspan="3">2.17a</td></tr>
<tr><td>30</td><td>2.10b-d</td><td>2.49a-c</td><td>2.30ab</td></tr>
<tr><td>35</td><td>1.49d</td><td>2.10b-d</td><td>1.80b</td></tr>
<tr><td rowspan="3">12%</td><td>25</td><td>2.18a-d</td><td>1.90b-d</td><td>2.04ab</td><td rowspan="3">2.25a</td></tr>
<tr><td>30</td><td>2.02b-d</td><td>2.50ab</td><td>2.26ab</td></tr>
<tr><td>35</td><td>2.86a</td><td>2.06b-d</td><td>2.46a</td></tr>
<tr><td rowspan="3">Board Density × Resin Content</td><td>8%</td><td>1.87b</td><td>2.33a</td><td colspan="2" rowspan="3">Press Time</td></tr>
<tr><td>10%</td><td>1.86b</td><td>2.48a</td></tr>
<tr><td>12%</td><td>2.36a</td><td>2.15ab</td></tr>
<tr><td rowspan="3">Board Density × Press Time</td><td>25</td><td>1.96c</td><td>2.41ab</td><td colspan="2">2.19a</td></tr>
<tr><td>30</td><td>2.02bc</td><td>2.43a</td><td colspan="2">2.23a</td></tr>
<tr><td>35</td><td>2.10a-c</td><td>2.13a-c</td><td colspan="2">2.11a</td></tr>
<tr><td colspan="2">Board Density</td><td>2.03b</td><td>2.32a</td><td colspan="2"></td></tr>
</table>

-Means with the same letters are not significantly different.

The combination effects of the three factors on LE after 24 hours of submersion showed that the minimum (2.02 %) was observed in most of the boards manufactured at 8 % resin content containing density 0.6 g/cm$^3$ with time of pressing 25 minutes. It is clear from the result that increasing density of board will raising the linear expansion, which agreed with other workers (Ganev *et al.*, 2005 and Ramli *et al* .,2002) Also, it was observed that the LE will lower by exceeding the levels of resin content in the panels. These results agreed with other workers (Young *et al.*, 2011) The boards that made with press time 35 minutes was superior, the reason was that it causes to hardening the resin on the surface of OCCs and reduced the rate of linear expansion positively. This was agreed with other investigators (Heinemann *et al.*, 2002 and AHA,1995).

Table (9): Studied effect of factors on the LE (%) of the manufactured FCBs after 24 hours of submersion in water.

| Linear Expansion after 24 hours | | | | | |
|---|---|---|---|---|---|
| Resin Content (%) | Press Time (minutes) | Board Density | | Resin content × Press Time | Resin Content |
| | | Lower Density (D1) (0.6 g/cm$^3$) | Higher Density (D2) (0.7 g/cm$^3$) | | |
| 8% | 25 | 2.02d | 6.64b | 4.33b | 4.71b |
| | 30 | 2.47d | 7.59a | 5.03a | |
| | 35 | 2.07d | 7.46a | 4.77ab | |
| 10% | 25 | 2.38d | 8.09a | 5.23a | 5.08a |
| | 30 | 2.49d | 7.67a | 5.08a | |
| | 35 | 2.42d | 7.44a | 4.93a | |
| 12% | 25 | 2.53d | 7.30ab | 4.92a | 4.04c |
| | 30 | 2.40d | 4.58c | 3.49c | |
| | 35 | 2.82d | 4.58c | 3.70c | |
| Board Density × Resin Content | 8% | 2.19d | 7.23b | Press Time | |
| | 10% | 2.43d | 7.74a | | |
| | 12% | 2.58d | 5.49c | | |
| Board Density × Press Time | 25 | 2.31c | 7.35a | 4.83a | |
| | 30 | 2.45c | 6.61b | 4.53b | |
| | 35 | 2.43c | 6.50b | 4.47b | |
| Board Density | | 2.40b | 6.82a | | |

-Means with the same letters are not significantly different.

## Conclusion

The results revealed that it was possible to manufacture fiber composite board from OCCs by using dry way process. Generally the superior results of the mechanical properties achieved from higher board density 0.7 g/cm$^3$, but for the physical properties lower board density 0.6 g/cm$^3$ was superior. The results indicated that by raising the content of resin in board, all the studied properties revealed an enrichment in their values. In general, the time of press at 30 minutes gave a higher value for properties compared to others pressing time. It was observed which most of the thickness swelling, linear expansion and water absorption, occurred within the first 2 hours of submersion in water, and then after 24 hours submersion, a little extend in percentages of these properties observed. Generally, the results revealed that the interaction among the main factors had significant effects on the mechanical and physical properties.

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**استخدام رقائق نفايا الكارتون في صناعة الالواح الليفية المركبة**

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**الخلاصة**

نفذت هذه التجربة لدراسه الصفات الفيزيائية والميكانيكية للالواح الليفية المتوسطة الكثافة المصنعة من حاويات الكارتون بإستخدام ثلاث متغيرات تتضمن كثافة اللوح (0,6 و 0,7) غم/سم³، محتوى اللاصق من اليوريا فورمالديهايد (8%، 10%، 12%) وفترة الضغط (25، 30 و 35) دقيقة. اظهرت النتائج ان كثافة اللوح عامل مهم يؤثر على صناعة الالواح الليفية المتوسطة الكثافة، كثافة اللوح اظهرت تأثيراً معنويا على معامل المرونة ومعامل الانكسار، في حين ليس لها تأثير معنوي على قوة التماسك، كثافة اللوح العالية 0,7 غم/سم³، تفوقت على كثافة اللوح المنخفضة 0,6 غم/سم³. نسبة محتوى اللاصق مع فترة الضغط اعطت تأثير معنوي على الصفات الميكانيكية ما عدا قوة التماسك. كذلك لوحظ تحسن الالواح عند 12٪ من محتوى اللاصق مع 30 دقيقة فترة الضغط للصفات الميكانيكية. التداخل الثلاثي بين العوامل الرئيسية اظهرت تأثيرا معنوياً على معامل الانكسار، معامل المرونة وقوة التماسك. بشكل عام الالواح من الكثافة العالية 0,7 غم/سم³ مع 12٪ من محتوى اللاصق عند فترة الضغط 30 دقيقة اعطت صفات ميكانيكية أحسن من الالواح الاخرى. اعتمادا على الصفات الفيزيائية، كثافة اللوح اظهرت تأثيراً معنوياً على امتصاص الماء والانتفاخ بالسمك والتمدد الطولي بعد ساعتين واربعة وعشرون ساعة من الغمر في الماء. محتوى اللاصق عند 12٪ وفترة الضغط 30 دقيقة اظهرت صفات ميكانيكية وفيزيائية أفضل.

**الكلمات الدالة**: الالواح الليفية المضغوطة، رقائق بقايا الكارتون، الصفات الميكانيكية، الصفات الفيزيائية.

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