INDUSTRY
WOOD
ENGINEERING

WOOD INDUSTRY & ENGINEERING

2019 Volume: 1
Issue: 2

KARADENIZ TECHNICAL UNIVERSITY
FOREST INDUSTRY ENGINEERING DEPARTMENT

Wood Industry and Engineering

YEAR : 2019 VOLUME : 1 ISSUE : 2

Wood Industry & Engineering is an international scientific journal and published biannually.

Authors are responsible for the content of their work.

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December 2019, Trabzon, TURKEY

Wood Industry and Engineering

YEAR : 2019 VOLUME : 1 ISSUE : 2

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Volume: 01 Number: 02 Paper Type: Research Article
Pages: 40-51 Received: 03.12.2019

THE POTENTIAL OF DIFFERENT PULPING PROCESSES IN PRODUCTION OF PULP-PLASTIC COMPOSITES (PPC) FROM BAGASSE AND RICE STRAW

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Abstract

Natural fibres are renewable, biodegradable, low-cost, low-density raw materials with high stiffness and strength compared to the other conventional products such as glass, aramid and carbon. There are a large variety of natural fibers such as rice straw, rice husk, wheat straw, corn stalks, palm, bagasse, hemp, flax and other agricultural residues. Natural fibers contain various organic materials (mainly celluloses as well as hemicelluloses and lignin) and there are several chemical treatments such as bleaching, esterification, silane treatment, use of compatibilizer, acetylation, alkali treatment and treatment with other chemicals in order to enhance the fiber matrix adhesion, which improve the physical and mechanical properties of composites.

This study investigates different pulping processes as a novel chemical treatment on bagasse and rice straw fibers and consequently, properties of biocomposites. By pulping processes, the treated natural fibers as a biofiller could be used to produce the new classes of bio composites defined as pulp- plastic composites (PPCs). Different pulping processes which are categorized in mechanical, semi-chemical and chemical methods led to natural fibers with different anatomical and chemical properties such as surface modification and delignification in comparison with untreated fibers. Furthermore, the comparison of natural fibers treated by chemical and mechanical pulping processes and effects of these treatments on physical and mechanical properties of natural fibers are worth considering.

Therefore in this paper, High-density polyethylene (HDPE), bagasse and rice straw fibers treated by four pulping processes (AS-AQ (alkaline sulphite anthraquinone), SODA-AQ (soda anthraquinone), MEA (monoethanolamine) and chemical mechanical pulping (CMP)) and maleic anhydride polyethylene as coupling agent were used to produce pulp plastic composites (PPCs) by injection molding. The physical and mechanical properties of corresponding composites were evaluated according to ASTM standards. The results showed that compared to untreated bagasse and rice straw/HDPE composite, the addition of bagasse and rice straw pulp fibers increased significantly the mechanical properties such as tensile strength and modulus, flexural strength and modulus, and hardness. The chemical pulps-reinforced composites showed better mechanical strengths than that of CMP-reinforced composites, but in some properties, CMP pulp composites have comparable results to the chemical pulp-reinforced composites. Natural fibers (untreated and treated) increased water absorption and thickness swelling of composites compared to pure HDPE. The comparison of PPCs from bagasse and rice straw untreated and treated fibers will be also presented and discussed.

Keywords: Biocomposite, Pulp, Natural fibre, Bagasse, Rice straw

1. Introduction

Wood plastic composites (WPCs) are a relatively new class of materials and one of the fastest growing sectors in the wood composites industry. WPCs have experienced significant market expansion in recent years as a replacement for solid wood, mainly in outdoor applications such as railings, decking, landscaping timbers, fencing, playground equipment, windows and door frames, etc. (Hosseini 2013). With increased wood costs and competition of wood resources from traditional wood sectors, developing

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alternative, cheap, and environmentally friendly natural fiber sources for plastic composite is highly needed (Hosseini et al.

2014). The utilization of lignocellulosic material, such as wood or nonwood as a reinforcing component in polymer composites (thermoplastic or thermoset), has received considerable attention particularly for price-driven/high-volume application (Felix and Gatenholm 1991, Joseph et al. 1996, Bledzki et al. 1996, Gassan and Bledzki 1997, Rozman et al. 1999, Rozman et al. 2001). This development has been brought about by several advantages offered by lignocellulosic materials, such as: (1) low density, (2) low cost, (3) non-abrasive nature, (4) safe fiber handling, (5) high possible filling levels, (6) low energy consumption, (7) high specific properties, (8) biodegradability, (9) a wide variety of fiber types, (10) recyclability, and (11) generation of a rural/agricultural based economy (Mapleston 1997, Scheller 1996). As can be seen by the recent trends, lignocellulosic materials have been the subject of intensive studies in producing fiber-reinforced plastic (Felix and Gatenholm 1991, Joseph et al. 1996, Bledzki et al. 1996, Gassan and Bledzki 1997, Rozman et al. 1999, Rozman et al. 2001, Rozman et al. 1998, Valadez-Gonzalez 1999, Marcovich et al. 1998, Gassan 2002, Marcovich 2001a,b)

Blending of different polymers to achieve superior properties is a widely used process (Park 2008). Solution blending is one of the processes that are used for blending varieties of polymers and making polymer composite (Deka and Maji 2010, Deka et al. 2011). But the major problems to make composite are the immiscibility among different polymers and decrease in interfacial adhesion between polymers and wood. This results in the formation of inferior composites. In order to improve the miscibility among the polymers as well as with wood, a third component called compatibilizer is used (Ashori 2008). Compatibilizer is such a compound which can interact with the hydrophobic polymer through their non polar group and with the hydrophilic wood flour (WF) through their polar group. This leads to an improvement in interfacial adhesion that enhances the properties (Chiu et al. 2010). Different types of compatibilizer like glycidyl methacrylate (GMA), polyethylene grafted glycidyl methacrylate (PE-g-GMA), maleic anhydride grafted polypropylene (MAPP), maleic anhydride grafted polyethylene (MAPE), etc. are widely used to enhance the compatibility among different polymers and WF (Devi and Maji 2007, Dikobe and Luyt 2007, Kim et al. 2007).

In general, the low compatibility of natural fibers with the hydrophobic polymeric matrices persists as their major disadvantage. In spite of a small cost increase, fiber surface treatments may be able to partially overcome these limitations. Simple treatments such as mercerization (Vazquez et al. 1999), heat treatment (Sapieha et al. 1989), sizing (Mutjé et al. 2006) or refining (Nakagaito and Yano 2004) have been attempted with discreet positive effects. More recently, newer treatments have been reported to improve the fiber/matrix compatibility in natural fiber composites. Corona discharges (Belgacem et al. 1994), treatment with high-frequency ultrasounds (Gadhe et al. 2006), vacuum ultraviolet- induced surface oxidation (Hollander et al. 1994, Kato et al. 1999), graft copolymerization (Mondal et al. 2002), treatment with silanes (Gironès et al. 2007) and other chemicals have been positively applied. One of the most popular treatments is alkaline treatment (Rozman et al. 1998, Valadez-Gonzalez et al. 1999, Marcovich et al. 1998, Gassan 2002, Marcovich 2001a,b, Gassan and Bledzki 1999). According to Bledzki and Gassan (Bledzki and, Gassan 1999), alkaline treatment of natural fiber would make the fibrils more capable to rearrange themselves along the tensile deformation.

Soda anthraquinone (SODA-AQ), alkaline sulfite anthraquinone (AS-AQ) and Monoethanolamine (MEA) are the most important chemical pulping methods to treat lignocellulosic non-wood natural fibers. SODA-AQ pulping is a promising and environmentally friendly method compared to sulphur based processes: Kraft and Sulphate (Khristova et al. 2002). SODA-AQ pulping is categorized as alkaline pulping processes with using mainly NaOH and partial anthraquinone (AQ) in cooking liquor. Alkaline sulphite anthraquinone (ASAQ) pulping is another alkaline pulping process with cooking liquor consisting of a mixture of Na2SO3 and NaOH which is able to delignify lignocellulosic materials, particularly in present of anthraquinone (AQ). The extent of delignification depends on the lignin structure as well as on the adjusted Na2SO3 to NaOH ratio. Monoethanolamine (MEA) pulping process is an organosolv pulping process which has appropriate performance on lignocellulosic non-wood natural fibers (Hedjazi et al. 2009). The most important advantage of MEA pulping of annual plants is the direct MEA recovery by distillation. After distillation of MEA, the residual organic matter could be used either as chemical feedstock or as nitrogen containing organic fertilizer, which, contrary to nitrogen in minerals, has slow-release long-term effects because nitrogen is gradually released by microbial degradation of the carrier material. The most prominent feature of MEA pulping is the exceptionally good preservation of hemicelluloses resulting in unusually high pulp yield. Green and Sanyer (1982) presumed that carbohydrates in the presence of MEA are stabilized against peeling reactions by reduction of reducing end groups. Compared to the SODA pulping, MEA pulping gives 12% higher yield (Hedjazi et al. 2009). The chemical-mechanical pulping (CMP) process has the advantages of a mild chemical treatment with cooking liquor consisting of a mixture of

Na2SO3 and NaOH and of high pulping yield compared with the chemical pulping process. Additionally, a lower refining energy is required in the CMP process than in mechanical pulping and this is because of chemical treatment in chemical-mechanical pulping (CMP) process.

The objective of present study is to investigate the influence of different pulping processes as treatments of bagasse and rice straw fibers on the physical and mechanical properties of pulp plastic composites (PPCs) and presentation a comparative study on performance of bagasse against rice straw as natural fiber reinforcement factor in biocomposites.

2. Materials and Methods

2.1. Materials

Injection molding grade high-density polyethylene (HDPE) was supplied by Jam Petrochemical Co. (Iran), with melt flow index of 18 g/10min and density of 952 kg/m^3. Maleic anhydride polyethylene (MAPE), as a coupling agent was obtained from Kimiajavid chemical products (Iran), with trade name PE-G 101, melt flow index of 50-80 g/10min, and maleic anhydride content of 0.8-1.2 %. The bagasse fibers were provided by Pars Paper Co., Khuzestan province, south west of Iran. Bagasse fibers were ground into flour with particle size of 40 mesh by screening. Rice straw was obtained from rice farms of north of Iran. The rice straw was cut into shorter length of 5-7 cm to incorporate in pulping processes. Bagasse and Rice straw pulp fibers which are treated by pulping processes (AS-AQ, SODA-AQ, MEA, and CMP) were investigated in this study and both of them were ground into flour subsequently.

2.2. Sample Preparation

Bagasse and Rice straw fibers turned to pulps by four pulping processes under different pulping conditions including various cooking time and chemical ratio. However, the optimum pulping conditions which used to produce pulp plastic composites are given in tables 1 and 2. Pulps were dried in an oven at 103±2 ºC for 24 hours. Polymer to fibers ratio for all reinforced composites were 60:40 wt.%. MAPE amount was reduced from polymer amount. Formulation of the composites and abbreviations used for the corresponding composites are given in Table 3.

Table 1. Pulping conditions and the properties of produced bagasse pulps

Process	Abbreviation	Features			
		Time (Min)	Yield (%)	Kappa	Details
Alkaline sulphite anthraquinone	AS-AQ	90	62.16	12.3	16% alkalinity, NaOH to Na_2S ratio 50:50, AQ:0.1%, 160°C
Sodium hydroxide anthraquinone	SODA-AQ	90	61.44	11.45	20 % alkalinity, AQ:0.1 %, 160°C
Monoethanolamine	MEA	90	76.8	12.5	MEA to H_2O ratio 75:25, 160°C
Chemi- mechanical pulping	CMP	30	86.4	-	NaOH to Na_2SO_3 ratio 4:10 on the basis of OD bagasse and NaOH, 160°C

Table 2. Pulping conditions and the properties of produced rice straw pulps

Process	Abbreviation	Features			
		Time (Min)	Yield (%)	Kappa	Details
Alkaline sulphite anthraquinone	AS-AQ	90	50	20	16% alkalinity, NaOH to Na_2S ratio 20:80, AQ:0.1%, 160°C
Sodium hydroxide anthraquinone	SODA-AQ	45	49.8	19	16 % alkalinity, AQ:0.1 %, 160°C
Monoethanolamine	MEA	30	55.25	18	MEA to H_2O ratio 50:50, 160°C
Chemi- mechanical pulping	CMP	30	85	-	NaOH to Na_2SO_3 ratio 8:18 on the basis of OD bagasse and NaOH, 160°C

Table 3. Composition of the studied formulation

Composites *	Bagasse (wt.%)	Bagasse pulp (wt.%)	Rice straw (wt.%)	Rice straw pulp (wt.%)	MAPE (wt.%)	HDPE (wt.%)
PE	-	-	-	-	-	100
PE/B	40	-	-	-	5	55
PE/AS-AQ	-	40	-	-	5	55
PE/SODA-AQ	-	40	-	-	5	55
PE/MEA	-	40	-	-	5	55
PE/CMP	-	40	-	-	5	55
PE/R	-	-	40	-	5	55
PE/AS-AQ	-	-	-	40	5	55
PE/SODA-AQ	-	-	-	40	5	55
PE/MEA	-	-	-	40	5	55
PE/CMP	-	-	-	40	5	55

* PE:HDPE, B:Bagasse, AS-AQ:Alkaline sulfite anthraquinone, SODA-AQ:Soda anthraquinone, MEA:Monoethanolamine, CMP:Chemical mechanical pulping, R:Rice straw

Composites were prepared by following processes:

The compositions were extruded by Collin twin screw extruder (screw speed of 60 rpm, L/D 16, Germany, 1990), then they were grounded to prepare the granules using a pilot scale grinder (WIESER, WGLS 200/200 model). Experimental specimens were prepared by injection molding (Injection pressure 100 kg/m^2, temperature 180 C°, Imen Machine, Iran) according to ASTM standard. Dimension of specimens for tensile and flexural properties were 165×19×3.2 and 100×12×5 mm, respectively.

2.3. Mechanical Testing

Injection-molded specimens were tested following ASTM standards, D 638 for tensile properties, D 790 for flexural properties, and D 256 for notched Izod impact strength. The flexural properties were measured in three-point bending tests. Flexural and tensile tests were conducted using an Instron Universal Testing Machine (model 4486) at crosshead speed of 8 mm/min at room temperature. Impact test was performed by a digital impact test machine (SANTAM, SIT-20 D model) using conventional V notched specimens. Three replicates were tested for each property and each formulation.

2.4. Physical Testing

Physical properties, namely, water absorption (WA) and thickness swelling (TS) were tested in according to ASTM D 570. Before testing, the weight and thickness of each specimen were measured. Conditioned specimens of each type of composite were soaked in distilled water at room temperature for 24 hours. For each measurement, specimens were removed from water, patted dry and then measured again. Each value obtained represented the average of three specimens. WA and TS were calculated according to Eqs. (1) and (2).

$$WA\ (\%) = \frac{W_{f-} W_i}{W_i} \times 100 \quad (1)$$

$$TS\ (\%) = \frac{T_{f-} T_i}{T_i} \times 100 \quad (2)$$

Where W_f (gr) and T_f (mm) are the weight and thickness at given time, respectively and W_i (gr) and T_i (mm) are the initial weight and thickness, respectively.

One-way variance of analysis was conducted using SAS statistical software (9.1 version). The Duncan test, at the 99% confidence level, was used for comparing and grouping of the mean values.

3. Results and Discussion

3.1. Tensile Properties

The effect of bagasse and rice straw pulps content on the tensile strength and modulus of composites are presented in Fig. 1. Natural fibers have higher modulus compared to the HDPE and it is expected to have higher modulus values when the amounts of them are increased in the matrix (Dönmez Çavdar et al. 2015). Bagasse and rice straw fibers (in both form of treated and untreated) led to significant increase of tensile strength and modulus of natural composites compared to pure HDPE sample (Fig. 1). The addition of natural fibers resulted in a reinforcement of the HDPE matrix in terms of stiffness and strength (Migneault et al. 2015).

Alkali treatment leads to an increase in tensile strength and modulus of composites. These changes in mechanical properties are affected by modifying the fiber structure, basically via the crystallinity ratio, degree of polymerization, and orientation (Gassan and Bledzki 1999). It is also noteworthy that the AS-AQ, SODA-AQ, MEA, and CMP bagasse fibers showed similar performance in both tensile strength & modulus and there is no clear difference concerning tensile strength and modulus between chemical and mechanical pulps. Untreated rice straw and CMP rice straw composites showed similar results of tensile modulus and also minimum value among rice straw reinforced composites. By contrast, AS-AQ and SODA-AQ rice straw composites reached to maximum performance.

According to Fig. 1a, the maximum values of tensile modulus (4076.2 MPa) belong to PE/CMP bagasse composite. As it was expected, the minimum value of tensile modulus (1235.4 MPa) belongs to pure HDPE. Addition of AS-AQ rice straw pulp to composites demonstrated the maximum values of tensile modulus (3648.6 MPa). Generally, composites which are reinforced by both treated bagasse and rice straw fibers with AS-AQ and SODA-AQ pulping processes shown effective results between others. This is due to role of anthraquinone (AQ) in pulping processes by improving pulping factors.

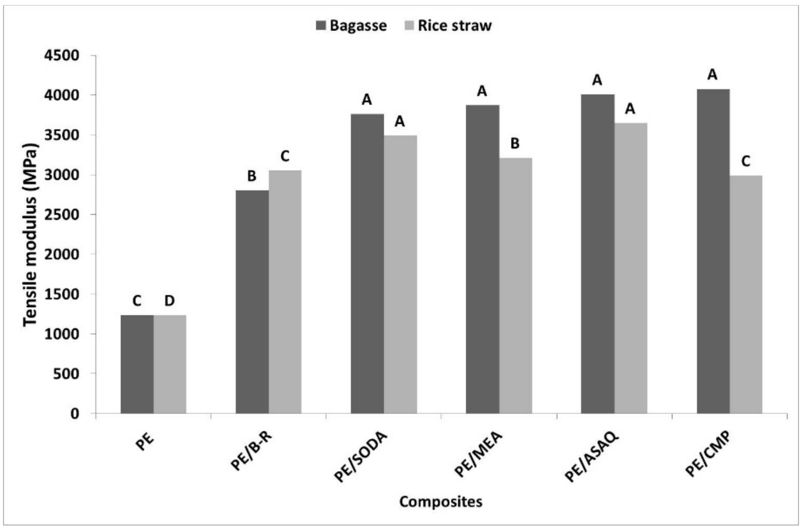

Figure 1a. Tensile modulus as function of bagasse and rice straw pulps

According to Fig. 1b, addition of natural fibers led to significant and positive effect on tensile strength of pulp plastic composites compared to pure HDPE with minimum value of tensile strength (22.71 MPa). From Fig. 1b, MEA fibers filled composite containing bagasse fibers reached to maximum tensile strength (44.87 MPa) among all biocomposites (both bagasse and rice straw reinforced composites). Fig. 1b also shows that AS-AQ fiber filled composite containing treated rice straw exhibited the highest tensile strength (32.74 MPa) compared to other rice straw reinforced composites. The tensile strength of oil palm empty fruit bunch (EFB) pulp polypropylene composites showed improvement as the NaOH content in the treatment was increased (Tay et al. 2010). However, the results of tensile strength demonstrated higher performance of bagasse filled composites compared to rice straw reinforced composites. Compared to that of chemical pulp reinforced HDPE composites, the better strength of CMP reinforced HDPE composites are rather surprising, because it is well known that chemical pulps are preferred reinforcing fiber source for paper products prepared from CMP in paper industry. By contrast, mechanical pulping processes such as chemical-mechanical pulping (CMP) and thermal-mechanical pulp (TMP) show higher reinforcement in polymer composite; this improvement is result of more remained lignin is mechanical pulping processes in comparison to chemical pulping processes. Other researchers reported similar results that TMP-reinforced PP composites have the highest tensile strength compared to bleached Kraft pulp (BKP) PP composites (Li and Sain 2003).

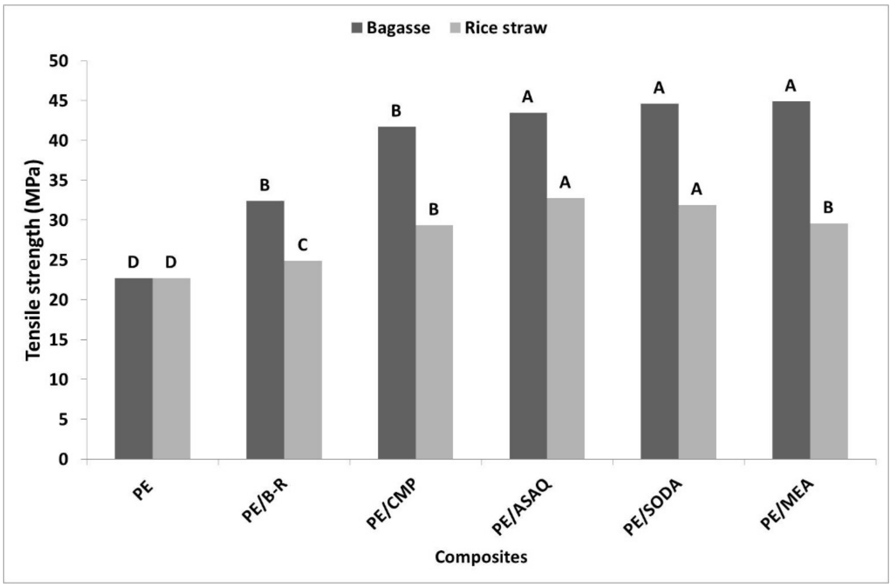

Figure 1b. Tensile strength as function of bagasse and rice straw pulps

3.2. Flexural Properties

Flexural strength and modulus of pulp plastic composites compared to untreated fiber composites which could be considered as common wood-plastic composites and pure HDPE are shown in Fig. 2. The addition of untreated fibers and both bagasse and rice straw fibers which were treated by different pulping processes led to noticeable increase in flexural strength and modulus results. This is due to the fact that the natural fibers have higher modulus than polymer matrix (Mengeloğlu and Karakus 2008, Bouafif et al. 2009, Dönmez Çavdar et al. 2011). The results of flexural modulus showed two different trends for bagasse and rice straw reinforced composites (Fig. 2a). On the one hand, the minimum flexural modulus of pulp plastic composites containing bagasse fibers belongs to untreated bagasse-HDPE composite (2158.11 MPa) and the addition of treated bagasse fibers by pulping processes led to significant increase in flexural modulus of composites with maximum value of 2803.89 MPa for CMP bagasse composite (Fig. 2a). On the other hand, untreated rice straw composite with maximum flexural modulus of 2953 MPa showed the best performance of flexural modulus among all bio-composites. As it is obvious from figure 2a, all of pulping processes as rice straw treatments demonstrated noticeable decrease and negative effect on flexural modulus of rice straw composites. In term of rice straw treated composites, chemical pulping processes including SODA-AQ, AS-AQ, and MEA pulping processes showed higher flexural modulus compared to CMP-rice straw composite. Chemical pulping processes led to more delignification and solubilization of lignin and subsequently, higher fiber strength. Cellulose was reported to be positively related with stress transfer and benefit the mechanical strength of the polymer composites (Shebani et al. 2009, Liu et al. 2014, Migneault et al. 2014).

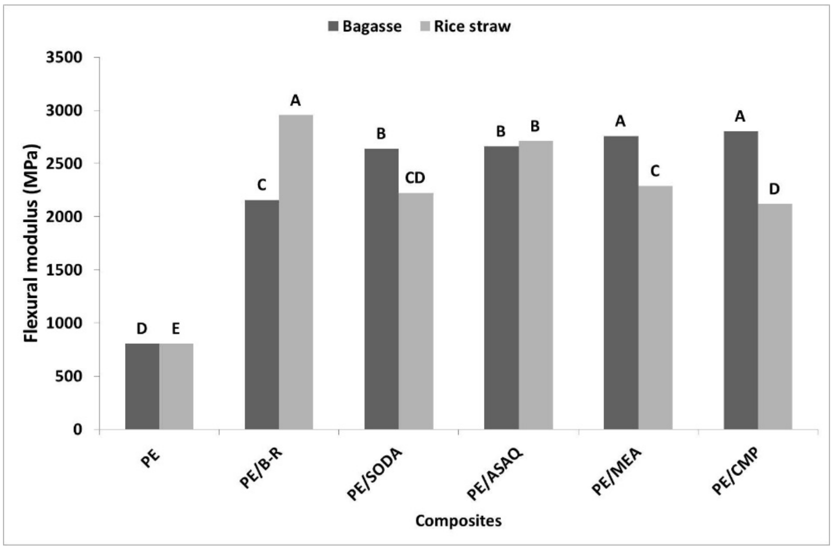

Figure 2a. Flexural modulus as function of bagasse and rice straw pulps

As shown in Fig. 2b, the minimum values of flexural strength belong to pure HDPE (26.55 MPa) and untreated bagasse and rice straw composites which are 45.79 and 40.49 MPa, respectively. Flexural strength results of composites demonstrated that bio-composites with treated fibers by pulping processes shown better performance compared to untreated natural fiber composite and pure HDPE in both cases of bagasse and rice straw filled composites (Fig 2b). The chemical treatment of fiber improved the adhesion between fiber surface and polymer matrix by modifying fiber surface and also increasing fiber strength and their mechanical properties (Li et al. 2007). MEA and AS-AQ bagasse composites depicted maximum (61.6 MPa) and minimum (57.88 MPa) flexural strength values among other pulping processes. By contrast, AS-AQ rice straw composite showed the highest flexural strength (44.87 MPa) and other treatment methods had not significant difference in flexural strength (Fig 2b). An alkali treatment applied on different tropical wood polymer composites improved the strength of up to 16% and the modulus of 13% maximum (Islam et al. 2012). The alkaline impregnation may cause fiber fibrillation and increase adhesion between fiber and polymer matrix (Bisanda and Ansell 1991, Mohanty et al. 2000, Habibi et al. 2008). This is also supported by some researchers who studied on the effects of alkaline treatment on properties of reinforced low density polyethylene composites (Ikhlef et al. 2012).

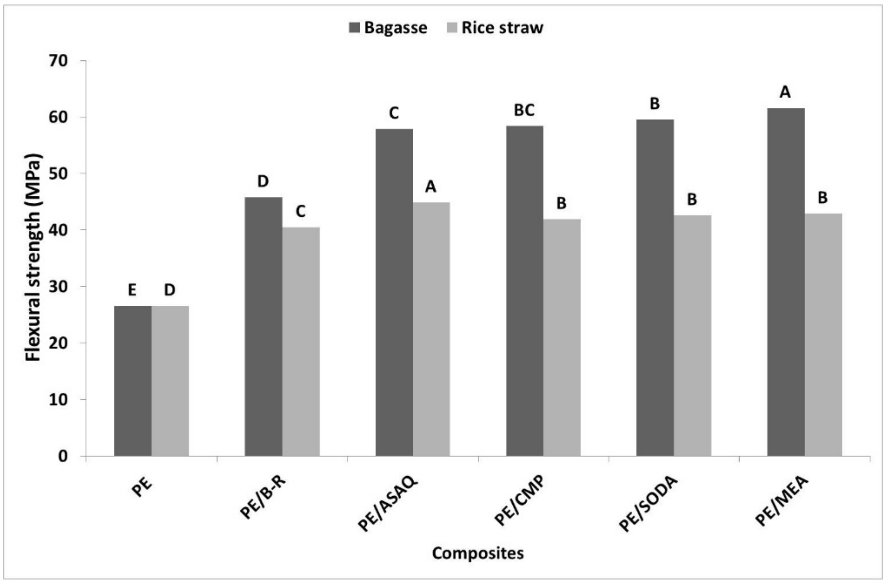

Figure 2b. Flexural strength as function of bagasse and rice straw pulps

3.3. Impact Strength

Impact strength values of the four types of HDPE/pulps fibers composites for both bagasse and rice straw/HDPE composite are shown in Fig. 3. As it can be seen in Fig. 3, the addition of all types of fibers (treated and untreated) decreased the impact strength of HDPE matrix, but untreated bagasse composite (B/PE) showed so close impact strength value (60 J) to pure HDPE (60.88 J). This negative effect may be ascribed to the reduction of polymer matrix content and poor compatibility between the fibers and polymer matrix. Decreasing of impact strength values by addition of natural fibers are observed in many studies (Klyosov 2007, Mengeloğlu and Karakus 2008, Basiji et al. 2010, Hosseini et al. 2014). Different types of pulps showed no significant influence on impact strength of rice straw composites compared to untreated rice straw reinforced composite (Fig 3). However, all types of bio-composites counting treated and untreated rice straw fibers showed significant and higher values of impact strength compared to pure HDPE and also other bagasse filled composites. The maximum impact strength value was related to SO-AQ, AS-AQ, MEA, and untreated rice straw with 74 J. the Izod impact strength of CMP rice straw composite and pure HDPE were 73 and 60.88 J, respectively.

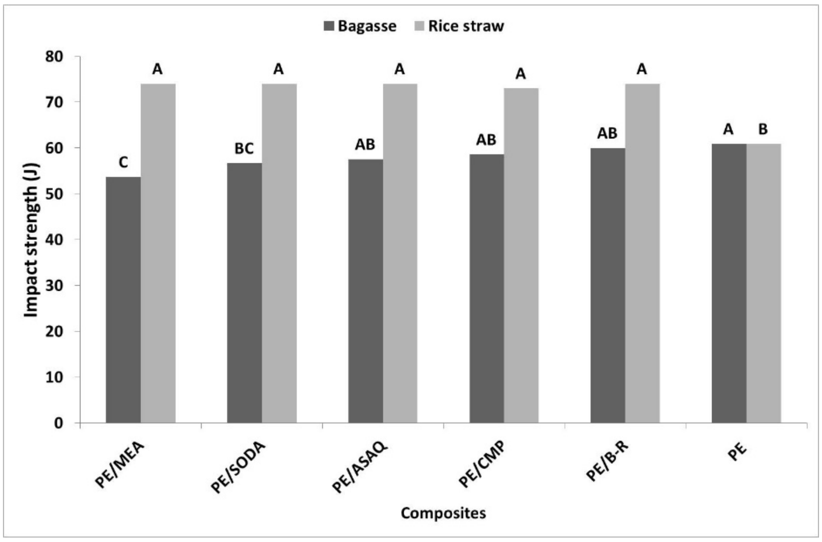

Figure 3. Comparison of impact strength of the composites as function of bagasse and rice straw pulps

3.4. Water Absorption

The water absorption results of pure HDPE and fiber reinforced composites containing bagasse and rice straw are shown in Fig 4. Mechanical properties of composites are known to be greatly affected by the presence and distribution of water, and this distribution should be taken into consideration during testing (Gnatowski et al. 2015). The value of water absorption capacity of pure HDPE (0.12 %) was significantly increased after the addition of pulps and untreated fibers into the pure HDPE for both bagasse and rice straw composites. The hydrophilic nature of natural fibers (free hydroxyl groups) caused an increased in the water absorption. These hydroxyl groups strongly interact with water molecules by hydrogen bonding and then favor water absorption by fibers (Pouzet et al. 2015). AS-AQ, SODA, and CMP bagasse composites exhibited almost same values of water absorption, whereas MEA bagasse composite showed the highest WA (0.46 %) compared to other pulp plastic composites due to high hemicelluloses content of this type of pulp. The addition of treated and untreated rice straw fibers into HDPE matrix led to no significant change of WA among all types of natural fiber reinforced composites. However, untreated rice straw composite showed maximum WA (1.5 %), whereas AS-AQ rice straw composite demonstrated the minimum value of water absorption (1.19 %), (Fig 4). The different trend in mentioned composites is due to fiber properties, agglomeration of their fibers and consequently, formation of composites. It is noteworthy from Figure 4 that all water absorption values of bagasse composites were less than 0.5 %, whereas WA values of rice straw reinforced composites were in range of 1.19-1.5 %.

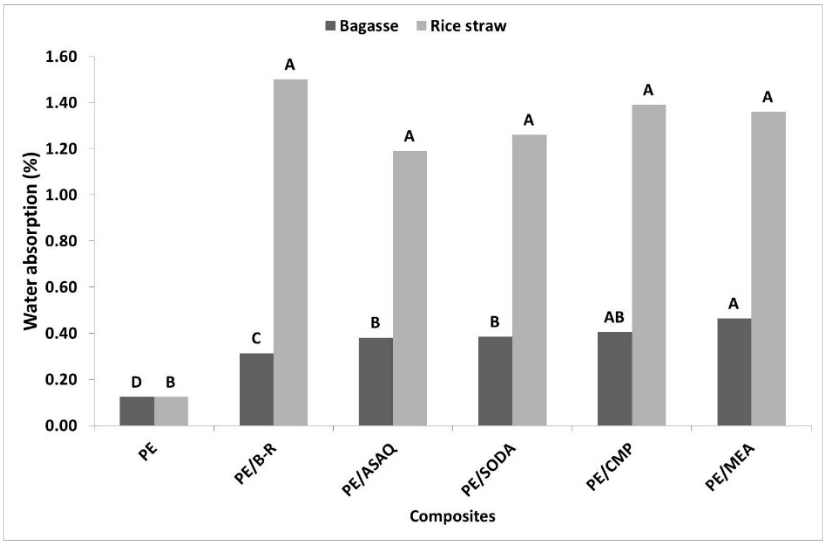

Figure 4. Comparison of water absorption (WA) of the composites as function of bagasse and rice straw pulps

3.5. Thickness Swelling

Fig. 5 depicted the thickness swelling (TS) values of natural fibers/HDPE composite and pure HDPE. As shown in Fig. 5, by addition of both bagasse and rice straw fibers and pulps into HDPE; the thickness swelling values are increased. The increasing of thickness swelling could be expected due to the inherent features of lignocellulosic materials (the water uptake capacity). Once again, reinforced composites by bagasse pulp fibers (specially, SODA-AQ pulp composite) shown better performance (lower TS of 0.46 %) in comparison with untreated bagasse composite (0.1 %). All pulping processes as rice straw treatments showed significant and positive effect on thickness swelling by decreasing maximum TS of untreated rice straw composite (1.95 %) to minimum TS (0.71 %) for AS-AQ rice straw filled composite. It is obvious from Fig. 5 that chemical pulping treatments on both fibers led to lower TS in comparison with CMP-pulp and untreated natural composites.

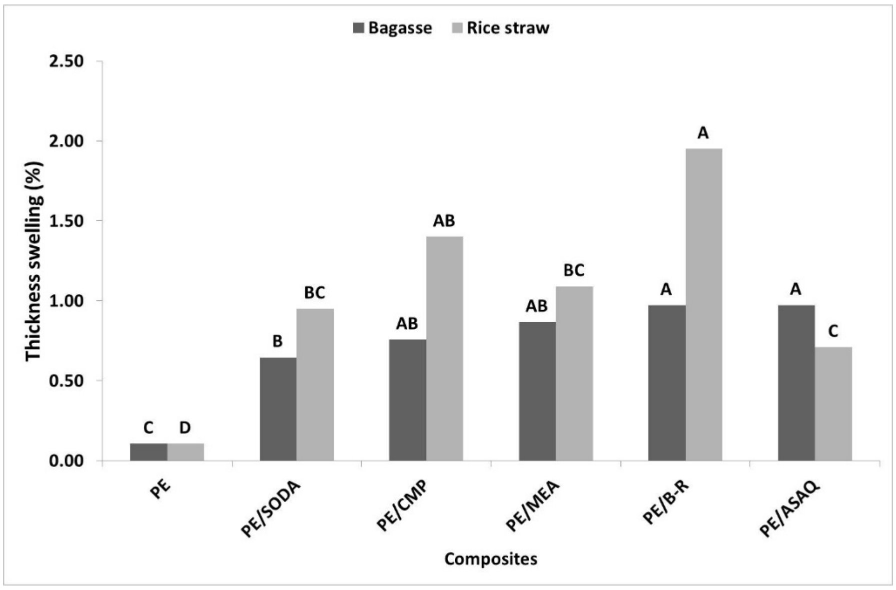

Figure 5. Comparison of thickness swelling (TS) of the composites as function of bagasse and rice straw

4. Conclusion

The present study investigated effect of four pulping processes (ASAQ, SODA, MEA, and CMP) as chemical treatment of bagasse and rice straw fibers on physical and mechanical properties of pulp plastic composites (PPCs). Treated bagasse fibers by pulping processes increased tensile, flexural, and water absorption properties of composites. By contrast, treated bagasse fibers decreased impact strength and thickness swelling of pulp plastic composites. The addition of rice straw treated fibers by chemical and mechanical pulping processes led to increase of tensile strength and modulus and flexural strength properties of composites. The addition of treated rice straw also caused negative effects on some properties by decreasing flexural modulus and thickness swelling of rice straw treated composites. In term of Izod impact strength and water absorption, treated rice straw fibers led to no significant change compared to untreated rice straw composite. This study demonstrated that chemical treatments are more effective on bagasse fibers compared to rice straw, but untreated rice straw in comparison to untreated bagasse fibers showed better performance in many properties. The addition of rice straw and bagasse fibers (both treated and untreated) illustrated positive and negative effect on Izod impact strength of biocomposites compared to Pure HDPE, respectively. According to results of water absorption, the minimum WA among all types of fiber reinforced composites belongs to untreated bagasse composite, whereas rice straw filled composites (both treated and untreated) showed noticeable increase in water absorption. Thickness swelling of untreated bagasse and rice straw composites remarkably decreased by addition of treated fibers via four pulping processes. TS results also demonstrated better performance of chemical pulping processes for decreasing TS of composites compared to chemical mechanical pulping (CMP) process. According to this research, the pulp-plastic composites (PPCs) are superior to untreated fiber reinforced composites (both bagasse and rice straw composites) and PPCs could be introduced as serious alternatives of natural fiber reinforced composites.

5. Acknowledgments

The authors gratefully acknowledge Department of Wood and Paper Science and Technology, Natural Resources Faculty, University of Tehran, Iran for the testing equipment used in this study. Further acknowledgement goes to Iran Polymer and Petrochemical Institute (IPPI) for the laboratory equipment used in the PPC panel manufacture. This study was presented in ORENKO 2018 – International Forest Products Congress held by Karadeniz Technical University, Trabzon.

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Wood Industry and Engineering

http://dergipark.org.tr/wie

Volume: 01 Number: 02
Pages: 52-56

Paper Type: Research Article
Received: 11.11.2019

APPLICATION OF DES (DEEP EUTECTIC SOLVENTS) TO WOOD EXTRACTIVES

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Abstract

Deep eutectic solvents (DES), known as environmentally friendly, recyclable, nonpoisonous, low volatility, non-flammability and harmless are first found by Abbott et al. in 2003. In the last decade, scientists are working with DES in different areas. Mainly, they focus on isolation of cellulose and lignin. Regard to extractives, to the best of our knowledge DES was not studied before. In this study, it was aimed to determine the extractive composition of Scotch pine with deep eutectic solvents.

Pinus *sylvestris* L. was used as wood material. As deep eutectic solvent (DES) Choline chloride (Merck 5.00117), ethylene glycol (Merck 1.00949) and urea (Merck 1.08487) were used with molar ratio of choline chloride; ethylene glycol (1:2 m/m), and choline chloride: urea (1:2 m/m). Sequential soxhlet extraction was performed first with n-hexane and then acetone-water with 5 g wood sample for 6 hours. With DES two extractions were performed in an ultrasonic (UB) and hot-water bath (HWB) at 60°C for 30 min. 0.05 g wood samples were used for these extractions. Identification and quantification were done with Shimadzu GCMS-QP2010 GC-MS and Shimadzu GC 2010 FID-GC.

Similar results were obtained with DES and organic solvents. Fatty acids, resin acids and stilbenes are the main chemical groups. Oleic acid (1.4-9%), linoleic acid (1.6-8%) and levopimaric acid (0.6-17.7%) are dominant compounds, found in all extracts. Also, monomethyl pinosylvin (51.5%) was found in acetone:water mixture. DES can be an alternative to organic solvents in wood extraction.

Keywords: Deep Eutectic Solvents (DES), Extractives, Scots pine

1. Introduction

Deep eutectic solvents (DES) are the mixtures of two or more compounds with a low melting point then preliminary compounds (Soares et al., 2017). They composed of hydrogen bond donor and hydrogen bond acceptor which support the dissolution (Li and Row, 2016). Hydrogen bond acceptors are generally quaternary ammonium salts while hydrogen bond donors involves amines, carboxylic acids, alcohol, polyoses or carbohydrates (Shishov, 2017). DES has some advantages compared to organic solvents; easy to prepare high purity compounds with low cost and biocompatibility (Hayyan et al.2013). Studies point out that DES are environmentally friendly, recyclable, nonpoisonous, low volatility, non-flammability and harmless solvents (Abbott et al., 2004; Jhong et al., 2009; Hayyan et al., 2012; Singh et al., 2012; Wu et al., 2012 Lynam et al. 2017).

DES were used in the following processes: the determination of bioactive compounds (Gu et al., 2014), the extraction of anthocyanins (Bosiljkov et al., 2017),the removal of aromatic hydrocarbons from aliphatic compositions (Hou et al., 2015), the analysis of volatile substances (Nie et al., 2017), the analysis of sugar amount in the corncob (Procentese et al., 2015), the increment of the cellulose derivation from the corn stoves for the butanol fermentation (Xu et al., 2016), the fractionation of lignocellulosic biomass (van Osch et al., 2017).

DES are mainly applied on cellulose and lignin (Lynam et al., 2017; Liu et al., 2017). To the best of our knowledge, isolation of low molecular compounds (fatty-resin acids) from wood with DES was not studied before. In this study, it was aimed to determine the extractive composition of Scotch pine with deep eutectic solvents.

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2. Materials and Methods

2.1. Material

Pinus sylvestris L (Scots pine), a widely studied wood species, was used as a wood material. Samples were taken from 630 m altitude of Hasankadi-Bartin province of Turkey and prepared according to TAPPI T 257- cm-02. After debarking and cutting in to matchstick size, samples were dried in a freeze dryer and grounded in the Wiley mill.

Choline chloride (Merck 5.00117), ethylene glycol (Merck 1.00949), glycerin (Merck 1.04092) and urea (Merck 1.08487) were used as deep eutectic solvent (DES). Eutectic mixtures molar ratio was as; choline chloride; ethylene glycol (1:2 m/m), choline chloride:glycerol (1:2 m/m) and choline chloride: urea (1:2 m/m). Also organic solvents n-hexane and acetone were used.

2.2. Extraction Methods

Three different extraction procedures, was applied. Traditional successive soxhlet extraction was performed with n-hexane and acetone-water respectively. 5 g wood sample was extracted 6 hours with each organic solvent. The other two extractions were performed in an ultrasonic (UB) and hot-water bath (HWB) at 60°C for 30 min. with deep eutectic solvents. 0.05 g wood samples were used for these extractions. 500 µl of aliquot from each extract was taken to a test tube and 1 ml of acetone has added. 700 µl of acetone phase was evaporated under nitrogen and was silylated.

2.3. Identification

Identification of compounds were performed with Shimadzu GCMS-QP2010 GC-MS equipped with TRB-5MS column (30 m x 0.25mm (0.25 µm thickness). Temperature program was started at 120 °C set for 1 min. then rised to 310 °C with a 6 °C/min. waiting for 20 minutes. The injection temperature was set to 260 °C, with 1:25 split mode, ion source was 200 °C and ionization energy 70eV. Wiley and NIST libraries were used. For quantitative analysis, Shimadzu GC 2010 FID-GC was used with TRB-5 column (30 m x 0.25 mm (0.25 µm thickness). Temperature program was set as above.

3. Results and Discussion

Extractive composition of Scots pine wood was analyzed with organic solvents applied classically (soxhlet) and by new biodegradable deep eutectic solvent (DES). The results are represented in Table 1. Fatty acids, resin acids and stilbenes (pinosylvin monomethyl ether) are the main chemical groups identified.

Total amount of fatty acids concerning palmitic acid, oleic acid and linoleic acid were found 19% in hexane extract. Except ChCl-Gly with HWB (19.6 %) the amount of total fatty acids was low (13.9-17%) with other solvents and extraction method. Oleic acid was found to be the major fatty acid in hexane. The results are in agreement with literature (Yildirim and Holmbom, 1978). Thus the ratio of this acid was 5.5%, 4.9% and 5.4% in ChCl-EG, ChCl-Gly, ChCl-Urea respectively in UB. With HWB, amount of oleic acid was low.

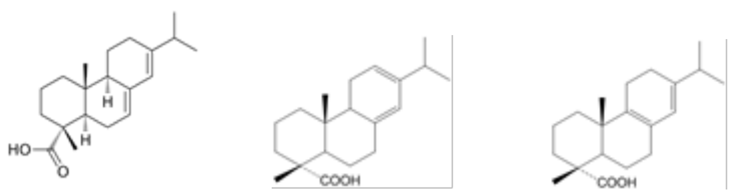
Table 1. Extractives of P. *sylvestris* wood obtained by organic and DES solvents (%)

	RT	Compound	H	A-W	ChCl-EG (1:2 molar)		ChCl-Glycol (1:2 molar)		ChCl-Urea (1:2 molar)	
					UB	HWB	UB	HWB	UB	HWB
1	15,12	Palmitic acid	0.1	-	0.4	0.9	1.0	3.8	0.7	2.2
2	16,54	Heptadecanoic acid	-	-	0.3	0.5	0.8	0.8	1.9	1.4
3	17,86	α-Linolenic acid	2.0	0.8	2.1	2.1	2.0	1.9	2.1	1.9
4	18,14	Linoleic acid	8.0	1.6	5.9	6.4	5.2	6.7	5.5	6.7
5	18,22	Oleic acid	9.0	1.4	5.5	4.7	4.9	6.4	5.4	4.8
6	19,48	Monomethyl pinosylvin	3.2	**51.5**	**12.0**	**15.5**	**16.4**	**16.1**	5.9	10.9
7	19,72	Pimaric acid	7.1	0.3	6.3	5.3	4.9	4.5	7.7	4.9
8	19,97	Sandracopimaric acid	1.1	-	1.3	0.8	1.0	1.5	1.3	0.9
9	20,14	Isopimaric acid	3.3	**-**	5.6	6.1	**10.2**	7.5	5.7	7.5
10	20,16	n.i.	-	**41.0**	-	-	-	-	-	-
11	20,45	Palustric acid	**14.3**	0.5	**12.4**	**11.6**	**11.0**	9.3	**12.5**	**13.9**
12	20,76	Levopimaric acid	**16.5**	0.6	**12.7**	**11.3**	**10.7**	**9.5**	**17.7**	**11.5**
13	20,88	Dehydroxyabietic acid	7.1	0.9	**10.4**	9.0	8.6	8.5	6.1	9.5
14	21,30	Abietic acid	**15.0**	0.8	**14.5**	**14.8**	**13.1**	**14.1**	**13.0**	**14.7**
15	22,63	Neoabietic acid	**13.0**	0.5	**10.7**	**10.9**	**10.1**	**9.5**	**14.5**	9.3

H: Hexane; A-W: Acetone-water; UB:ultrason bath; HWB: Hotwater bath; n.i: not identified.

Resin acids, more than 70% of total extracts composed of pimaral and abietal type of acids (Fig.1). The most abundant compounds were levopimaric acid (16.5%) and abietic acid (15%) in hexane. With DES solvents amount of levopimaric acid varied between 9.5-17.7% and abietic acid 13-14.8%. UB method showed better result than HWB at 60°C. As known resin acids have antiviral, antibacterial and antifungal effects (Savluchinske-Feio et al, 2006) and used in pharmacy and food industry. Specially for food industry residue of organic solvent is a big problem. With DES more secure extracts can be obtained. The amounts of total resin acids are almost compatible with hexane.

Pinosylvin and pinosylvin monomethyl ether which have an inhibition factor against some fungus and effect the decay resistance of wood (Venäläinen et al. 2004, Vainio-Kaila et al.2015) was found 51.5% in acetone:water extract. Sequential extraction was applied with organic solvents to recover first fatty and resin acids and then to extract pinosylvin monomethyl ether (Fang et al, 2013). With DES, the best results were obtained with ChCl:Glycol treated samples. The amount of pinosylvin monomethyl ether with ChCl:Glycol was 14.4% and 13.2% in ultrasonic and hot water bath respectively. In other DES applications hot-water bath give better results.



Abietic acid Levopimaric acid Palustric acid

Figure 1. Some resin acids found in the P. *sylvestris* wood.

Ultrasonic (UB) and hot-water bath (HWB) two different method applied to DES. As seen in Fig.2 total amount of resin acids were 5% more with UB compared to HWB at 60°C. However, with fatty acids the situation was reverse. Fatty acids gave better results with HWB. The structure of fatty acid is, linear long chains and HWB application seems to be enough. Resin acids forms from ring structures with one or more double bonds. UB was more effective for these structures.

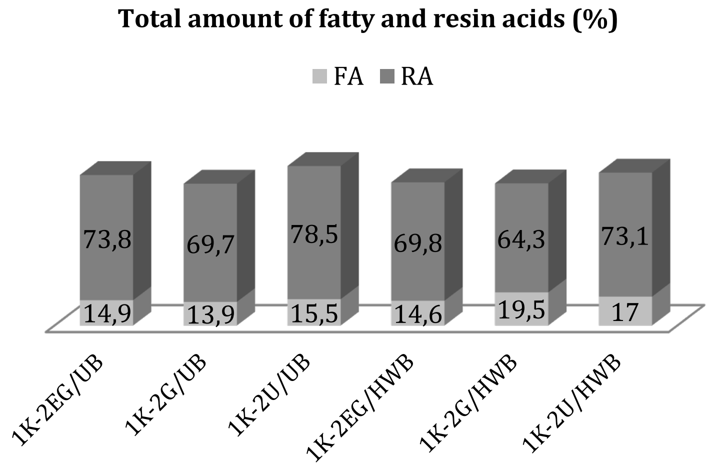


Figure 2. Total amount of fatty and resin acids with DES (%)

4. Conclusion

Organic solvents (hexane, acetone, ethanol, toluene etc.) are used in the extraction procedures. These are petroleum-based solvents and have some environmental problems with high-cost. Deep Eutectic Solvents (DES) are cheap and eco-friendly green chemicals used since 2003. This study showed that, DES can be used for the wood extraction. For fatty and resin acids, DES can be an alternative for organic solvents. Also, extraction procedure decreased to 30 min. with ultrasonic bath. Choline chloride: urea combination gave better results for P. *sylvestris* wood.

5. Acknowledgments

This study is a part of a project 2018-FEN-A-006 supported by Bartin University and was presented in ORENKO 2018 – International Forest Products Congress held by Karadeniz Technical University, Trabzon.

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Wood Industry and Engineering

http://dergipark.org.tr/wie

Volume: 01 Number: 02
Pages: 57-62

Paper Type: Research Article
Received: 13.11.2019

EFFECT OF DRYING TYPES AND POLYSTYRENE DENSITY ON THERMAL CONDUCTIVITY OF POLYSTYRENE COMPOSITE PARTICLEBOARD

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Abstract

Thermal conductivity of wood material is superior to other building materials because of its porous structure. Thermal conductivity is a very important parameter in determining heat transfer rate and is required for development of drying models in industrial operations such as adhesive cure rate. Thermal conductivity is used to estimate the ability of insulation of material. Thermal conductivity of wood material has varied according to wood species, direction of wood fiber, resin type, and addictive members used in manufacture of wood composite panels.

The aim of the study is to produce a new wood composite material with insulating properties by using insulating material called as polystyrene instead of formaldehyde based adhesives as bonding material. Five different wood species (beech, poplar, alder, pine, spruce), six different polystyrene species with different density values were used in this study and three layers particleboard in 18 mm thickness was produced. Urea formaldehyde resin (UF) was used in conventional panels manufacturing as adhesive. Technical drying was applied half of the test groups, while the other group was conditioned until reach to 12% equilibrium moisture content at room temperature as natural before manufacturing process to determine the effect of drying. The thermal conductivity of new composite panels were determined according to ASTM C 518 & ISO 8301.

According to the results from the study, thermal conductivity values obtained from natural drying were found to be higher than technical drying. The type of binder that gives the lowest thermal conductivity values among tree species in natural drying is generally S5. The lowest values in technical drying were obtained from panels bonded with XPS.

Keywords: Thermal Conductivity, Polystyrene Composite Particleboard, Drying Types, UF,

1. Introduction

Reducing energy consumption of buildings is required in order to counteract global warming induced by carbon dioxide, and thermal insulation of a building is an important part of this process. One of the development concepts used in the design of insulation materials is to aim to achieve a low thermal conductivity (k-value). An alternative development concept is to aim to use environmentally friendly products. One aspect of being environmentally friendly is effective utilization of unused resources. Using agricultural wastes, forest product wastes, textile wastes, and so on, as the raw materials of thermal insulation products is favourable for working towards a sustainable society based on resource recycling (Sekino, 2016). Many types of insulation materials are available which differ with regard to thermal properties and many other material properties as well as cost. Current thermal insulation materials in the construction market are generally inorganic materials e.g. extruded polystyrene (XPS), expanded polystyrene (EPS), polyisocyanurate and polyurethane foam (Cetiner and Shea, 2018). Expanded polystyrene is proved to be an excellent insulating medium which exhibits consistent thermal performance over the range of temperatures normally encountered in buildings (Lakatos and Kalmar, 2012). Expanded polystyrene has a thermal conductivity coefficient λ=0.03 w/mK, which has led to the wide use of polystyrene panels for the rehabilitation and thermal insulation of buildings (Claudiu et al., 2015). Expanded polystyrene, commonly known as styrofoam, is a polymer material present in a wide variety of

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products used in daily life, ranging from disposable goods to construction materials, due to its low cost, durability, and light weight (Jang et al., 2018). Its manufacture involves the heating of expandable beads of polystyrene with steam, and the placement of these heated expanded polystyrene beads into moulds to create prismatic blocks of EPS (Horvath, 1994). EPS has a very low density. An individual bead of EPS would be approximately spherical and contains only about 2% of polystyrene and about 98% of air (Dissanayake et al., 2017). The EPS is a chemically inert material not biodegradable, ie, it does not decompose, does not disintegrate, does not disappear in the environment and does not contain CFCs, consequently the EPS does not chemically contaminate the soil, water or air. However it can be an environmental problem if not recycled because it is considered an eternal material and it takes up too much space (due to its low density) (Schmidt et al., 2011.). Hence, reuse of EPS is beneficial in terms of environmental protection (Fernando et al., 2017). Wood–styrofoam composite (WSC) panels may be a very suitable solution for environmental pollution caused by styrofoam waste and also formaldehyde released from wood based panels (Demirkir et al., 2013).

Due to the increasing demand for wood products and the decreasing in the quality and presence of wood raw materials, the importance of composite wood products has increased steadily. This has led to an enormous increase in the use of adhesives in the forest products industry and has improved the use of wood raw materials resources. It is stated that adhesives used in about 70% of application in forest product industry (Aydin et al., 2010). Among the wide range of adhesives/resins employed in the wood industry, the most important are the amino resins. These include urea-formaldehyde (UF) resins, melamine-formaldehyde (MF) resins and melamine-urea-formaldehyde (MUF) resins. Their widespread use is due mainly to low cost and good performance. UF resins are commonly used in the manufacture of wood products, especially PB and MDF, due to their high reactivity, low cost and excellent adhesion to wood (Gonçalves et al., 2018). Over 90% of particleboard panels are bonded with urea formaldehyde resin which provides strong and durable bonds at a low cost (Nemli and Ozturk, 2006). The major disadvantages are the low moisture resistance and formaldehyde emission during the production and life time of the panels (Gonçalves et al., 2018). Formaldehyde is one of the most ubiquitous and priority pollutants indoors. Numerous studies have verified that short-term exposure to formaldehyde could cause eye, nose and throat irritation (Liang et al., 2016). The International Agency for Research on Cancer (IARC) classified formaldehyde as carcinogenic to humans, which led to stricter regulations on the emissions of formaldehyde (Resetco et al., 2016). Due to this carcinogenic nature, alternative, non-formaldehyde based adhesives, have been under intensive investigation to mitigate the emission problem (Sulaiman et al., 2018). Although some of these new adhesives have already been used in industrial applications, their supply is limited which may be due to the high modification costs or some their poor properties, for example, low wood resistance (Frang et al., 2013). Therefore, the chemicals and adhesives will use are both cheap and easily accessible and its technological properties qualify according to usage of wood based panels (Colak et al., 2016).

WSC can be manufactured without synthetic resins such as urea-formaldehyde or phenol-formaldehyde. Therefore WSC manufacturing can be suitable for both environmental and economic perspective. WSC manufacturing process also does not need a gluing machine or the preparation of glue mixture. So, the production process has been simplified (Demirkir et al., 2013).

The objective of this study was to investigate the thermal conductivity properties of particleboard manufactured with polystyrene instead of formaldehyde based adhesives used in particleboard production.

2. Materials and Methods

Beech (*Fagus orientalis Lipsky*), poplar (*Populus deltoides I-77/51*), alder (*Alnus glutinosa subsp. barbata*), pine (*Pinus sylvestris*) and spruce (*Picea orientalis L.*) wood particles, were used in the manufacture of particleboards. They were chipped using a hacker chipper before the chips were reduced into smaller particles using a knife ring flaker. First, the wood particles were screened using a horizontal screen shaker. The chips that pass through a 3 mm mesh screen and leave on a 1.5 mm mesh screen are classified in the middle layer and the chips that pass through a 1.5 mm mesh screen and leave on a 0.5 mm mesh screen are classified in the outer layer for use. After these processes, technical drying was applied half of the test groups (particles were dried using a lab-customized hot air-dryer at 90°C to 3% moisture content) while the other group was conditioned until reach to 12% equilibrium moisture content at room temperature as natural before manufacturing process to determine the effect of drying. Six different polystyrene species with different density values (10, 16, 20, 24, 30, 30-32 kg/m^3) instead of formaldehyde based adhesives were used in the manufacture of particleboards as bonding material. Urea formaldehyde resin (UF) was used in conventional panels manufacturing as adhesive. It was used urea formaldehyde resin with a solid content of 55%. Based on oven-dry particle weight, 8% and 10% resin were applied using an atomizing spray gun for the core and face layers, respectively. The ratio of the face thickness to the total thickness of a panel known as the shelling ratio was 0.40 for all samples. 20% solution of ammonium chloride (NH_4Cl) as a hardener was added at 1% in oven-dry-weight basis to resin.

In the production of polystyrene composite particleboard (PCP); the waste fragments of each polystyrene species were broken in a size of 1.5 - 3 mm in a polystyrene crusher. After these processes, the polystyrene chips were mixed homogeneously with 10% polystyrene for the outer layer and 8% for the middle layer based on the particle weight. It was formed PCP panel drafts. Polystyrene composite particleboards manufactured with 3 layer as shown in Figure 1. No hardener was used in the production of PCP panels.

Figure 1. Polystrene composite particleboards draft

Conventional and PCP panels were manufactured at a pressure of 23-25 kg cm2 at 150°C for 10 min. The ratio of the face thickness to the total thickness of a panel known as the shelling ratio was 0.35 for all specimens. The dimensions and target density of particleboards were 55 cm × 55 cm × 1.8 cm, and 0.68 gr/cm3, respectively. After pressing, panels were conditioned at a temperature of 20°C and 65% relative humidity for three weeks. Two panels for each panel type were produced. Types of test panels as well as bonding types are given in Table 1.

Table 1. Form of the groups according to bonding types

Groups	**Bonding Types**	**Density (kg/m^3)**
Conventional (Control)	Urea Formaldehyde (UF)	-
S1	Expanded Polystyrene (EPS)	10
S2	EPS	16
S3	EPS	20
S4	EPS	24
S5	EPS	30
S6	Extruded Polystyrene (XPS)	30-32

The thermal conductivity of the panels were determined according to ASTM C 518 & ISO 8301 (2004). Sample size required is 300 x 300 x 18 mm. Two specimens were used for each test group. The Lasercomp Fox-314 Heat Flow Meter shown in Fig. 1 was used for the determination of thermal conductivity. The top and lower layers of it was set for 20°C and 40°C for all specimens, respectively. The panels temperature during the measurement of the thermal conductivity was maintained to these constant temperatures.

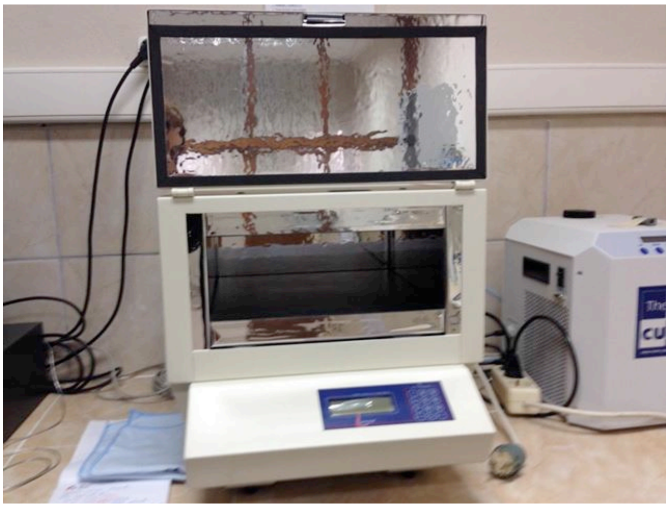

Figure 2. Lasercomp Fox-314 heat flow meter

3. Results and Discussion

Average values of thermal conductivity of conventional particleboard (control) and polystyrene composite particleboard are given in Table 2. In Figure 3, it is shown that the effect of wood species, bonding types and drying technique on thermal conductivity of panels.

Table 2: Average values of thermal conductivity of panels (W/mK)

Drying Type	Wood Species	Control (UF)	S1	S2	S3	S4	S5	S6
Natural Drying	Beech	0,1048	0,1008	0,09891	0,09413	0,09467	0,09245	0,09945
	Poplar	0,0939	0,1004	0,09266	0,09276	0,09307	0,09529	0,09385
	Alder	0,1003	0,09674	0,09700	0,09668	0,09664	0,09385	0,09446
	Pine	0,1042	0,09705	0,09578	0,09482	0,09802	0,09428	0,09616
	Spruce	0,1047	0,1011	0,1023	0,09794	0,09739	0,09692	0,1017
Technical Drying	Beech	0,1048	0,08995	0,08742	0,09167	0,08866	0,08621	0,08221
	Poplar	0,0939	0,08250	0,08316	0,08443	0,08239	0,08461	0,08423
	Alder	0,1003	0,08642	0,08662	0,08957	0,08783	0,08398	0,07904
	Pine	0,1042	0,08128	0,08679	0,08602	0,08441	0,08557	0,07907
	Spruce	0,1047	0,09318	0,09075	0,08788	0,08783	0,08673	0,08266

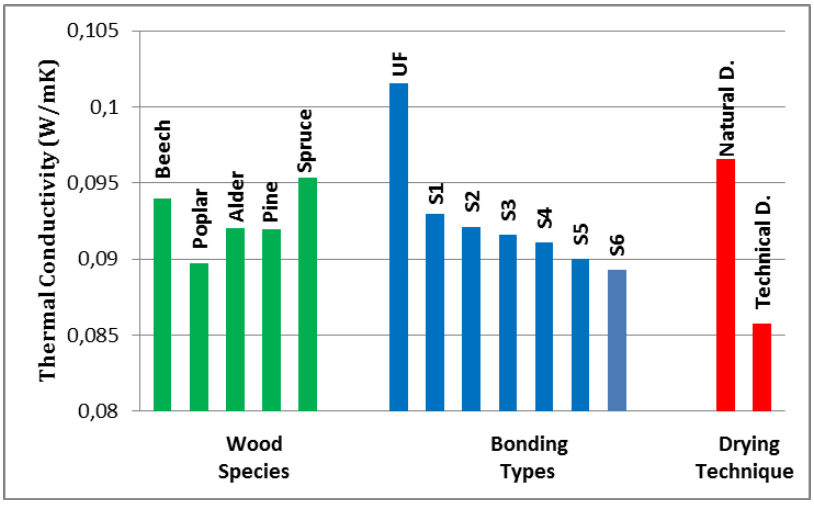

Figure 3. Effects of wood species, bonding types and drying technique on the thermal conductivity of particleboard (W/mK)

The heat conductivity of wood is dependent on a number of factors of varying degrees of importance. Some of the more significant variables affecting the rate of heat flow in wood are the following: (1) density of the wood; (2) moisture content of the wood; (3) direction of heat flow with respect to the grain: (4) kind, quantity, and distribution of extractives or chemical substances in the wood. Such as gums, tannins, or oils: (5) relative density of springwood and summerwood; (6) proportion of springwood and summerwood in the timber; (7) defects, like checks, knots, and cross grain structure (MacLean, 1941). Several studies about thermal conductivity of wooden materials showed that thermal conductivity was influenced from the thickness of composite materials, density, moisture content, the ratio of early and late wood zones, temperature, and flow direction of heat (Suleiman et al., 1999; Bader et al., 2007; Sonderegger and Niemz, 2009; Demirkir et al., 2013).

As can be seen from Table 2, the thermal conductivity values of conventional particleboards manufactured with urea formaldehyde adhesive were found to be higher than those of PCP panels. Generally, the lowest thermal conductivity values were obtained from the polystyrene composite particleboard bonded with S5 and XPS in the natural and technical drying, respectively.

According to the results from the study, thermal conductivity values obtained from natural drying were found to be higher than technical drying. In literature, the effect of the temperature on thermal conductivity of wood varied. Zhou et al. (2013) indicated for the MDF panels that thermal conductivity increased with the temperature up to 50°C and then decreased with increasing temperature in the range of 50°C to 100°C. On the other hand, it was stated that thermal conductivity of wood increases as temperature of the wood increases (Counturier et al., 1996). Tenwolde et al. (1988) also reported that the conductivity increased approximately 10 percent for every 50°C increase in temperature. The density of air filling the voids in the wood decreases as temperature increases, and this causes lower heat conduction through the voids (Suleiman et al., 1999; Aydin et al., 2015).

As shown in Figure 3, the usage of high density polystyrene in the manufacturing of PCP panels caused an decrease in thermal conductivity values. The panels manufactured from spruce gave the highest thermal conductivity values. The lowest values were found in the panels manufactured from poplar. It is known that density and moisture content have increasing effect on thermal conductivity of wood. As can be seen from Fig. 3, the lowest thermal conductivity values were determined for the panels obtained from poplar. The highest thermal conductivity values were obtained from spruce and beech. It was stated that the thermal conductivity of wood-based composites, as for wood, are strongly dependent on density and thermal conductivity of wood increases as density of the wood increases (Kamke and Zylkowski 1989; Kol and Altun 2009; Aydin et al., 2015). Also the extractive contents of spruce wood may have an increasing effect on the thermal conductivity of spruce particleboard panels. Simpson and Tenwolde stated that extractive content and a number of checks and knots in wood also play an important role on thermal conductivity (Demirkir et al, 2013).

4. Conclusion

The aim of the study was to investigate those effects of wood species, bonding types and drying technique on thermal conductivity properties of polystyrene wastes in particleboard production as a bonding material. Thermal conductivity values of traditional particleboard panels with urea formaldehyde adhesive were found to be higher than those of PCP panels. This study showed that particleboards produced from polystyrene wastes can be used as an alternative insulation material for internal use.

5. Acknowledgments

The authors acknowledge the financial support of this study by TUBITAK (The Scientific and Technical Research Council of Turkey) (Project No: 214O743). This study was presented in ORENKO 2018 – International Forest Products Congress held by Karadeniz Technical University, Trabzon.

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Wood Industry and Engineering
http://dergipark.org.tr/wie
Volume: 01 Number: 02
Pages: 63-76
Paper Type: Research Article
Received: 09.12.2019

A RESEARCH ON THE EFFECTS OF DEMOGRAPHIC AND SOCIO-ECONOMIC STATUS FACTORS ON CONSUMER PREFERENCES IN FURNITURE PURCHASE (CASE OF BLACK SEA REGION)

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Abstract

Consumer behaviour is an issue that must be studied by businesses in terms of marketing. The stages of purchasing any product can be different for each customer. Rapidly developing economic changes lead to strategic decisions such as gain new customers, the customer retention. Home furniture is very important in Forestry Products Industry in terms of both export and domestic consumption. In this study, factors affecting consumers in the Eastern Black Sea region when purchasing furniture (before, during, and after) were investigated. In addition, strategies for acquiring new consumers for furniture businesses were presented. The data were collected by face-to-face survey method and analyzed in SPSS statistics program and the results were explained.

Keywords: Furniture, Customer, Socio-economic status, Preference

1. Introduction

In order for a person to be regarded as a consumer in terms of marketing, the following are essential: (1) the need, (2) income and (3) spending request (Akyüz, 2006). The scope of the consumer term is quite broad and people, families, manufacturer and seller (commercial) enterprises, private and public institutions are the major consumption units. Consumer is defined as a real person who buys a marketing mix for personal desires, wants and needs and is in a purchasing capacity (Korkut and Kaval, 2015; Öztürk, 2006). Consumers prefer goods and services that provide the highest benefit and quality at the lowest cost and that suit them best. There are many factors that they pay attention when making this preference (Korkut and Kaval, 2015; Demircioğlu, 2012). For this reason, enterprises must have to take into account consumers' demands and needs, consumer behaviour characteristics while producing goods and services (Korkut and Kaval, 2015).

In accordance with their preferences and desires, consumer behaviour can express a range of processes related to producing and delivering goods or services to consumers (Penpece, 2006). The fact that consumer behaviour is influenced by external factors such as culture, family, advisory group, socio-cultural factors, marketing environment, indicates that it has both a structure that can change and adapt (Akyüz, 2006). Determination of consumer behaviour provides competitive advantages to the enterprises by developing effective market strategies and directing consumers (Gerlevik, 2012). Consumer markets are constantly changing and demographics are one of the most important changes. As the needs and demands of consumers differ, market segmentation according to demographic characteristics will be beneficial for enterprises (Akyüz, 2006). Therefore, marketers should constantly analyze consumer demands and preferences, shopping and purchasing behaviours and build their strategic decisions on this information (Öztürk, 2006).

Furniture, one of the most influential factors in the arrangement of a space, is an important factor in the design and comfort of a house. The function of furniture in our lives has not only been limited to being an object used at home, but it has become goods that establishes and transmits its own meaning structures in every period (Arpacı, 2014). For this reason, buying process of furniture is very important for consumers. The furniture sector includes (Erdinler and Koç, 2015):

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(1) Manufacturers such as seating groups, kitchen, office furniture,
(2) Industrial enterprises supplying raw materials, machinery and other investment materials to these manufacturers,
(3) Contract manufacturers.

The socio-cultural, psychological, demographic and situational factors of each consumer are different from each other. These characteristics of consumers who are influential on consumer preferences are socio-demographic (age, gender, family structure, education, occupation etc.), economic (income level, general economic status etc.) and behavioural (culture, social class, motivation, perception, attitude, personality, etc.) (Burdurlu et al., 2004). This is reflected in the purchasing process and shapes the preferences of consumers (Andaç, 2008). The most influential factors for the need for furniture are (Akyüz, 1998):

(1) It is obsolescence of the existing furniture,
(2) It is the need for new furniture. Because the children in the family grow up,
(3) It is other family-related factors,
(4) It is the increase in income,
(5) It is influence of friends groups,
(6) It is outdated furniture.

Reaching the right product that is needed is possible if consumers correctly identify their needs and possibilities. Having knowledge of consumers about furniture types and furniture characteristics will help to make their preferences in the most appropriate way (Arpacı and Obuz, 2013).

1.1. Social Class

In general, status is that people are graded according to certain criteria in a social hierarchy. Social class is the process of grading people in the social hierarchy and it has a hierarchical character. Because of this feature, members of the same class have almost the same status, while members of the other classes have more or less status. Because of the similar behaviour of social class members, the social class can be the basis for the market segmentation (Odabaşı, and Barış, 2002).

The most comprehensive study about the social class discrimination in Turkey was done by Zeta-Nielsen Research Company. According to this study, Turkish society is divided into six different classes named as groups A, B, C1, C2, D, and E. When the characteristics of these classes are examined, Turkish society is basically divided into three classes: upper, middle and lower. Groups A and B are the upper class, groups C1 and C2 are the middle class, and groups D and E are the lowest class. Furniture purchasing decisions also differ according to social classes. Social classes are more or less homogenous and socially hierarchical.

Similar values, lifestyles, interests and behaviours are seen in the same social class members. For example; clothing, housing, furniture, entertainment and mass media behaviours of individuals in the same social class are similar. People in different social classes have different desires and consumption values (Kalınkara, 2016).

2. Materials and Methods

The universe of our study constitutes 18 provincial centers located in the Black Sea Region. The number of consumers who applied the survey was found by stratified sampling according to the population sizes of 18 provincial centers and a total of 2370 surveys were evaluated.

The decision making behaviours of family members in furniture purchasing were evaluated according to different demographic characteristics. Socio-economic status groups (A, B, C1, C2, D and E) have been examined separately and socio-economic status is shortened in comments as SES.

Crosstab, frequencies, weighted averages and chi-square test were used for the results. Chi-square test results were applied on all demographic variables and significant differences were determined. The null (H_0) hypothesis which indicates that there are significant differences between consumer groups, was accepted when the P value is less than 0.05, while the alternative (H_1) hypothesis, which indicates that there are no significant differences between the consumer groups, was accepted when the P value is greater than 0.05. Table 1 gives the questions about which subjects consumers evaluate when purchasing furniture.

Table 1. Types of survey questions

Statement 1	Need for furniture and demand to purchase
Statement 2	Studies conducted before purchasing
Statement 3	Assessments regarding price before purchasing
Statement 4	Assessments regarding where to purchase
Statement 5	Assessments regarding the timing of purchasing
Statement 6	Assessments regarding colour, pattern, form, design
Statement 7	Assessments regarding brand and quality
Statement 8	Assessments regarding the final decision on buying
Statement 9	Assessments regarding the usefulness after purchase

3. Results

The distribution of demographic characteristics of the consumer groups participating in the survey was given in Table 2. As seen in Table 2, 56.1% of the consumers who participated in the survey are male and 43.9% is female. 33.5% of the respondents are low, 40.1% is in the middle and 26.4% is in the high income groups. The education levels of consumer groups are as follows: 18.9% is primary school, 11.8% is secondary school, 32.1% is high school, 34.5% is bachelor and 2.7% is postgraduate. The majority of the consumer groups participating in the survey are over the age of 31. It is seen that 35.4% of the surveyed families are in elementary family structure (4 people). The ownership status of the houses in which the families live is as follows: 61.8% is homeowner, 33.2% is rent and 4.9% is lodging building.

Table 2. Demographic characteristics of consumers

Demographic characteristics of consumers		Number (N)	Percentage (%)	Cumulative Total
Gender	Male	1330	56.1	56.1
	Female	1040	43.9	100
Income level	Low	794	33.5	33.5
	Middle	949	40.1	73.6
	High	626	26.4	100
Education status	Primary school	449	18.9	18.9
	Secondary school	279	11.8	30.7
	High school	761	32.1	62.8
	Bachelor's degree	818	34.5	97.3
	Postgraduate	63	2.7	100
Age group	18-24	125	5.3	5.3
	25-31	525	22.3	27.6
	32-38	659	28	55.7
	39-45	604	25.7	81.3
	46 and over	439	18.7	100
Number of individuals in the family	1 person	8	0.4	0.4
	2 people	257	11.4	11.7
	3 people	457	20.2	31.9
	4 people	804	35.6	67.5
	5 people	454	20.1	87.6
	6 people	223	9.9	97.4
	7 people	49	2.2	99.6
	8 people	9	0.4	100
Ownership status	Rent	784	33.2	33.2
	Homeowner	1459	61.8	95.1
	Lodging building	116	4.9	100

It was analyzed whether there are any differences between the answers given for "statement 1 (need for furniture and demand to purchase)" and all factors (demographic characteristics, male and female SES groups and total consumer SES groups). In tables, according to demographic characteristics, male and female SES groups and total consumer SES groups, Chi-square (X^2) test results of answers given by consumers were given.

The results of the X^2 test related to statement "1" were given in Table 3.

Table 3. The results of the X^2 test related to the need for furniture product and demand to purchase

Factors in Relationship		χ^2	p	df	Results
Need for furniture and demand to purchase	Gender	349.077	0.000	2	Significant
	Education	17.69	0.024	8	Significant
	Income	6.49	0.165	4	Insignificant
	Age	130.19	0.000	8	Significant
	Male SES	42.068	0.000	10	Significant
	Female SES	13.721	0.186	10	Insignificant
	Total SES	69.695	0.000	10	Significant

p<0.05 indicates a significant difference between the variables

Table 3a. Percentage distributions of statement "1" and statement "2"

Needs and demand of purchase					Studies conducted before purchasing					
Demographic and social class variables		Itself	Partner	Wife and husband	Demographic and social class variables		Itself	Partner	Wife. husband and children	Wife and husband
Gender	Male	12.9	35.9	51.2	Gender	Male	28.5	18.9	16.2	35.8
	Female	43	11	46		Female	29.2	19.7	15.9	32.8
Education	Primary school	31.8	25.8	42.4	Education	Primary school	30.8	25	17.2	27
	Secondary school	24.4	24.7	50.9		Secondary school	29.6	20.2	19.9	28.9
	High school	22.4	25.1	52.5		High school	28.6	19.3	15	35.8
	Bachelor's degree	27.2	24	48.7		Bachelor's degree	27.6	16.1	15.3	38.7
	Postgraduate	23.8	30.2	46		Postgraduate	30.2	14.3	12.7	42.9
Income	Low	27.1	22.4	50.6	Income	Low	33.1	17.9	18.1	29.7
	Middle	26.6	24.9	48.5		Middle	28.8	17.5	17	35.2
	High	24.3	28.1	47.6		High	23.4	23.7	12	39.5
Age	18-24	49.6	8.8	41.6	Age	18-24	36.8	8.8	7.2	37.6
	25-31	33	14.1	53		25-31	31.2	15.4	9.3	40.6
	32-38	27.2	24	48.8		32-38	29	17.9	13.7	39.2
	39-45	21	30.2	48.8		39-45	27.4	20.9	22.4	29.4
	46 and over	15.7	36	48.3		46 and over	25.6	26.1	20.6	27.2
Male SES	A class	7.4	51.9	40.7	Male SES	A class	10.2	30.6	13	43.5
	B class	9.3	32.8	57.9		B class	24.7	18.9	14.7	41.7
	C1 class	10.2	33	56.8		C1 class	29.2	17.2	18.8	34.2
	C2 class	17.1	35.9	47		C2 class	32.1	17.2	15.6	34.4
	D class	19.3	38.5	42.2		D class	30.6	21.9	15	32.5
	E class	23.8	28.6	47.6		E class	54.8	9.5	14.3	21.4

Table 3a - Continued

Female SES	A class	37.2	7	55.8	Female SES	A class	33.7	16.3	12.8	37.2
	B class	48.2	8	43.8		B class	29.5	10.7	11.6	45.1
	C1 class	46.3	9.3	44.4		C1 class	35.8	11.6	18.6	31.2
	C2 class	39.4	14.1	46.5		C2 class	36.6	19.7	25.4	16.9
	D class	41.7	12.5	45.8		D class	20.8	18.8	20.8	33.3
	E class	38.7	13.8	47.5		E class	23.3	30.1	15.8	30.1
All Consumer SES	A class	20.6	32	47.4	All Consumer SES	A class	20.6	24.2	12.9	40.7
	B class	27.4	21.4	51.2		B class	27	15.1	13.3	42.9
	C1 class	22.1	25.5	52.5		C1 class	31.1	15.2	18.8	33.3
	C2 class	21.2	31.9	46.9		C2 class	32.9	17.8	17.2	31.3
	D class	25.2	31.9	42.9		D class	29.2	21.1	16.3	32.1
	E class	37.7	15.4	46.9		E class	27	28.6	15.4	28.4

When Table 3a is taken into consideration, both men and women said that the demand to purchase furniture is caused by women. As the level of education in the families increases, it can be said that the ability to act together for "statement 1" increases. It has been seen that as the age increases, the demand for the purchase of furniture in the results of bilateral discussion with family members increases. As the level of income increases, the demand to purchase furniture is caused by women. For male SES groups, the following results were obtained:

(1) 31.7% of group “A” consumers said that the demand to purchase furniture is caused from their wives, while this rate for group “B” consumers decreased by 20.1%.
(2) In the middle-class consumer groups, the demand to purchase furniture is the result of bilateral discussion. To furniture purchasing demand, the rate of the shared decision making in the group “C1” is 53.2%, whereas in group “C2” this rate is 44%.
(3) It has been observed that the rate of shared decision making in lower-class consumers decreases. This rate is found to be 40.8% in group “D”.

For all consumer groups, the following results were obtained:

(1) The rate that the demand to purchase furniture is caused from their partners (wife or husband) in group “D” is 32.5% and this rate is 15.7% in the E group.
(2) The rate of shared decision making was found to be highest in group “C1” and the rate is 52.8%.

The results of the X^2 test related to studies conducted before furniture purchasing was given in Table 4. There were significant differences between studies conducted before furniture purchasing and all factors.

Table 4. The results of the X^2 test related to studies conducted before furniture purchasing

Factors in Relationship		χ^2	p	df	Results
Studies conducted before purchasing	Gender	15.357	0.000	4	Significant
	Education	45.94	0.000	16	Significant
	Income	39.29	0.000	8	Significant
	Age	188.11	0.000	16	Significant
	Male SES	59.781	0.000	20	Significant
	Female SES	86.058	0.000	20	Significant
	Total SES	69.583	0.000	20	Significant

$p<0.001$ indicates a significant difference between the variables

When Table 3a is taken into consideration, 35.8% of males and 32.8% of females stated that they made the shared decision on studies conducted before purchasing. As education levels increase in families, the rate of the shared decision making of studies conducted before purchasing also increase. This rate was found as 27.0% in primary school level, 28.9% in secondary school level and 38.7% in bachelor's degree. When income levels are examined, it appears that it is effective in children in families with higher income levels on studies conducted before purchasing. This effect is less in the middle and low income levels. For male SES groups, the following results were obtained: 43.5% of group "A" said that they made shared decision in studies conducted before purchasing and this ratio is 21.4% in group "E". For female SES groups, the following results were obtained: 45.1% of the consumers in group "B" stated that they made shared decision in studies conducted before purchasing, whereas 36.6% of the consumers in "C2" group stated that they carried out these studies by themselves. For all consumer groups, the following results were obtained: 42.9 % of the consumers in group "B" stated that they made shared decision in studies conducted before purchasing, whereas this rate is the lowest in group “E” consumers with 28.4%.

The results of the X^2 test related to assessments regarding price before purchasing were given in Table 5. There were significant differences between assessments regarding price before furniture purchasing and all factors.

Table 5. The results of the X^2 test related to assessments regarding price before purchasing

Factors in Relationship		χ^2	p	df	Results
Assessments regarding price before purchasing	Gender	232.092	0.000	3	Significant
	Education	79.49	0.000	12	Significant
	Income	44.64	0.000	6	Significant
	Age	29.79	0.000	12	Significant
	Male SES	96.747	0.000	15	Significant
	Female SES	103.387	0.000	15	Significant
	Total SES	308.987	0.000	15	Significant

$p<0.001$ indicates a significant difference between the variables

Table 5a. Percentage distributions of statement “3” and statement “4”

Assessments regarding the price of furniture products					Assessments regarding where to purchase					
Demographic and social class variables		Itself	Partner	Wife and husband	Demographic and social class variables		Itself	Partner	Wife. husband and children	Wife and husband
Gender	Male	49.2	6.4	43.9	Gender	Male	35.3	13.6	14.6	36.1
	Female	23.1	22.3	52.9		Female	20.9	19.4	14.6	43.1
Education	Primary school	38.7	19.8	41	Education	Primary school	34	21.3	13.9	30.9
	Secondary school	47.3	18.1	32.9		Secondary school	35.8	16.8	16.5	29.7
	High school	39.9	11	48.4		High school	29.7	15.1	15.2	39.2
	Bachelor’s degree	32.9	10.8	54.9		Bachelor’s degree	23.8	14.2	13.7	46.3
	Postgraduate	23.8	9.5	63.5		Postgraduate	22.6	14.5	14.5	48.4
Income	Low	43.7	11.9	43.5	Income	Low	37.9	14.6	15.7	30.9
	Middle	39	14.9	44.9		Middle	27.7	14.8	15.4	41
	High	28.1	12.9	57.8		High	19.6	20.3	12.1	46.9
Age	18-24	36.8	16.8	45.6	Age	18-24	31.7	9.8	9.8	42.3
	25-31	34.9	11	51.6		25-31	28.4	11.6	9.9	47.2
	32-38	35.7	13.7	49.8		32-38	28.4	15.7	13.1	42.6
	39-45	39.3	16.1	43.8		39-45	28.6	20	19	32.4
	46 and over	42.6	11.1	45.9		46 and over	30.5	19.4	17.8	32.3
Male SES	A class	20.4	10.2	65.7	Male SES	A class	12.2	28	10.3	46.7
	B class	39.2	8.8	51.9		B class	25.8	8.8	14.6	50.8
	C1 class	52.5	3.8	43.2		C1 class	39	13.1	14.9	32.6
	C2 class	58.8	4.2	36.7		C2 class	43.8	10.1	13.3	32.8
	D class	53.4	11.8	34.8		D class	36	19.9	17.4	26.7
	E class	59.5	4.8	33.3		E class	45.2	14.3	19	21.4

Table 5a - Continued

Female SES	A class	19.8	15.1	64	Female SES	A class	12.8	17.4	17.4	52.3
	B class	23.2	13.4	61.2		B class	23.2	12.1	12.5	50.4
	C1 class	33	10.8	54.2		C1 class	25.9	12.7	14.6	43.9
	C2 class	36.6	12.7	47.9		C2 class	28.2	16.9	12.7	42.3
	D class	22.9	22.9	50		D class	18.8	27.1	10.4	37.5
	E class	15.5	37.3	46.6		E class	16.8	27.5	16.6	38.1
All Consumer SES	A class	20.1	12.4	64.9	All Consumer SES	A class	12.4	23.3	13.5	49.2
	B class	32.1	11	55.9		B class	24.6	10.4	13.7	50.5
	C1 class	45.8	6.3	47		C1 class	34.5	13	14.8	36.3
	C2 class	54.9	6.1	38.2		C2 class	41.1	11.1	13.3	34.5
	D class	46.2	14.3	38.1		D class	32.9	21	15.7	29
	E class	20.1	33.8	45.4		E class	20.1	26.7	16.5	35.7

When Table 5a is taken into consideration, 49.2% of male consumers said that they carried out assessments regarding price by themselves, whereas this rate was found to be 23.1% in female consumers. Also, 52.9% of female consumers said that they made shared decision with husband in assessments regarding price. In economic decisions, male consumers seem to dominate in the family. As education level and income level increase, the rate of the shared decision making in the family on assessments regarding price before furniture purchasing increases. The rate of the shared decision making in primary school level is 41%, whereas it is 63.5% in postgraduate level. The rate of the shared decision making was found to be 43.5% at low income level, whereas this rate was found to be 57.8% at high income level. For male SES groups, the following results were obtained: 65.7% of the consumers in group "A" stated that they made shared decision in assessments regarding price before purchasing, whereas in group "C2", this value decreased to 36.7%. For female SES groups, the following results were obtained: 64% of the consumers in group "A" stated that they made shared decision in assessments regarding price before purchasing, whereas in group "D", this value was 50%. For all consumer groups, the following results were obtained: 64.9 % of the consumers in group "A" stated that they made shared decision in assessments regarding price before purchasing, whereas this rate was 38.1% for group "D".

The results of the X^2 test related to assessments regarding where to purchase were given in Table 6. There were significant differences between assessments regarding where to purchase and all factors.

Table 6. The results of the X^2 test related to assessments regarding where to purchase

Factors in Relationship		χ^2	p	df	Results
Assessments regarding where to purchase	Gender	74.147	0.000	4	Significant
	Education	66.37	0.000	16	Significant
	Income	77.93	0.000	8	Significant
	Age	128.46	0.000	16	Significant
	Male SES	111.115	0.000	20	Significant
	Female SES	58.030	0.000	20	Significant
	Total SES	157.611	0.000	20	Significant

p<0.001 indicates a significant difference between the variables

When Table 5a is taken into consideration, regarding gender, 35.3% of male consumers stated that they made assessments regarding where to purchase by themselves, while for female consumers this rate was found to be 20.9%. It can be said that male consumers are more dominant in terms of assessments regarding where to purchase. With the increase of the education level, the rate of shared decision making in the family for assessments regarding where to purchase also increased. I was found that as the income level of consumers increased, they made shared decision in assessments regarding where to purchase. For male SES groups, the following results were obtained: 46.7% of respondents forming group "A" stated that they made shared decision for assessments regarding where to purchase, whereas the rate of consumers in the group "B" (50.8%) was very close to the group "A". For female SES groups, the following results were obtained: the rate of shared decision making in the family on assessments regarding where to purchase was highest for “B” consumers (52.3%). For all consumer groups, the following results were obtained: the rate of shared decision making of the groups "A and B” is higher levels than other groups.

The results of the X^2 test related to assessments regarding the timing of purchasing were given in Table 7. There were no significant differences between “assessments regarding the timing of purchasing” and “age”, whereas there is a significant difference compared to other factors.

Table 7. The results of the X^2 test related to assessments regarding the timing of purchasing

Factors in Relationship		χ^2	p	df	Results
Assessments regarding the timing of purchasing	Gender	14.027	0.003	3	Significant
	Education	63.79	0.000	12	Significant
	Income	28.47	0.000	6	Significant
	Age	14.25	0.285	12	Insignificant
	Male SES	83.537	0.000	15	Significant
	Female SES	57.793	0.000	15	Significant
	Total SES	115.267	0.000	15	Significant

$p<0.05$ indicates a significant difference between the variables

Table 7a. Percentage distributions of statement “5” and statement “6”

Assessments regarding the timing of purchasing					Assessments regarding color. pattern. form. design					
Demographic and social class variables		Itself	Partner	Wife and husband	Demographic and social class variables		Itself	Partner	Wife. husband and children	Wife and husband
Gender	Male	32	11.8	55.6	Gender	Male	10.2	29.7	26.7	33.1
	Female	25.6	14.3	59		Female	37.4	7.1	25.2	28.3
Education	Primary school	32.1	18.8	48.7	Education	Primary school	26.2	19.9	31.8	21.9
	Secondary school	29.4	17.2	51.6		Secondary school	22.9	20.8	28	27.2
	High school	31.7	11.2	56.8		High school	20	20.7	26.1	32.4
	Bachelor’s degree	26.2	9.7	63.2		Bachelor’s degree	21.5	18.7	22.8	35.3
	Postgraduate	15.9	14.3	65.1		Postgraduate	23.8	19	17.5	39.7
Income	Low	33.5	13.6	52.2	Income	Low	22.9	19.5	29.4	27.2
	Middle	30.1	13.1	55.7		Middle	21.8	18.7	26.4	31.9
	High	22.3	11.7	65.2		High	21.6	21.8	21.2	34.5
Age	18-24	36	17.6	45.6	Age	18-24	35.2	10.4	12	34.4
	25-31	29.1	12.8	57		25-31	30.2	14.3	11.9	41.3
	32-38	29.5	10.8	59		32-38	21.3	16.3	27.7	34.8
	39-45	27.9	13.8	57.1		39-45	19.9	23.3	32.2	24.4
	46 and over	28.5	14.1	57.2		46 and over	13	29	35.8	21.7
Male SES	A class	12	18.5	65.7	Male SES	A class	1.9	38	20.4	39.8
	B class	24.7	9.7	65.6		B class	8.5	26.4	22.5	42.6
	C1 class	31	10.4	58.6		C1 class	9.1	28.8	29.4	32.5
	C2 class	41.9	10.1	47.4		C2 class	13.6	29.5	27.9	28.2
	D class	38.5	17.4	43.5		D class	14.9	31.7	26.1	26.7
	E class	42.9	14.3	42.9		E class	19	28.6	28.6	23.8

Table 7a - Continued

Female SES	A class	22.1	16.3	60.5	Female SES	A class	44.2	9.3	7	39.5
	B class	29.9	6.7	61.2		B class	37.1	4	19.6	36.6
	C1 class	27.1	8.4	64.5		C1 class	37.9	7	29	23.4
	C2 class	31	8.5	60.6		C2 class	33.8	9.9	28.2	28.2
	D class	37.5	10.4	50		D class	37.5	10.4	25	20.8
	E class	19.2	22.8	57.3		E class	34.9	8.1	30.7	25.5
All Consumer SES	A class	16.5	17.5	63.4	All Consumer SES	A class	20.6	25.3	14.4	39.7
	B class	27.4	8.3	63.3		B class	22.2	16	21	39.5
	C1 class	29.8	9.8	60.4		C1 class	18	22	29.3	29.5
	C2 class	39.5	9.8	50.1		C2 class	17	25.7	28.4	28.4
	D class	38.1	15.7	44.8		D class	20.5	26.2	25.7	25.7
	E class	22.5	22	54.8		E class	34.2	9.7	30.2	25.2

When Table 7a is taken into consideration, 55.6% of males and 59% of females stated that they made the shared decision on assessments regarding the timing of purchasing. İslamoğlu (1990) found that men and women decided together for durable consumer goods in terms of the timing of purchasing. For assessments regarding the timing of purchasing, as the education and income level of consumers increased, the rate of the shared decision making increased. For male SES groups, the following results were obtained: the rate of shared decision making in the family in terms of the timing of purchasing were 65.7% in group "A", 47% in group "C2" and 43.5% in group "D". For all consumer groups, the following results were obtained:

(1) The highest rate of shared decision making in the family was found 63.4% in group "A", whereas the lowest was found in group "D".
(2) The highest self-decision-making rate was found group "C2", whereas the lowest was found in group "A". Group "C2" followed by group "D".

The results of the X^2 test related to assessments regarding color, pattern, form, design were given in Table 8. There were significant differences between assessments regarding color, pattern, form, design and all factors.

Table 8. The results of the X^2 test related to assessments regarding color, pattern, form, design

Factors in Relationship		χ^2	p	df	Results
Assessments regarding color, pattern, form, design	Gender	363.851	0.000	4	Significant
	Education	44.41	0.000	16	Significant
	Income	17.87	0.022	8	Significant
	Age	277.73	0.000	16	Significant
	Male SES	44.066	0.001	20	Significant
	Female SES	52.948	0.000	20	Significant
	Total SES	128.845	0.000	20	Significant

$p<0.05$ indicates a significant difference between the variables

When Table 7a is taken into consideration, 37.4% of female consumers said that they carried out assessments regarding color, pattern, form, design by themselves, whereas this rate was found to be 10.2% in male consumers. It can be said that the female consumers are more dominant in determining the form, the pattern, the color and the design of the furniture in the family. In primary school-level, it was observed that it is effective in children in determining the form, the pattern, the color and the design of the furniture. To determining the form, the pattern, the color and the design of the furniture, as the income level of consumers increased, the rate of the shared decision making increased. As the ages of the consumers have increased, the self-decision-making rates of consumers have decreased. For male SES groups, as the level of social class decreased, the rates of shared decision making of consumers have decreased. For female SES groups, as the level of social class also decreased, the self-decision-making rates

of consumers and the rates of shared decision making of consumers have decreased. For all consumer groups, the following results were obtained:
(1) The highest rate of shared decision making in the family was found in groups "A "and "B".
(2) The highest self-decision-making rate was found in group "E".

The results of the X^2 test related to assessments regarding brand and quality were given in Table 9. There were no significant differences between "assessments regarding brand and quality" and "gender", whereas there is a significant difference compared to other factors.

Table 9**.** The results of the X^2 test related to assessments regarding brand and quality

Factors in Relationship		χ^2	p	df	Results
Assessments regarding brand and quality	Gender	3.352	0.34	3	Insignificant
	Education	34.15	0.001	12	Significant
	Income	29.09	0.000	6	Significant
	Age	21.10	0.049	12	Significant
	Male SES	51.35	0.001	15	Significant
	Female SES	51.424	0.000	15	Significant
	Total SES	68.489	0.000	15	Significant

p<0.05 indicates a significant difference between the variables

Table 9a. Percentage distributions of statement "7" and statement "8"

Assessments regarding brand and quality					Assessments regarding the final decision on buying				
Demographic and social class variables		Itself	Partner	Wife and husband	Demographic and social class variables		Itself	Partner	Wife and husband
Gender	Male	29.6	12.4	56.9	Gender	Male	44.7	7.1	48
	Female	28	14.9	55.9		Female	25	16.5	56.5
Education	Primary school	35.3	17	47.1	Education	Primary school	38.7	18.9	40.9
	Secondary school	29.7	12.9	55.6		Secondary school	38	12.3	48.9
	High school	28.7	13.3	57.5		High school	37.4	11	50.5
	Bachelor's degree	26.4	11.9	60.1		Bachelor's degree	33.8	7	58.3
	Postgraduate	15.9	15.9	66.7		Postgraduate	19.7	9.8	70.5
Income	Low	33.4	13.5	51.7	Income	Low	39.7	13.1	46.2
	Middle	29.7	14.3	55.3		Middle	38	11.5	49.6
	High	22	12.5	64.3		High	28.2	8.5	61.9
Age	18-24	40.8	10.4	47.2	Age	18-24	44	14.4	40.8
	25-31	30.9	12.8	54.7		25-31	32.6	13.8	52.6
	32-38	28.6	12	58.7		32-38	37.4	11.3	50.8
	39-45	28.6	15.8	54.7		39-45	33.3	9.2	56.4
	46 and over	24.9	14.8	59.1		46 and over	40.2	9	48.7
Male SES	A class	12	21.3	63.9	Male SES	A class	27.8	13.9	57.4
	B class	24.5	11.7	63		B class	37	7.5	55.1
	C1 class	31	10.8	57.5		C1 class	45.7	4.9	49.4
	C2 class	32.8	9.1	56.5		C2 class	50.2	5.9	43.3
	D class	36.6	19.3	44.1		D class	54.1	8.8	37.1
	E class	40.5	9.5	47.6		E class	50	14.3	35.7

Table 9a - Continued

Female SES	A class	15.1	16.3	68.6	Female SES	A class	9.3	4.7	84.9
	B class	28.1	8	60.7		B class	28.6	8.9	60.7
	C1 class	33.6	11.2	54.7		C1 class	34.1	6.1	57.9
	C2 class	26.8	15.5	57.7		C2 class	39.4	9.9	46.5
	D class	18.8	22.9	54.2		D class	21.3	34	44.7
	E class	28	19.4	52.6		E class	17.8	28.7	51.2
All Consumer SES	A class	13.4	19.1	66	All Consumer SES	A class	19.6	9.8	69.6
	B class	26.5	10	61.7		B class	33.3	8.2	57.4
	C1 class	31.7	10.9	56.8		C1 class	41.9	5.4	52.2
	C2 class	31.8	10.3	56.5		C2 class	47.9	6.4	44.4
	D class	32.4	20	46.7		D class	46.4	14.5	39.1
	E class	29.6	18.7	51.3		E class	21	27.4	49.5

When Table 9a is taken into consideration, as the ages, income level, and education levels of the consumers have increased, the rates of shared decision making of consumers have increased. In addition, as the ages, income level, and education levels of the consumers have increased, the self-decision-making rates of consumers have decreased. For "male SES groups", "female SES groups", and "all consumer groups", as the level of social class decreased, the rates of shared decision making of consumers have decreased.

The results of the X^2 test related to assessments regarding the final decision on buying were given in Table 10. There were significant differences between assessments regarding the final decision on buying and all factors.

Table 10**.** The results of the X^2 test related to assessments regarding the final decision on buying

Factors in Relationship		χ^2	p	df	Results
Assessments regarding the final decision on buying	Gender	133.506	0.000	3	Significant
	Education	67.85	0.000	12	Significant
	Income	39.23	0.000	6	Significant
	Age	28.88	0.004	12	Significant
	Male SES	46.443	0.000	15	Significant
	Female SES	126.088	0.000	15	Significant
	Total SES	235.473	0.000	15	Significant

p<0.001 indicates a significant difference between the variables

When Table 9a is taken into consideration, 44.7% of male consumers said that they carried out assessments regarding the final decision on buying by themselves, whereas this rate was 25% in female consumers. It can be said that male consumers are more effective in making the final decision on purchasing furniture in the family. İslamoğlu (1990) emphasized that men play an important role in making final decisions on durable consumer goods. As the ages, income level, and education level of the consumers have increased, the rates of shared decision making of consumers have increased. For "male SES groups", "female SES groups", and "all consumer groups", the highest rates of shared decision making are "A" and "B" groups, respectively. In other words, as the level of social class of consumers increases, the decision making and assess of consumers together is increasing.

The results of the X^2 test related to assessments regarding the usefulness after purchasing were given in Table 11. There were significant differences between assessments regarding the usefulness after purchasing and all factors.

Table 11. The results of the X^2 test related to assessments regarding the usefulness after purchasing

Factors in Relationship		χ^2	p	df	Results
Assessments regarding the usefulness after purchasing	Gender	29.409	0.000	4	Significant
	Education	60.84	0.000	16	Significant
	Income	62.98	0.000	8	Significant
	Age	163.73	0.000	16	Significant
	Male SES	54.831	0.000	20	Significant
	Female SES	61.238	0.000	20	Significant
	Total SES	79.744	0.000	20	Significant

$p<0.001$ indicates a significant difference between the variables

Table 11a. Percentage distribution of statement "9"

Assessments regarding the usefulness after purchasing furniture					
Demographic and social class variables		Itself	Partner	Wife, husband and children	Wife and husband
Gender	Male	21.6	17.6	45.1	14.7
	Female	26.6	11.2	43.3	17
Education	Primary school	26.3	14.5	36.4	22.1
	Secondary school	29.5	15.8	36.7	16.2
	High school	22.8	15.3	43.3	17.4
	Bachelor's degree	21.1	14.2	51.8	10.9
	Postgraduate	27	14.3	49.2	9.5
Income	Low	27.7	14.3	38.2	18.2
	Middle	25.4	15.4	41.3	16.4
	High	16.3	14.4	56.7	11.4
Age	18-24	38.4	9.6	40.8	0.8
	25-31	26.5	14.1	49.3	7.8
	32-38	22.1	15.4	44.4	17.4
	39-45	22.8	16.9	41.2	18.9
	46 and over	20.7	12.8	43.7	22.1
Male SES	A class	10.2	13	63	11.1
	B class	16.7	20.5	51.9	10.9
	C1 class	22.4	19.3	42.4	14.9
	C2 class	22.1	16.2	43.8	17.2
	D class	29.8	14.9	35.4	18.6
	E class	38.1	11.9	33.3	14.3
Female SES	A class	18.6	12.8	60.5	7
	B class	29.5	8	50.9	11.2
	C1 class	26.2	9.3	44.9	15.4
	C2 class	32.4	14.1	38	15.5
	D class	25	8.3	35.4	25
	E class	25.1	13.5	37	23.3
All Consumer SES	A class	13.9	12.9	61.9	9.3
	B class	22.9	14.8	51.1	11
	C1 class	23.5	15.9	42.9	15.4
	C2 class	23.6	15.9	43.2	16.7
	D class	29	13.3	35.2	20
	E class	26.7	13.7	36.6	21.7

When Table 11a is taken into consideration, in all demographic and socio-economic variables, it was observed that it is effective in children on assessments regarding the usefulness after purchasing furniture.

4. Conclusion

It was found that the partners (husband and wife) decide together on factors such as the need to the purchase of furniture, studies conducted before the purchase of furniture, assessments regarding the timing of purchasing, and assessments regarding brand and quality. Although decision-makers are women on assessments such as form, colour, pattern, design in furniture, decision-makers are men on assessments such as price, where to purchase, and the final decision on buying. Moreover, although the partners decide together on the need to purchasing, women are more dominant than men.

It was found that in factors affecting consumers when purchasing furniture, as income level and education level of the consumers increase, the rates of shared decision making of consumers increase in general.

When we examined the factors that influence the consumer's preference in terms of age, the following results were obtained:

(1) The highest rate of shared decision making in the family on factors such as the need to the purchase of furniture, studies conducted before the purchase of furniture, assessments regarding price, assessments regarding where to purchase, and assessments regarding form, color, pattern, design is in the age range 25-31.
(2) The highest rate of self-determination on the need to the purchase of furniture is in the age range 18-24.
(3) The highest rate of shared decision making on assessments such as where to purchase, and the final decision on buying is in the age range 39-45.
(4) The highest rate of shared decision making on assessments regarding the timing of purchasing is in the age range 32-38.
(5) The highest rate of shared decision making on assessments regarding brand and quality is the age group of 46 and above.

In terms of social class, the highest rate of shared decision making of consumers on all factors is in groups “A and B". That is, as the class level of consumers decreases, the rate of shared decision making of consumers decreases. One of the remarkable results is that more than 50% of the consumers in group "C2” carried out assessments regarding price on their own.

In all demographic and socio-economic variables, it was observed that it is effective in children on assessments regarding the usefulness after purchasing furniture.

5. Acknowledgments

This study was presented at the "1st International Technology Science and Design Symposium" and published in the full text book.

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Wood Industry and Engineering
http://dergipark.org.tr/wie
Volume: 01 Number: 02
Pages: 77-80
Paper Type: Research Article
Received: 26.12.2019

INVESTIGATION OF PHYSICAL PROPERTIES OF PLYWOOD TREATED WITH FIRE RETARDANT CHEMICALS

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Abstract

The treatment with fire retardant chemicals is the most effective process to protect wood and wood based products from fire. Therefore, the usage of fire retardant chemicals has been increasing. However, the fire retardant chemicals have an effect on other physical, mechanical and some technological properties of the materials treated with them. In this study, it was examined that the effect of fire retardant on physical properties of plywood. Alder (*Alnus glutinosa* subsp. *barbata*) and Scots pine (*Pinus sylvestris* L.) were used as wood species; zinc borate, monoammonium phosphate and ammonium sulphate were used as fire retardant chemicals and UF resin was used as adhesive. The veneer sheets were treated with immersion method. Physical properties of the plywood panels such as thickness swelling and water absorption, density and equilibrium moisture content of the panels were determined according to TS EN 317, TS EN 323-1 and TS EN 322, respectively. Thickness swelling and water absorption values of panels produced with the veneers treated with fire retardant chemicals were less than those of control panels for 2 h. However, there is no statistical difference in these results for 24 h. In addition, it was found that the density values of panels treated zinc borate was the highest in the all groups for Scots pine.

Keywords: Alder, Fire retardant, Physical properties, Plywood, Scots pine

1. Introduction

Plywood is preferred as constructional material and has conventionally played an important role in light frame construction. Plywood and other wood-based materials are extensively used in the production of furniture, engineered flooring, housing, and other industrial materials (Bohm et al. 2012). However, the usage and application areas of plywood are limited since the plywood is a flammable material. Therefore, there has been much interest in the fire-retardant-treatment of wood-based panels (Cheng and Wang 2011). The plywood panels treated with fire retardant chemicals are extensively used in usage. Especially, they are generally preferred in furniture industry and construction applications (Tanritanir and Akbulut 1999; Winandy 2001; Ayrilmis et al. 2006).

The wooden materials treated with fire retardant chemicals enable an applicable alternative to conventional non-combustible products where a higher level of fire safety is necessary or desirable (White and Mitchell 1992). Boron compounds are known one of the best fire retardant chemicals due to their beneficial effects like neutral pH, protective efficiency, and less effect on mechanical strength than the others (Levan and Tran 1990). Also, phosphorus-containing compounds like mono- and di-ammonium phosphates are considered very effective fire retardant chemicals, so they have been preferred for wooden and wood-based products for quite a long time (Grexa et al. 1999).

The fire retardant chemicals are harmless to human, animals and plants, there is also a less release of smoke and less toxic gases when burned and these are important parameters for consumers to select one of such products. It was also shown the fire retardant chemicals influence the physical, mechanical and some technological properties of the materials treated with them (He et al. 2014; Yao et al. 2012).

In this study, it was examined that the effect of fire retardant on physical properties of plywood. For this purpose, the panels produced as three ply-plywood and it was determined thickness swelling and water absorption, density and equilibrium moisture content as physical properties.

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2. Materials and Methods

In this experimental study, 2 mm-thick rotary cut veneers with the dimensions of 500 mm by 500 mm were obtained from alder (*Alnus glutinosa* subsp. *barbata*) and Scots pine (*Pinus sylvestris* L) logs. While the alder veneers were manufactured from freshly cut logs, Scots pine logs were steamed for 12 h before veneer production. The horizontal opening between knife and nosebar was 85% of the veneer thickness, and the vertical opening was of about 0.5 mm in the rotary cutting process. The veneers were then dried to 6–8% moisture content with a veneer dryer. After drying, veneer sheets were treated with some fire retardant chemicals. For this aim, 5% aqueous solutions of zinc borate (ZB), monoammonium phosphate (MAP) and ammonium sulphate (AS) were used. The veneers were subjected to re-drying process at 110°C after their immersion in fire retardant solutions for 20 min.

Three-ply-plywood panels having 6 mm thickness were manufactured by using urea formaldehyde resin. The formulations of adhesive mixture used for plywood manufacturing are given in Table 1. Veneer sheets were conditioned to approximately 5–7% moisture content in a climatization chamber before gluing. The glue mixture was applied at a rate of 160 g/m^2 to the single surface of veneer by using a four-roller glue spreader. Hot press pressure was 12 kg/cm^2 for alder and 8 kg/cm^2 for Scots pine while the hot pressing time and temperature were of about 6 min and 110ºC, respectively. Two replicate panels were manufactured for each test groups.

Table 1. The formulations of UF glue mixture used for the manufacturing of plywood

Glue Type	Ingredients of Glue Mixture	Parts by weight
UF	UF resin (with 55% solid content)	100
	Wheat flour	30
	Hardener - NH_4Cl (with 15% concentration)	10

Physical properties of the plywood panels such as thickness swelling and water absorption at 2 and 24 hours, density and equilibrium moisture content of the panels were determined according to TS EN 317 (1999), TS EN 323-1 (1999) and TS EN 322 (1999), respectively. The obtained data were statistically analyzed by using the analysis of variance (ANOVA) and Duncan's mean separation tests.

3. Results and Discussion

The density and equilibrium moisture content mean values and Duncan's test results of plywood panels according to the wood species and fire retardant chemicals were shown in Table 2. In addition, the thickness swelling and water absorption values at 2 and 24 hours and Duncan's test results were given in Table 3.

Table 2. Density and equilibrium moisture content means and Duncan's test results of plywood panels (P < 0.05)

Wood Species	Fire Retardants Chemicals	Density (g/cm^3)		Equilibrium Moisture Content (%)	
Alder	Control	0,639	a*	8,63	b
	ZB	0,646	a	8,39	a
	MAP	0,640	a	8,57	ab
	AS	0,626	a	8,55	ab
Scots Pine	Control	0,575	a	8,89	a
	ZB	0,649	b	8,62	a
	MAP	0,600	a	8,70	a
	AS	0,599	a	8,33	a

* The mean values marked with the same symbol are statistically identical.

Table 3. Thickness swelling and water absorption means and Duncan's test results of plywood panels (P < 0.05)

Wood Species	Fire Retardants Chemicals	Thickness Swelling (%)				Water Absorption (%)			
		2 h		24 h		2 h		24 h	
Alder	Control	3,70	b*	9,71	a	33,71	b	48,41	a
	ZB	3,27	ab	9,40	a	32,06	a	48,10	a
	MAP	2,43	a	8,93	a	31,74	a	47,96	a
	AS	2,29	a	8,75	a	31,34	a	47,80	a
Scots Pine	Control	3,70	a	8,15	a	32,47	b	39,33	a
	ZB	3,46	a	8,72	a	28,02	a	40,80	a
	MAP	3,30	a	8,45	a	27,49	a	40,59	a
	AS	3,38	a	8,53	a	27,60	a	40,67	a

* The mean values marked with the same symbol are statistically identical.

As can be seen from Table 2, there was no statistical difference in the density values were obtained for the all groups of alder plywood. However, the mean obtained from panel treated zinc borate was statistically the highest in the all groups of Scots pine plywood. It was seen that there was generally a slight increase in the density values. The spaces in the control groups are filled with air, but the spaces of the specimens were impregnated are filled with impregnated materials. Increasing of density is expected result due to less air space (Aytaskin 2009; Demir 2014). There was no difference in the equilibrium moisture content means for the groups of Scots pine plywood. The mean of the control group of alder plywood was higher than the other groups of alder plywood.

As can be seen from Table 3, the thickness swelling and water absorption values of panels produced with the veneers treated with fire retardant chemicals were less than those of control panels for 2 h. Waterborne inorganic salts, such as boron compounds and phosphates, adversely affect swelling and expansion properties of wood and wood composites because of their hygroscopic characteristics and possible interaction between the deposition of boron and phosphate crystals and the monomer in the cell wall (Dundar et al. 2009). This explains some changes in the groups especially the thickness swelling and water absorption values of Scots pine for 24 h. However, there is no statistical difference in these results for 24 h. In literature, phosphate and the boron compounds did not have a significant negative effect on the dimensional stability of sandwich and LVL panels (Rosero-Alvarado et al. 2018; Dundar et al. 2009).

4. Conclusions

In this study, it was aimed to investigation of the effect of fire retardant on physical properties of plywood. As a result of this study, thickness swelling and water absorption values of panels produced with the veneers treated with fire retardant chemicals were less than those of control panels for 2 h. However, there is no statistical difference in these results for 24 h. In addition, it was found that the density values of panels treated zinc borate was the highest in the all groups for Scots pine.

It has been determined that the impregnation process generally improves the physical properties of wood materials. It was affected differently especially the swelling and water absorption of the wood materials depending on the wood species. Therefore, these changes in the strength values and the probability of moisture exchange in the usage must be taken into attention, depending on the wood species used before impregnation.

5. Acknowledgments

This study was presented in ITESDES 2018 held by Giresun University, Giresun.

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Wood Industry and Engineering

http://dergipark.org.tr/wie

Volume: 01 Number: 02 Pages: 81-87

Paper Type: Review Article Received: 11.11.2019

INNOVATIVE APPROACHES IN WOOD INDUSTRY

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Abstract

For businesses to act in accordance with the developing technology will enable them to differentiate from their competitors with innovative approaches in a competitive environment. In addition to competitive elements such as cost, aesthetics, functionality, etc., all the innovative approaches of a business from design to final product are also an important mechanism in getting the edge over the competition.

Innovative thinking has different and important effects on the development of business models. Traditional revenue models involve unforeseen risks. For example, wrong and weak preferences that may occur in the parameters such as selection of job type and job site, determination of target group, pricing policy etc. can cause the related business model to fail. It is, however, possible to prevent financial losses by exhibiting the innovative approaches that minimize these risks.

In order businesses to survive, it has become essential to maximize their profitability because of the high-ranking competition as a result of the global economy. In this context, the businesses that operate efficiently are able to achieve the desired profit margins. Otherwise it has become nearly impossible for them to survive.

In the wood industry, the final products are produced by passing the raw material obtained from forest resources through various processes. Within all this complex structure, the businesses often suffer financial losses or cannot take huge leaps because of traditional habits. Apart from this, the handling of production processes and marketing the products with a new perspective form an important basis for the economic breakthroughs.

Within the framework of this academic research, the effects of the innovative methods and the transformations that these methods would bring in to the wood industry besides its traditional structure are examined.

Keywords: Innovative approach, Wood industry, Sectoral competition, Furniture.

1. Innovation Perception of Enterprises

1.1. What is Innovation?

Innovation is an approach that encompasses all the processes carried out to develop new or improved products, services, or production methods and to make them commercially viable (Çetin 2017).

Oslo Guide, a joint-publication of OECDO and Eurostat, and translated into Turkish by TÜBİTAK, describes "innovation" as follows: “An innovation is the execution of a new or significantly improved product (good or service), or a process, a new marketing method or a new organizational method in inter-business applications, workplace organization or external relations.” (Oslo Manual 2006). As can be understood from this definition, innovation cannot be isolated from any of an enterprise's activities, in fact, it means an integrated approach covering an enterprise’s all activities.

Innovation is doable by turning new ideas and discoveries into commercial benefits for the sustainability of the enterprises. That is, innovation management is a process where the introduction of new ideas turns into financial gain (Taşkın 2014).

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1.2. Innovation Requirement

The competitive conditions in which the enterprises operate are constantly changing with the influence of the environment and technology. Innovation and R&D in this changing environment is indispensable in terms of the development of an enterprise. Being constantly dynamic and in change-oriented activities in order to be at the top of a competition bring success to an enterprise. Certainly, being in search of innovation in business model and differentiating from other competitors bring efficiency and success (Karayılmazlar et al. 2006).

In enterprises which adopt traditional management approach, the expected change and innovation do not occur at desired level due to the management's attitude. As a result, the enterprise lags behind its competitors over time and loses market share.

Enterprises are not able to increase productivity and quality without R&D and adding knowledge to processes. It is also not possible to increase the volume of their trades unless new products are developed that contain knowledge.

It is possible for enterprises to create higher added-value with people with a high level of knowledge and a high investigative personality. However, for enterprises it does not go further than low-cost and less intelligent labor employment since the goal is to produce low-cost products without added-value (Kavrakoğlu 2016).

The development and change in wood industry have preferred or transferred of what has been done until today. From now on, it is necessary to adopt "more creative production approach than imitationist one. For this, employees must be motivated, encouraged in creativity and innovation, and a productive environment needs to be established to improve innovation." (Karayılmazlar et al. 2006).

2. Innovation Approach

2.1. Innovation and R&D Concepts

Innovation can be done in the total process cycle as well as in entire process and its sub-processes. Innovation should not be considered like R&D. One has to make an expense for the research to be carried out and consequently a new product or service can be created in accordance with information obtained. Innovation, however, can be done in every topic and in every field and the outcome that is achieved as a result of the change of a current method or process is also an innovation. The important thing at this point is whether innovation provides added-value and whether it creates plus-value to the enterprise. If answers to these questions are "yes", it can be said that one is doing an innovative work.

According to the OECD Frascati manual, the definition of R&D is given as "R&D comprise creative and systematic work undertaken in order to increase the stock of knowledge -including knowledge of humankind, culture and society -and to devise new applications of available knowledge." (Gök, 2002).

2.2. Innovation Areas

Innovation can be applied to all processes of an enterprise, but these areas have been categorized in a close-approaches in the literature. The Oslo guide has been grouped under four titles to cover these areas.

a-Product Innovation: It is the introduction of a new or significantly improved product or service according to their current characteristics and intended use (Oslo Manual 2006). Here, the term of product has been used as to cover products and services. It includes innovative work to be done in anywhere of the entire flow from innovations to be done in the processes to innovations occurring during the use of end-consumers in the production of product or service.

Innovation in the way of the deliverance of a product or service (i.e. in efficiency or use of capacity) can include the change in the current production method such as increasing the efficiency of the production using the same production model but new additional equipment or increasing the capacity using different production models.

b-Process Innovation: It is the application of a new or significantly improved production or delivery method (Karayılmazlar et al. 2006). With innovations to be done in the processes, the unit production time can be shortened, delivery costs can be reduced or innovations can be conceived to enhance quality with making significant differences for the costumers.

c-Marketing Innovation: It is a new marketing method that involves the important changes in the designing or packaging the product, the position of it in market, and presentation and pricing of it (Karayılmazlar et al. 2006). It can be thought as a way for an enterprise to enter new markets to increase the sales, to develop different marketing strategies or to develop new methods that can respond to customer demands more successfully.

d-Organizational Innovation: It is a new organizational method in the commercial application of an enterprise, in the workplace organization or in the external relations (Karayılmazlar et al. 2006). It is anticipated that the constitution of a new structure that has not been implemented before in the organizational structure and increasing the satisfactory of employees and customers within it.

In the classification of the innovation process of which the short descriptions and scopes are given above, the possible subheadings with the headings are shown in Fig. 1. It is divided into four main themes and each theme has been detailed thoroughly.

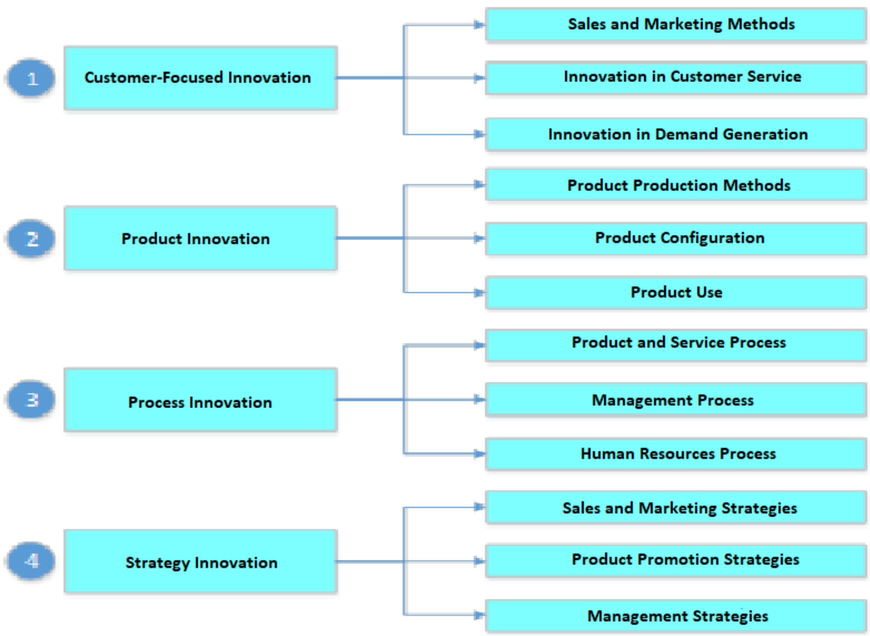

Figure 1. Innovation Themes

2.3. Interaction in Innovation

There are two different interactions that trigger the formation of innovation. The first is the innovation that is shaped by finding solutions to unmet needs and problems in current applications (Brem and Voigt, 2009) This is called market-demanding innovation and market pull. A schematic diagram of how the market pull works is given in Fig. 2. The emergence of LPG-powered automobiles is a good example for this. High fuel prices, especially in Turkey, have led the consumers to more affordable fuels. Then, LPG products which can be installed to the vehicles afterward have emerged.

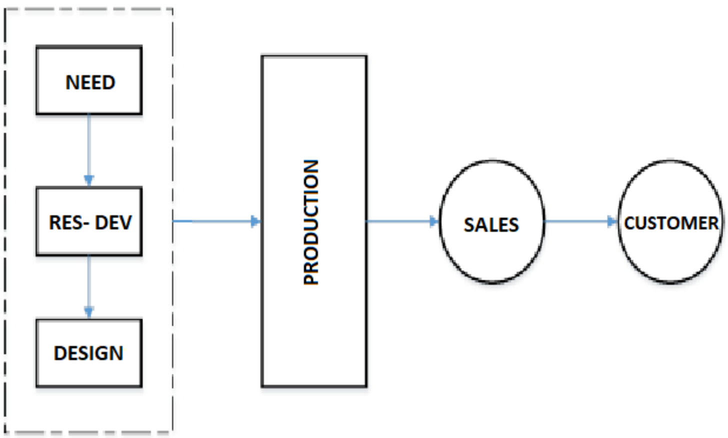

Figure 2. Market Based Innovation Process

As known, cars are out of factory having gasoline or diesel-powered engines. The same engine is put into operation by the installation of LPG tank and equipment particularly for pulling the cost of gasoline down.

The second is the innovation method which is developed with R&D studies and carried out with the use of new technology or new materials and brings more effective solutions along with. This is called the technology push because of the development of the technology. The best example of this type of innovation that is formed by the technology push and schematically shown in Fig. 3 is smart phones.

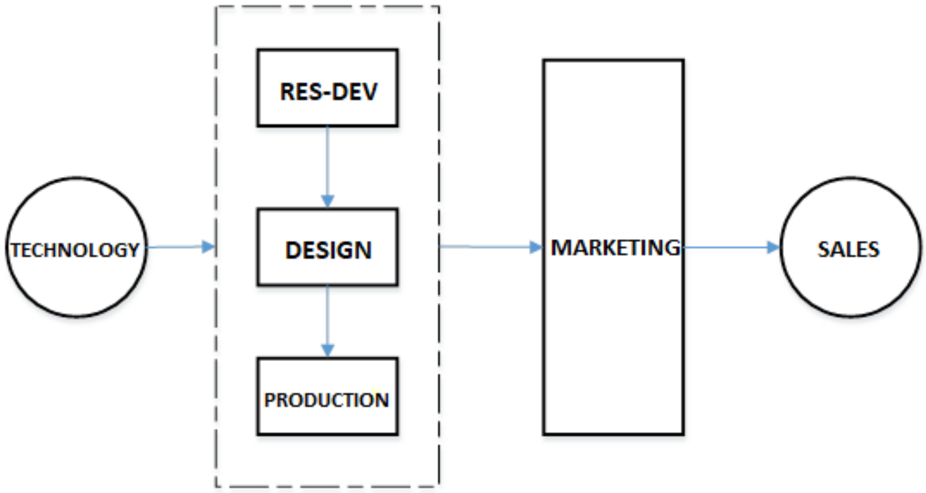

Figure 3. Technology Based Innovation Process

An enterprise's innovation capacity is closely related to its competitiveness. The strength of competitiveness and innovation of enterprises depend on the size of the enterprise and the orientation to exportation (Cao, 2004). According to this definition, as a result of the aforementioned processes of innovation, the enforced improvement by the demand from the market or the development of technology becomes important in terms of the development and continuity for an enterprise. The failure of an enterprise in developing an innovation lags it behind its competitors which would result an enterprise to collapse in future. For instance, it is known that some of globally-known companies in 90's have become collapsed today.

3. Innovation in Furniture Manufacturing Operation

The furniture industry in Turkey is predominantly occupied by workshops and small-scale enterprises, which adopt traditional methods. In recent years, however, the number of medium and large-scale enterprises has started to increase rapidly. According to SGK data of 2014, the furniture industry is in the 4th place with 20.867 enterprises in the manufacturing industry. It is in the 7th place with 165,118 employees. At the end of 2014, it is estimated that the worth of the production of the furniture industry is 19 billion USD and of the consumption is 14 billion USD in Turkey (Orta Anadolu İhracatçı Birlikleri Genel Sekreterliği, 2016).

The European Union Furniture Industry has undergone significant changes in recent years. The main factors that trigger this change are the desire of the exporter to enhance the quality, design and innovation value (European Commission Furniture Industry).

In addition to the increasing globalization and digitization of markets, relying on only innovation and design are not enough to protect the intellectual property rights. Rapid and strong research and innovation also require financial support. In this context, SMEs do not have sufficient financial strength and hence the level of innovation does not develop at the same rate.

As a result of being in a search of a solution to the demands and problems in the furniture industry, hinges with brakes on cabinet doors, which can be described as an innovation pull, can be given as an example. The brake system that was firstly installed to the cabinet doors as a separate apparatus can be produced integrated with the hinges in parallel with the technological improvement. Also, the examples to the innovation push in the furniture industry are laminate flooring and sofa beds, where a sofa have a mechanism which turns into a bed. Use of solid wood in the production of flooring for a long period of time has caused resource shortage and led to new search and together with developing material and processing techniques, HDF (high density fiberboard), which is a wood-based material, and laminated flooring materials of which upper side has wood-like patterns have been produced. Particularly in places where the use of wood is requested, laminated flooring -laminating wooden sheets to counter material- has been brought into service.

In 2015, as a result of the study initiated to solve the capacity problem experienced in the CNC surface finishing machine in an office furniture producing enterprise, to which consultancy services are provided, machine capacity is increased by 100% and unit processing time is shortened with the novel approach in the production process. In this study, every stage of the current business process was examined to reach the solution and brainstorming has been done with the engineers in the enterprise on which phase of the process the improvement can be done. At the end of the study, with a developed method the number of parts processed by the machine in one operation was increased to two and the capacity increased twice. In Fig. 4, the current situation and the result after the innovation are shown schematically.

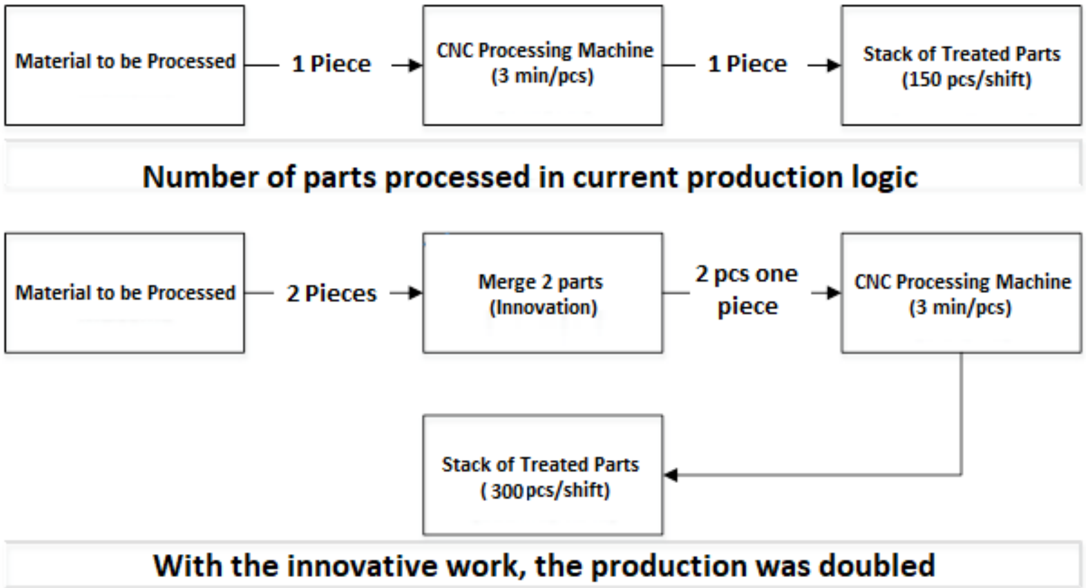

Figure 4. Innovation example in CNC table

Innovation here has emerged with the enforcement of conditions and is a good example for the innovation pull.

Another example for the innovation in the Turkish Furniture Industry in recent years is "smart bed" products. Various smart beds were developed under the brand "MedBed" and several patent applications were made by Zeki Candan, Faculty Member of Istanbul University Forest Products Engineering Department and Özkan Ocak, Forest Products Engineer. The body temperature of the person lying on the bed, especially the infants, is detected and when the emergency is arisen, the situation is automatically transmitted to the relatives and doctor of the person lying and emergency medical service (Smart Bed: "MedBed" 2015).

Actually, there are many innovations that have been done in wood sector with the enforcement of the conditions. However, because of the lack of recording and that the concept of innovation is not fully known in the sector, innovations are not emerged or neither attributed so.

3.1. Meaning of Innovation in Furniture Industry

The sector closely follows the development of Machinery Park by importing the technology. However, it is a disadvantage that the number of enterprises aiming to improve by investing only in machinery is high. In fact, it shows that the industry cannot provide real development. One of the most important deficits of the furniture industry is the slow pace of work on managerial structuring. In fact, this shows that the industry has not developed fully. One of the most important deficiency of the furniture industry is the slow pace of work on managerial structure. Particularly investment on white-collar personnel is extremely low and employment of engineer is not sufficient. This also affects the work or analysis that can be done on innovation.

Today, there are many furniture enterprises that can be said large-scale in terms of their structures. When these companies are examined, it seems that managing some of these enterprises as a large-scale workshop leads to the formation of idle capacity. However, unnecessary machinery investment can be prevented by using the available capacity efficiently. The most important work to be done for this is the establishment of managerial infrastructure.

The flaws in the establishment of the concept of innovation in the industry and having lower R&D investments of the enterprises than that of in UN countries are caused by this gap. It is seen that in the furniture sector, where engineering studies should be predominant, the enterprises still work on the initiative of the chief. The enterprises in furniture industry need to carry out the operations with a professional engineering approach. Otherwise, the intensive competition around the world is expected to continue to take the enterprises down

4. Conclusion and Recommendations

The opportunities of innovation management available to industry needs to be analyzed and evaluated correctly. Adopting an innovative approach to stand out of the competition should be the management's priority. In this regard, as stated in the research done by Taşkın (2014), the lack of training of the employees needs to be eliminated to be able to seize the innovation approach in the furniture production enterprises.

As mentioned above, managerial structures must be rearranged and shaped according to modern management approach so that enterprises can successfully carry out the innovative work.

Leaving the classical management approach behind and moving towards a more participatory structure will spread innovative approach to the basis.

In order to ensure full participation in the innovation approach, the enterprise management should be open to new ideas. In addition, a functioning proposal and performance evaluation system will stimulate employee motivation and innovative approach.

5. Acknowledgments

The authors thank Chamber of Forest Engineers Istanbul Branch and Istanbul University-Cerrahpaşa for supporting this study. This study was presented in ORENKO 2018 – International Forest Products Congress held by Karadeniz Technical University, Trabzon.

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