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FLAMMABILITY BEHAVIOURS OF KNITTED FABRICS CONTAINING PLA, COTTON, LYOCELL, CHITOSAN FIBERS

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Abstract

In recent years, studies have focused on the development of fire retardant products that are produced without the use of flame retardants with toxic effects and do not have harmful effects on humans and the environment. In this work, it has been compared the flame retardant properties of some biodegradable fibers obtained from different sources. It is important to investigate the performance of textile surfaces obtained from renewable fibers for flame retardant products and to improve their usage possibilities. The fire retardancy properties of knitted fabrics containing PLA, cotton, lyocell, and chitosan fibers were studied by analyzing the LOI values and burning behaviors. Single jersey knitted fabrics composed of 100% PLA, 100% Lyocell, 95% PLA 5% Chitosan, 95% Cotton 5% Chitosan, 95% Lyocell 5%Chitosan, 80%PLA 15%Cotton 5%Chitosan, 80%PLA 15%Lyocell 5%Chitosan were produced.

The flame speed of each material was determined and differences in the flammability behaviors of the fabrics were identified. The lowest flammability occurred for the fabric 95% PLA 5% Chitosan. The highest flammability was for 100% Lyocell knitted fabric.

Keywords: Flammability, Burning behavior, Flame Retardant Test Methods, LOI, PLA, Lyocell, Chitosan

PLA, PAMUK, LYOCEL, KİTOSAN LİFLERİ İÇEREN ÖRME KUMAŞLARIN YANMA ÖZELLİKLERİ

Özet

Son yıllarda yapılan çalışmalar, toksik etkileri olan alev geciktiriciler kullanılmadan üretilen, insan ve çevre üzerinde zararlı etkileri olmayan yangın geciktirici ürünlerin geliştirilmesine odaklanmıştır. Bu çalışmada, farklı kaynaklardan elde edilen bazı biyolojik olarak parçalanabilen sürdürülebilir liflerin alev geciktirici özellikleri karşılaştırılmıştır. Alev geciktirici ürünler için yenilenebilir liflerden elde edilen tekstil yüzeylerinin performansının araştırılması ve kullanım olanaklarının geliştirilmesi önemlidir. Pamuk, Lyosel ve Kitosan ve PLA lifleri içeren örme kumaşların alev geciktirici özellikleri, LOI değerleri ve yanma davranışları analiz edilerek incelenmiştir. %100 PLA, %100 Lyocell, %95 PLA %5 Kitosan, %95 Pamuk %5 Kitosan, %95 Lyocell %5 Kitosan, %80PLA %15 Pamuk %5 Kitosan, %80PLA %15 Lyocell %5 Kitosan liflerindentasarlanan süprem örme kumaşlar üretilerek, alev geciktirici özellikleri analiz edilmiştir. Her malzemenin alev hızı belirlenmiş ve kumaşların alev alma davranışlarındaki farklılıklar tespit edilmiştir. En düşük yanıcılık %95 PLA %5 Kitosan süprem kumaşta görülmüştür. En yüksek yanıcılık %100 Lyocell süprem kumaşta tespit edilmiştir.

Anahtar Kelimeler: Yanmazlık, Güç TutuşurlukTest Metodları, LOI, PLA, Lyocell, Kitosan

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1. Introduction

The fire protection of materials has become a serious issue in the textile industry. Textile structures that have good flame resistance properties are commonly used in special technical requirements[1,2].

In recent years, since the production of petroleum-based fibers causes environmental concerns and depleted natural oil resources, the development of biopolymers has become of growing interest in terms of sustainability. Using bio-based polymers in the production of textile fibers is a way to improve sustainable development for the textile industry[3].

Mostly flame retardant textiles are composed of inherently flame retardant fibers. Also, they can be manufactured by surface treatments with flame retardant chemical compounds or by adding the fire retardant materials to polymer solution before fiber spinning. The surface treatments are not very durable, their service life is relatively short. Inherently fire retardant fibers have durable fire-retardant properties but show relatively poor dyeability, weatherability, and higher material cost. Furthermore, the static charge generated introduces difficulties in yarn's spinnability[4,5].

Cellulose-based fibers are mostly used in textile applications due to their sustainable nature. They differ greatly in their flammability properties depending on their chemical composition. Cellulose fiber products pose a significant fire risk. Cotton fibers are easily flammable, continue to burn when the flame is removed [6,7].

PLA fibers are synthetic fibers obtain from %100 renewable resources such as corn, potato. PLA has drawn attention due to its properties such as biodegradability and low toxicity. On the other hand, it has a low melting point. Improving the flame retardant properties of PLA is necessary for extending its application areas since PLA can be used in various application areas from packaging to the automotive industry. On the other hand, PLA has resistance to UV, low flammability, low smoke generation, and low toxic gas released during the burning process, so make it is attractive for any kind of product[8,9,10].

The fire retardancy behavior of PLA fibers is higher than PES fibers. Although the limit of the oxygen index of PLA fibers is between 24 and 30, LOI is between 20 and 21 for PES, 18,4 for cotton, 25,2 for wool, 23 for silk, 17,4 for flax in literature. The factors which are self-extinguishing behavior, decreasing in the smoke generation, and fewer combustion calories result in low flammability in PLA compared to PES. However, PLA presents insufficient flame retardant properties for some applications with more strict requirements[8,11,12].

Chitosan is a polysaccharide and the second most important natural polymer in the world after cellulose, mainly extracted from marine crustaceans, crab, and shrimp shells. Chitosan is not intrinsically flame retardant, is a very good carbon source, if appropriately applied to a polymer substrate, can give rise to the formation of a stable protective char. Chitosan-based flame retardants have reduced the fire risks of the textile materials. Chitosan is natural wastage and renewable polymers having biodegradability, biocompatibility, nontoxicity, and adsorption properties. Chitosan contains linear polyamine, reactive amino groups, reactive a -OH group. It was seen in literature, more than 2% of chitosan used in the coating formulation has not improved significantly flame retardancy behavior of textile structures[13,14,15,16].

The flammability behavior of materials is important in the textile and apparel industry as it can lead to body injuries and property loss. Flammability of textile products is defined by characterizing their burning behavior, especially ease inflammability and constant burning after ignition. So many parameters, such as fiber content, yarn specifications, fabric weight and structure, finishes, and garment design, can affect the flammability of clothing and textile products[12,17].

Today, the industry is moving towards sustainable, cost-effective, and environmentally friendly technologies. So, researchers in the industry are working to develop a new class of bio-based products in the area of flame retardant finishing of textiles. However, this research area is still seeking new eco-friendly, cheap, and widely available flame retardant products [18].

In this study, the textile fibers are selected based on their renewable characteristics. The main objective is the development of effective flame retardant products with a low environmental impact. The flammability properties of the selected fibers described above are available in the literature. In this study, the effect of flammability behavior in fabric structures obtained from blends of fibers was investigated. In this way, it is aimed to develop new textile structures with increased non-flammability properties

2. Experimental

2.1. Materials

The specifications of the blending fibers in this study are given below. Raw materials have selected among environmentally friendly new generation fibers.

*Polylactic acid staple fibers (Ingeo™) (1.4dtex, 38,1 mm) (Fiber Innovation Technology/USA)

*Lyocell staple fibers (1.3dtex, 38 mm) (Tencels) (Lenzing AG/Austria)

*Chitosan staple fibers (1.67dtex, 38 mm)(Crabyons) (Swicofil AG/Switzerland)

*Cotton staple fibers(1,8dtex,38mm)(Abalıoğlu Textile)

Table 1. Designed Fabrics

SAMPLE	PLA (%)	COTTON (%)	LYOCEL (%)	CHITOSAN (%)
1	100	0	0	0
2	0	0	100	0
3	95	0	0	5
4	0	95	0	5
5	0	0	95	5
6	80	15	0	5
7	80	0	15	5

2.2. Method

The fibers were mixed in blowing machines (Marzoliand Trützschler-C-058-01) and fiber orientation was ensured incarding machine (Trützschler-DK 903) and drawing machine (Trützschler-HS 1000-Trützschler HSR 1000). Then, bands were roved and slivers were obtained on the flyer frame (Zinser,668), while yarns having a thickness of 30/1 were produced using the spinning machine (Zinser, 351). Then, the yarns were winded on a bobbin machine (Schlafhorst 338) and fixation treatment was applied to them. The yarns were knitted on a circular knitting machine (Mayer). Single jersey circular knitting machines of 30 in. diameter having 22 gauge have been used for knitting single jersey fabric. The samples were dyed at a liquor ratio of 10:1, in the dye bath. The dyeing was carried out in HT-sample dying machine (Thies, serial number:30210, the year 1996). Finally, the fabric samples were washed with cold water, squeezed, and dried. Mixtures of PLA and cellulosic based fibers were dyed by double dyeing procedure. Firstly, PLA fibers were dyed, then reactive dyeing was applied to cellulosic fibers. Pre-treatment procedures applied to polyester fibers were applied in mixtures containing PLA fiber and Cotton. Mixtures that did not contain cotton were dyed directly without pre-treatment. Double-process pre-treatment was applied in blends with high cotton content, and single-step pre-treatment was deemed sufficient for blends with low cotton content (<50%) and then directly dyed.

The technical parameters of improved structures are given in Table 2.

2.3. Burning Behaviour of Textile Fabrics

Ignition time and burning behavior were investigated to determine the flammability properties of fabrics. The samples were measured using James Heal and Halifax Flammability Tester. Samples were mounted in a steel frame after being conditioned for 24 hours, at 24°C and 65% relative humidity. A standardized flame source was applied to the surface from the bottom. Three specimens from horizontal and vertical directions samples for each textile fabric were processed and the average was taken for interpretation. The ignition time, flame and smoldering time (afterglows), and burning characteristics were recorded. The spreading rate of the flame was conducted under ISO 6941(Burning behavior of textile fabrics / Measurement of flame spread properties of vertically oriented specimens). The specimen was exposed from below to the flame source for 12 seconds. A standardized marker thread was placed to determine the spreading rate of the flame. When the flame spread and reached to mark, the thread was burnt and the respective marker timer was stopped. Three specimens (560 ×170 mm) of horizontal and vertical for each treated fabric type were conditioned and the time of flame spreading for both vertical and horizontal directions was recorded [2,19].

2.4. Limiting Oxygen Index

Limiting oxygen index (LOI) is a method to determine the minimum oxygen concentration in an oxygen/nitrogen mixture that will sustain the flame. The LOI test was carried out using an LOI instrument model number of M606 under ASTM: D2863. A test sample of 150 × 50 mm was placed in a transparent test chamber and ignited at the top. The oxygen concentration in the mixture of oxygen and nitrogen was increased slowly until the sample sustained burning. The volume fraction of the oxygen in the gas mixture was reported as the LOI[2,20].

Table 2. Technical parameters of improved fabrics

	Course*Wales (cm)	Weight (gr/m^2)
%100 PLA	**12*19**	**162**
%100 Lyocell	**11*16**	**101**
%95PLA%5Chitosan	**13*18**	**189**
%95Cotton%5Chitosan	**14*19**	**159**
%95Lyocell%5Chitosan	**12*16**	**124**
%80PLA %15Cotton%5Chitosan	**13*18**	**150**
%80PLA %15Lyocell%5Chitosan	**15*18**	**165**

3. Results and Discussions

3.1 Results

Measurement of the flame spread properties of the vertically oriented specimens was performed according to ISO 6941:2003. The results are given in Table 3.

Table 3. ISO 6941 (Burning behavior of textile fabrics / Measurement of flame spread properties of vertically oriented specimens)

Sample 1: %100 PLA	-It was completely burned when ignited for both horizontal and vertical directions. -The flame reached the vertical edge of the test piece. -Melts dripping from the fabric continued to burn after the fabric was completely burned. -A piece fell and continued to burn. -Time to the severance of the marker thread (20 cm) / 14s-Length,11s-Widht -Flame Burning Time/261s-Length,120s-Widht -Burning Area(cm)/Burned-Length, Burned-Widht
Sample 2; %100 Lyocell	-It was completely burned when ignited for both horizontal and vertical directions. - The flame reached the vertical edge of the test piece. - The test piece did not burn through a hole and did not melt. -No piece from the flaming test piece fell and continued to burn -Time to the severance of the marker thread (20 cm) / 3s-Length,4s-Widht -Flame Burning Time/41s-Length,37s-Widht -Burning Area(cm)/Burned-Length, Burned-Widht
Sample 3; %95 PLA %5 Chitosan,	-A part of the test piece was burned and damaged. -The flame did not reach the vertical edge of the test piece. -A hole formed in the test piece where the flame was held and melted. -No piece from the flaming test piece fell and continued to burn. -Time to the severance of the marker thread (20 cm) / 0s-Length,0s-Widht -Flame Burning Time/0s-Length,0s-Widht -Burning Area(cm)/2,7*6cm Burned-Length, 4,5*6,6cm Burned-Widht
Sample 4; %95 Cotton %5 Chitosan	-It was completely burned when ignited for both horizontal and vertical directions. -The flame reached the vertical edge of the test piece. -The test piece did not burn through a hole and did not melt. -No piece from the flaming test piece fell and continued to burn -Time to the severance of the marker thread (20 cm) / 4s-Length,5s-Widht -Flame Burning Time/46s-Length,50s-Widht -Burning Area(cm)/Burned-Length, Burned-Widht
Sample 5; %95 Lyocell %5 Chitosan	-It was completely burned when ignited for both horizontal and vertical directions. -The flame reached the vertical edge of the test piece. -The test piece did not burn through a hole and did not melt. - No piece from the flaming test piece fell and continued to burn -Time to the severance of the marker thread (20 cm) / 4s-Length,4s-Widht -Flame Burning Time/58s-Length,54s-Widht -Burning Area(cm)/Burned-Length, Burned-Widht

Sample 6; %80 PLA%15 Cotton%5 Chitosan	-It was completely burned when ignited for both horizontal and vertical directions. -The flame reached the vertical edge of the test piece. -The test piece did not burn through a hole and did not melt. - No piece from the flaming test piece fell and continued to burn -Time to the severance of the marker thread (20 cm) / 4s-Length,4s-Widht -Flame Burning Time/75s-Length,55s-Widht -Burning Area(cm)/Burned-Length, Burned-Widht
Sample 7; %80 PLA%15 Lyocell %5 Chitosan	-It was completely burned when ignited for both horizontal and vertical directions. -The flame reached the vertical edge of the test piece. -The test piece did not burn through a hole and did not melt. -No piece from the flaming test piece fell and continued to burn -Time to the severance of the marker thread (20 cm) / 4s-Length,4s-Widht -Flame Burning Time/57s-Length,62s-Widht -Burning Area(cm)/Burned-Length, Burned-Widht

In 100% Lyocell, the time taken to separate the marker thread by breaking was measured in the range of 3 seconds in the vertical direction and 4seconds in the horizontal direction. The flame burning time was 41 sec. in the vertical direction and 37 sec. in the direction of the horizontal. While all of the fabric was burning, the flame reached the vertical edge of the test piece. During the combustion, it was not observed that there was a hole, melting and falling of any part from the flamed test piece.

In 95% Cotton 5% Chitosan, the time taken to separate the marker thread by breaking was measured as 4 sec. in the vertical direction and 5 sec. in the horizontal direction. The flame burning time was 46 sec. in the direction of vertical and 50 sec. in the direction of horizontal. While the whole fabric was burning, the flame reached the vertical edge of the test piece. It was not detected that any part of the test piece was pierced during burning, melting, or falling from the flamed test piece.

In 95% Lyocell 5% Chitosan, the time taken for the separation of the marker thread by breaking was 4 sec. in the vertical direction and 4 sec. in the horizontal direction and the flame burning time was 58 sec. in the vertical direction and 54 sec. in the horizontal direction. While the whole fabric was burning, the flame reached the vertical edge of the test piece. During the burning, no holes were drilled, no melting was observed, and no parts fell from the flamed test piece.

In 80% PLA 15% Cotton 5% Chitosan, the time taken to separate the marker thread by breaking was determined as 4sec. in the vertical direction and 4sec. in the horizontal direction. The flame burning time was observed as 75 sec. in the vertical direction and 55 sec. in the direction of the horizontal. All of the fabric was burned and the flame reached the vertical edge of the test piece. During the burning, no holes were drilled, no melting was observed, and no parts fell from the flamed test piece.

In 80% PLA 15% Lyocell 5% Chitosan, the time taken for the separation of the marker thread by breaking was determined as 4sec. in vertical direction and 4sec. in the horizontal direction. The flame burning time was observed as 57sec. in the vertical direction and 62sec. in the horizontal direction. All of the fabric was burned and the flame reached the vertical edge of the test piece. During the burning, no holes were drilled, no melting was observed and no part fell off the flamed test piece.

95% PLA 5% Chitosan showed highest flame reterdancy considering the results. No flaming combustion was observed, the marker thread does not break within the specified time, no holes were drilled in the fabric during the process, there was no melting, the damaged part size was only 2,7*6 cm and 4,5*6,6cm in the direction of the vertical and horizontal. Even if 100% PLA jersey fabric was completely burned, the flame burning time was 261 sec. in the vertical direction and 120 sec. in the direction of the horizontal, indicating that slow-burning occurs. In addition, the time it takes for the marker thread to break was determined as 14 sec. in the vertical direction and 11 sec. in the horizontal direction and it was understood that the combustion occurs slower than other fabric types

Limiting oxygen index (LOI) of samples under ASTM: D2863 were measured and the results are given in Table 4. When the LOI value is above 25%, the relevant materials usually self-extinguish or do not tend to burn very easily. In materials with an LOI value of less than 25%, burning is very fast. 95% PLA 5% Chitosan jersey fabric has the highest LOI value as 25,6%. It is followed by 19% in 95% Lyocell 5% Chitosan and 100% Lyocell, 18,2% in 100% PLA, 80% PLA 15% Lyocell 5% Chitosan and 80% PLA 15% Cotton 5% Chitosan.

Table 4. Limiting Oxygen Index (LOI) values of samples

	LOI (%)
Sample 1; %100PLA	18,2
Sample2; %100 Lyocell	19
Sample 3; %95 PLA %5 Chitosan	25,6
Sample4; %95Cotton %5 Chitosan	18,2
Sample5; %95 Lyocell %5 Chitosan	19
Sample6; %80 PLA %15 Cotton %5 Chitosan	18,2
Sample7; %80 PLA %15 Lyocell %5 Chitosan	18,2

3.2. Discussion

Textile surfaces burn depending on the conditions of flame, heat, oxygen concentration, and time of exposure to flame. Factors such as polymer type, construction of the textile (weave/knit of fabric, yarn construction), weight/density, additives in the fiber, the type of chemical treatments, and the test conditions are important when measuring thermal protective capability. The availability of oxygen is another factor in determining the flammability of fabric. The construction of fabric can play an important role as it determines the amount of air present, the active surface area, and the flow of air through the fabric. The flame resistance ability of fibers mainly depends on the chemical composition. A mixture of the various chemical compounds plays a major role in the fire retardancy behavior of the fabric [5,17].

High-performance fire retardant polymers have highly aromatic chemical structures, rigid polymer chains. The aliphatic content, so the hydrogen-to-carbon ratio (H/C), and hence the flammability of the polymer is the lower. Generally, if polymers have aromatic units, H/C ratios are lower than 1, so their ability to generate volatile and flammable degradation products is very limited. Therefore they have LOI values of more than 30% and are sufficiently fire retardant for the specific applications [21,23].

Some durably flame retarded cellulosic fibers, wool, and polyamide fibers contain functional groups such as secondary amines and amine groups in their structures. Cellulose has primary and secondary hydroxyl groups. Cotton consists of cellulose in nature and as a result easily burning behavior with the generation of toxic flammable gases (levoglucosan, pyroglucosan, etc.) and high burning temperature. Morphology of the cotton fabrics shows capillary-based structure so heat and flammable gases can easily penetrate and ensure to burn [17,22, 24].

Although chitosan polysaccharides are chemically similar to cellulose, they show some differences. In cellulose, there is a hydroxyl (-OH) group attached to the second carbon atom, while chitosan has an amine (-NH2) group. The flame-retardant character of PLA fibers is higher than fibers such as cotton and polyester. It is stated in the literature that PLA has a self-extinguishing feature and extinguishes after 2 minutes of burning. PLA emits less smoke than fibers with improved non-flammability properties, the amount of energy released during combustion is 60% less than PES. Does not produce toxic gases and dioxins when burned. Lyocell fibers are an advanced type of regenerated cellulose fibers. They have the properties of cellulosic fibers because they are obtained by the chemical processing of cellulose[4].

The properties of the natural fibers depend on their structures and the source from where the fibers are obtained. Cotton fibers mainly consist of hemicellulose, and cellulosic micro-fibrils. A secondary wall is responsible for the mechanical properties of the fiber. Natural fiber itself is a composite structure where the microfibrils act as fibers while the lignin and hemicellulose act as a matrix. On the other hand, the hemicellulose is responsible for thermal and biological degradation properties while lignin and hemicellulose together are responsible for flame degradation properties. Natural fibers rapidly decompose under heat sources while polymers melt. The hemicellulose decomposition starts first at the beginning of flame and with the increase in temperature lignin also gets decomposed. Mass is lost continuously during the decomposition process because of the evaporating gases[15].

Many factors, such as fiber content, fabric weight and structure, finishes, and garment design, affect the flammability of textile products. Fiber content is the most important fabric property that affects flammability. Cellulosic fabrics, such as cotton and rayon, without a flame-resistant finish, can burn easily. It is stated in the literature that blends of fibers, or yarns of different fibers, are more likely to be flammable than fabrics made from a single fiber type. For example, although polyester is less flammable than cotton, cotton/polyester blends burn rapidly. These blends generate more heat than cotton fabrics. In the burning process, charred cotton in the blends acts as a supporter of the burning polyester fiber, which prevents the melting polyester from dripping away and allows the melting polyester to continue to contribute to the burning system. Fabric weight and structure heavier fabrics ignite less easily and burn more slowly than lighter weight fabrics. A tightly woven and knitted fabric also ignites more difficultly and burns lower than sheer fabrics. Because there is more air space and more oxygen among fibers in the sheer fabrics, lighter weight and sheer fabrics ignite and burn more easily. So that the rate of burning decreased as the fabric weight increased. The light-weight fabrics burn faster than the heavier ones notwithstanding what the fabric type was. As the fabric weight increased, the flame temperature increased, indicating that heavy fabrics provided more amount of fuel sustaining burning. Heavier fabrics burned at a slower rate than light fabrics due to the high flame temperature during burning besides flammability is affected by the surface structure of the fabric [18,19].

3.2.1.Flammability

In 95% PLA 5% Chitosan single jersey fabric, during the test, the sign yarn did not break, flaming did not occur. Only 2.7 * 6cm and 4.5 * 6.6cm parts of the sample in the direction of the vertical and 16 * 20cm parts of the sample in the direction of horizontal were damaged. A hole was formed and melting occurred only where the flame was held. So, it can be said that PLA (Polylactic Acid) fibers exhibit flame retardant properties as can be seen in the information given in the literature studies. It was remarkable that low flammability properties were not seen in other mixture ratios, especially in mixtures containing PLA fiber. It was seen that the weight of the fabric, which is another parameter affecting the flammability value, was effective. The fabric weight of this type, which has low flammability, was 185gr / m2. Therefore, when compared to other PLA fiber-containing mixtures, especially 100% PLA (127gr / m2) fabric, it has emited more smoke during burning, so there was no flaming and the burning of the fabric did not occur. Although 100% PLA single jersey fabric is seen as burned in the test results, the flame burning time is incomparably longer (261sec. and 120sec.) compared to other burned fabric types and the time taken for the sign yarn to break is 14sec. and 11sec. (other types with an average of 4-5sec.) is much longer than others. These values support the conclusion we have reached above. Finally, it has been concluded that when the appropriate weight and fabric structure are designed, new fabric types to be produced using PLA and Chitosan fibers can exhibit lower flammability.

3.2.2. LOI Value

It is seen that 95% PLA 5% Chitosan single jersey fabric has the highest LOI value as 25,6%. This result is in parallel with the burning behavior test results. The limiting oxygen index (LOI), LOI value, means the percentage of oxygen a material needs to continue to burn. Materials with an LOI value of more than 25 usually extinguish spontaneously in the air, while those with an LOI value of less than 25 are very easily burned. Classification of LOI values in the literature is LOI <20,95 as flammable, 21 < LOI < 25 as slow-burning. LOI values of 26–28% are sufficient to pass small burning tests. Cellulose-based fibers have very low LOI values (<19%) and are burned easily. Considering that the LOI value of cotton and viscose fiber is 18% and the LOI value of polyester fiber is 20-22%, wool has a relatively high LOI value (approx. 25%). The 25,6% LOI value reached supports the information that PLA fibers can exhibit lower flammability when designed with the appropriate fabric structure and weight.

In the light of this experimental study and the information obtained from the literature, following conclusions have obtained.

-Increasing the fabric weight of textile structures will increase flame retardant properties.

-PLA fiber content in all-fiber mixtures, has improved the flame retardant properties

-According to the results having in this study, the design of new fabric which is higher weight and more tightly structured will more increase flame retardant properties.

Designed fabric structures in this study can be used in many applications such as upholstered seating, mattresses, bed covers, duvets, pillows, automobiles textiles, protective clothing, etc. Considering the structural properties of PLA and Chitosan fibers, will be important to further research the textile surfaces obtained from these fibers in the development of flame retardant products and to develop their usage possibilities in future studies.

4. Conclusion

This paper investigates the flammability properties of PLA, Chitosan, Lyocell, Cotton fiber mixtures. Designed fabrics will be find a wide range of application areas as a result of their properties such as fire retardant, and eco-friendliness.

The objective of this study was the analysis of the flammability of textile materials. Especially it has been focused on flame retardant properties of PLA fibers and their blends which were selected from renewable fibers. The analyses on the knitted jersey fabrics have showed important findings to be used in the textile industry. Several criterias have affected the flame spread rate. Firstly, the composition of the material is the main factor. One of the other criteria is surface density.

In this work, the fire retardancy properties of PLA composites containing cotton, lyocell, and chitosan fibers were studied by analyzing the LOI values and burning behaviors. The experimental results showed that the incorporation of cotton and lyocell fibers decreased the LOI values, whereas addition of PLA and Chitosan fibers it was found to increase. Furthermore, Higher density of the fabrics has affected the results positively. Even if PLA fibers have a higher value of flame retardant properties, it is not been sufficient non- flammability character by themselves.

PLA fibers when used with other materials with low flammability, it has increased the fire retardant properties of those materials. The structures of the designed fabrics have effected the flammability behavior. Future studies to reduce the flammability of the materials can be on fiber blends and rearrangement of the weights and structures of the fabrics.

In conclusion, developments in the design of fire retardant textiles with low environmental impact will be important in the near future, creating an alternative for increased sustainability efforts.

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