Improvement of Leather Flame Retardancy through Nano Clay Addition

by

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Abstract

Leather is widely used in various industries including apparel, safety clothing, aircraft and automotive, due to its unique properties such as softness, air permeability, chemical resistance, high flexibility and reasonable mechanical resistance. Since leather products usually contain flammable organic compounds such as tanning, fatliquoring, dyeing and finishing materials, improvement of its flame retardancy is very important. A lot of flame retardants have been synthesized and applied to improve flame retardancy of leather. One of the best materials is nanoclay because it is easily available, environment-friendly and has a low cost. In this research, we propose a process that reduces the burning length of the leather and increases its thermal stability. For this purpose, clay nanoparticles by 1, 3, and 5 mass percent (relative to wet leather mass) were added to wet-blue bovine and goat leather under certain (temperature and time) conditions during the re-tanning process. The results of the TGA test on bovine leather samples showed that by increasing the amount of nanoclay, the thermal stability of samples was increased. SEM images prepared from the grain and cross-sections of bovine and goat leather samples showed that with a high percentage of nanoclay, particle agglomeration is partially visible. The results of the vertical flammability test also showed that the presence of clay nanoparticles reduced the burning length of leather samples. Tensile strength of bovine leather samples containing clay nanoparticles increased compared to the control sample. However, the tear strength of them did not differ significantly.

Introduction

Anti-fire or flame retarding characteristic of textiles has become very important due to the development in urbanization and technology advancements; specially regarding the use of electrical appliances which has increased the possibility of ignition. Leather is a material that due to its special properties such as softness, air permeability, chemical resistance and high flexibility, is widely used in various industries, including apparel, aircraft and automotive. Although leathers have much better flame resistance properties than fabric and plastic materials, its use requires improvement in flame resistance properties,[1] because the leather products after tanning, fat liquoring, dyeing and finishing processes could contain some inflammable and harmful organic compounds.[2] In recent years, the use of nanotechnology in leather production processes to improve leather performance and lower production costs has increased.[3]

The use of nanomaterials, when properly distributed in a polymer structure, can improve thermal, mechanical and fire resistance properties. One of the best nanomaterials, nanoclay, has received much attention as a reinforcing material for polymers due to its potentially high aspect ratio and unique intercalation characteristics.[4] Also it is easily available, environmentally friendly and has a low cost.[5] Adding a small amount of nanoclay into a polymer matrix exhibits an unexpected shift in properties including reduced gas permeability, improved solvent resistance, being superior in mechanical properties and thermal stability and enhanced flame retardancy.[4]

The optimal dispersion of nanoclay in the samples causes it to act as a barrier and prevent the penetration of oxygen and heat into the sample and prevent the release of flammable products. Montmorillonite (Mt), a special kind of clay, has become the subject of considerable interest over the past few years for its lamellar structure and larger surface area.[6]

Several studies have been made about nanoclay as a reinforcing material. Khalid Saeed et al.[7] studied the thermal properties of nanoclay/PEO. In another study, Binu et al.[8] concentrated on the analysis of the effect of nano filler (Cloisite15A) on the glass fiber mat reinforced polyester. They studied the effect of use various weight percentages of nano filler on mechanical, thermo mechanical properties and thermal degradation. In another study,[9] organoclay based acrylic polymer nanocomposites were used as filling agents for leather. That study was done by Essambo et al.

Articles are available about finishing natural leather to achieve improved functionality e.g. antibacterial or anti fogging leather. Pollini et al.[10] deposited silver coatings on the natural leather used in public transport system seats. Carvalho et al.[11] studied about antimicrobial activity of leathers covered with Ag–TiO2NPs.

There are some articles about the improvement of leather flame retardancy. Jiang et al.[2] reported the use of Montmorillonite and IFR nanocomposite on pig skin. Their research results

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Manuscript received June 22, 2020, accepted for publication July 20, 2020.

showed that the nanocomposite has good charring effect, can effectively improve non-flammability of leather and has good flame resistance properties. Olivares et al.[3] examined the effect of sodium montmorillonite on properties such as flame resistance; mechanical and thermal properties of bovine leather. They reported that the burning length of leather was reduced and the presence of clay mineral improved the thermal stability of leather. Wegene and Thanikaivelan reported a method to produce flame resistance leather using organic nanoclay and ammonium dihydrogen phosphate as flame retardant additives through surface coating. They showed that the flame resistance properties of leathers improved after treatment with flame retardant additives.[1] Lyu et al.,[6] used a nanocomposite containing montmorillonite as a fatliquoring agent. They showed that the flame retardancy and Limited Oxygen Index (LOI) value of a leather sample treated with nanocomposite could be increased. Yang et al.[12] reported the use of melamine resin on wet-blue leather. Their research results showed that the oxygen index and thermal stability of leather were improved significantly. Zhang et al.[13] examined the effect of phosphorus-nitrogen flame retardant retanning agent on properties of wet-blue goat leather. They reported that the oxygen index increased, but mechanical properties decreased. Baorong et al.[14] investigated the effect of phosphorus flame retardant (PFR), nitrogen and phosphorus intumescent flame retardant (NPIFR) and nitrogen and phosphorus flame retardant (NPFR) on the flame retardancy of leather. The results showed that the three types of flame retardants can enhance the fire retardancy of leather. Antifogging properties and flame retardancy of leather treated with modified layered double hydroxide (MLDH) and modified zanthoxylum bungeanum maxim seed oil (MZBMSO) was studied by Bin et al. They reported that the leather samples treated with those materials exhibited remarkable improvements in fogging value and reduction in the length of charring and smoke density.[15]

In the present work, wet-blue bovine and goat leather were examined and the effect of sodium montmorillonite, added during the re-tanning process, on the flame retardancy was investigated.

The main objective of this research was to figure out a method to improve the leather flame retardancy that would have the least dependency on the machinery and materials currently used in a plant. Therefore the materials used in this research were of commercial grade and were directly supplied from leather production lines.

Experiments

Materials and equipment

Wet chrome tanned bovine (0.1 g/cm^2) and goat (0.05 g/cm^2) leather were supplied from tanning plants located in Charmshahr industrial zone, Varamin, Iran. The supplied leather samples were produced through the tanning plants conventional leather processing and no change was made in their process with the aim of achieving a method that would be easily used in those leather plants.

Sodium formate, acrylic resin, vegetal tanning (Mimosa), neutralizer, acidic dyes as dyeing product, natural and synthetic fatliquors were purchased from Takshimi Co., Iran. Formic acid 98-100% and acetic acid 100% were purchased from Merck.

Sodium montmorillonite K10 with a cation exchange capacity of 48 meq/100gr and density 0.5-0.7 gr/cm^3, was purchased from NanoSany, Iran.

To investigate the effect of nanoclay presence on the thermal behavior of samples, thermal analysis (TGA) was carried out with heating rate of 10°C / min under nitrogen atmosphere on three samples of bovine leather using TA-instrument analyzer, manufactured in USA (ca. 1-2mg).

In case of grain surface images, XL30 SEM device, manufactured in Netherlands and 1x1 cm specimens were used. In case of cross sectional images, South Korea‘s AIS2100 SEM device and 1x2 mm specimens were used. Images with different magnifications were taken. Elemental analysis of samples was also performed.

Five specimens of each sample were prepared and their mechanical properties were evaluated using an Instron tensile testing machine at 100 mm/min crosshead speed according to Standard Numbers 3376 and 3377-1 of the International Organization for Standardization (ISO). The samples were placed in room conditions for 24 hours before the test and their thickness was measured at three different points.

Flame retardancy properties were evaluated through sixty seconds vertical flammability test according to Title 14-Aeronautics and Space, Part 25-Airworthiness standard, Appendix F to Part 25, Part I-Test Criteria and Procedures, published by the United States Department of Transportation of the Federal Aviation Administration suitable for testing the flammability of materials in vertical configuration (covered by paragraph (a) (1) (i) of this appendix).[2]

Specimens, 5×16 cm, were prepared and kept in room condition for 24 hours before the test. Samples‘ thickness was measured at three different points. The flame used in this test was a flame from a mixture of propane and butane gases (3.81 cm length). The flame was applied once to the center line of the lower edge of the specimen (1.90 cm above the top edge of the burner)[3] and was removed from the bovine samples after 60 seconds and from the goat samples after 12 seconds; due to the lower thickness. After the test, the burning length of the specimens was measured from the beginning

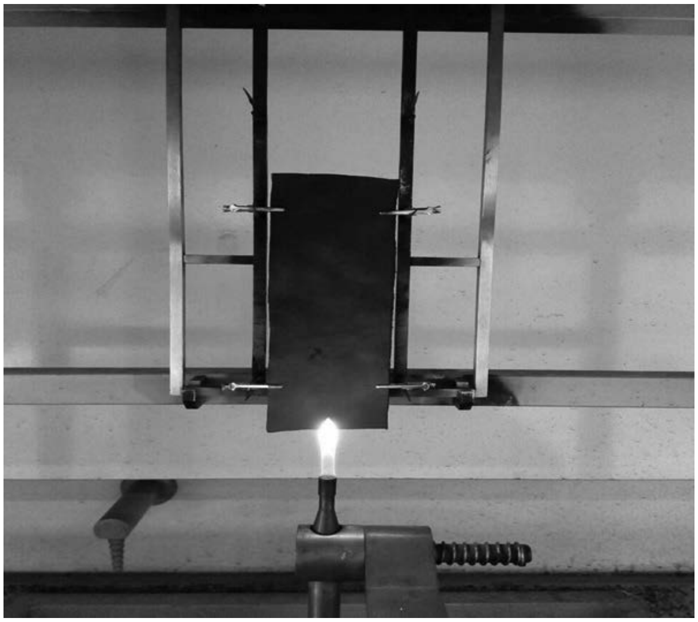

Figure 1. Sample placement for vertical flammability test.

of the burn to the burning peak. 3 specimens of each sample were prepared for this test. Fig. 1 shows sample placement for vertical flammability test.

Procedure

A dispersion of 5 mass percent of nanoclay in water was prepared using an ultrasonic mixer (frequency: 24 kHz, power: 200W, amplitude: 60%) for one hour. The prepared solution was placed on a magnetic stirrer at 250 rpm for 180 min before being used. This dispersion was added to the leather processing bath during the re-tanning step.

The order of the process steps and the percentage of materials added in each step are presented in Table I. This process is a commonly used version in Iran's leather plants and is based on BASF solutions for leather technologists.

At first, pieces of previously prepared wet blue leather (bovine and goat) were rewetted and weighed. This weight was used in calculating the amount of materials added at each step. In order to improve the material penetration into the leather structure, the baths were stirred every 10 minutes using a glass stirrer, and the leather pieces were pressed every 10 minutes by-hand.

The process steps, in accordance with table I, were as follows:

a) Washing

Wet blue pieces were washed in a bath containing acetic acid and water at 30°C for 5 min. After 5 minutes, the bath float was drained.

b) Neutralization

At this step wet blue pieces were placed in a bath containing water, sodium formate, neutralizer and acetic acid at 40°C for 40 minutes. At the end of this step, using scissors, the corner of leather pieces was cut and using a torrent paper, the pH of the leather cross section was measured. The pH at this stage should be 4.2. At the end of this step, the bath float was not drained and the next step materials were added to the same bath.

c) Retanning

Acrylic resin was added at this step to enhance the leather handle. The wet blue pieces remained in the bath at 40°C for 40 minutes. At the end of this time, Mimosa, neutralizer and acrylic resin were added to the bath and the wet blue leathers remained at the same temperature for 60 minutes.

Table I

Outline formulation of process.

Process	+	%	Product	°C	Dilution/ °C	Time (min)	pH, etc
Wash		200	Water	30			
		0.2	Acetic acid			5	6 Be
Drain float							
Neutralization	+	100	Water	40			
		1	Sodium formate				
		1	Neutralizer			40	pH 4.2
Retannage	+	4	Acrylic resin			40	
	+	1	Neutralizer				
		4	Acrylic resin				
		4	Mimosa			60	
	+	0.3	Formic acid 85%		1:10	10	
Drain float							
Short rinse							
Add nanoclay	+	100	Water	40		60	
			Nano clay				
Dyeing	+	100	Water				
		1	Acidic dye	50		20	
Fatliquoring	+	8	Natural and synthetic			40	
	+	0.5	Formic acid 85%		1:10	20	
	+	1	Acidic dye			20	
	+	0.5	Formic acid 85%		1:10	10	
Drain float							
Rinse beriefly							

Table II

Samples description

Sample Identification	Na^+Mt content [mass%]
Leather	0
Leather-Na^+Mt_1%	1
Leather-Na^+Mt_3%	3
Leather-Na^+Mt_5%	5
Leather-Na^+Mt_7%	7

d) Fixation

At the end of the previous step, formic acid (85%) was diluted 1:10 in water and added to the bath. After 10 minutes, the bath was drained and the leather pieces were rinsed for a short time with cold water.

e) Nano clay addition

At this step, only for flame retardant samples, baths containing nanoclay were prepared and retanned leather pieces were placed in these baths at 40°C for 1 hour. At the end of this step, the bath was drained and the samples were entered into the dyeing and fatliquoring baths. The amount of clay added for each sample is shown in Table II.

f) Dyeing and fatliquoring

The dyeing of the samples was done in two steps and after each step, the diluted formic acid was added to the bath. In the first step of dyeing, the samples were placed in a bath containing dye at 50°C for 20 minutes. At the end of this time, the fatliquor was added to the bath to soften the samples, and the time required to absorb the fatliquor was 40 minutes. After that, diluted formic acid was used for 20 minutes.

In the second step of dyeing, the dye was added to the previous bath and the samples were dyed again for 20 minutes at 50°C and finally the diluted formic acid was used for 10 minutes.

g) Washing and drying

After dyeing and fatliquoring step, the samples were rinsed with cold water and were dried using a hair dryer for 10 minutes, and then placed in room temperature to complete the drying step.

Results and Discussion

Thermal stability

The thermal stability of leather can be affected by the presence of nanoclay. For this purpose and to investigate the effect of nanoclay presence on the thermal behavior of samples, thermal analysis (TGA) was carried out in nitrogen.

It has been reported that the thermal degradation of sodium montmorillonite proceeds in two steps: first, the sample is dehydrated when the temperature increases from room temperature to 270°C and the water molecules adsorbed in pores and clay galleries are removed. The major decomposition region of the sodium montmorillonite is between 300-450°C, in which clay decomposes into aluminum oxide and silicon dioxide.Then, the sample undergoes dehydroxylation of structural –OH groups, which occurres between 500 and 700°C.[16]

Fig. 2 shows the TGA and DTG curves of three bovine leather samples. As can be seen in Fig 2, the decomposition mechanism of leather samples in nitrogen is a one-step process and the initial temperature of their decomposition, from the control sample, to the leather-Na^+Mt_5% and leather-Na^+Mt_7% samples

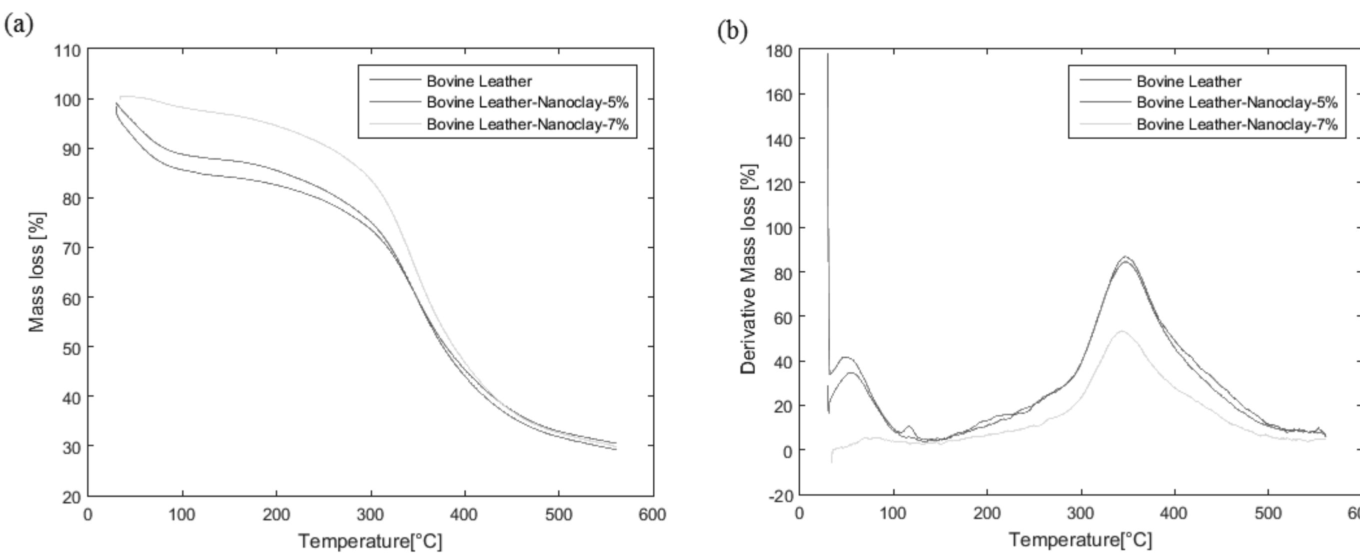

Figure 2. **(a)** TGA and **(b)** DTG curves of leather samples having different clay content in nitrogen.

increased. This increase in temperature indicates that the presence of nanoclay, protects leather samples against thermal decomposition. The greatest mass reduction of the samples is in 300-400°C, which can be attributed to collagen degradation in the samples. For better comparison, it can be said that 5 mass percent reduction for the control sample, the leather-Na^{+}Mt_5%, and leather-Na^{+}Mt_7%, happens at 42°C, 54°C and 192°C respectively which shows that by increasing nanoclay percentage, the thermal stability of the samples has increased.

Lowering the initial mass of the samples, which occurred between room temperature and 100°C, can be considered as loss of water and moisture.

According to the DTG curves, the temperature related to the highest amount of mass reduction, for the control sample is 346°C, for leather-Na^{+}Mt_5% is 349°C and for leather-Na^{+}Mt_7% is 344°C. Although T values are almost equal, the lost mass for samples at the relevant temperatures is 86.7%, 84.4% and 53.5%, respectively which shows that the sample with the highest amount of nanoclay, has more thermal stability and has the lowest mass reduction.

Morphology

SEM images were prepared from the grain and cross section of bovine leather, leather-Na^{+}Mt_1%, leather-Na^{+}Mt_3%, leather-Na^{+}Mt_5% and goat leather and leather-Na^{+}Mt_3% samples to observe their surface changes, as well as the presence of nanoparticles.

Fig 3(a) and (b), represent the grain surface of control goat leather and leather-Na^{+}Mt_3% samples, respectively. In Fig 3(a) the agglomeration of nanoparticles is not seen. However the agglomeration of nanoparticles in the sample containing nanoclay is seen compared to the control sample.

In Fig 4(b), which shows the grain surface of bovine leather-Na^{+}Mt_1% sample, there is no significant difference from Fig 4(a) which indicates the control sample. However, nanoparticles agglomeration are seen in the samples with 3% and 5% nanoclay.

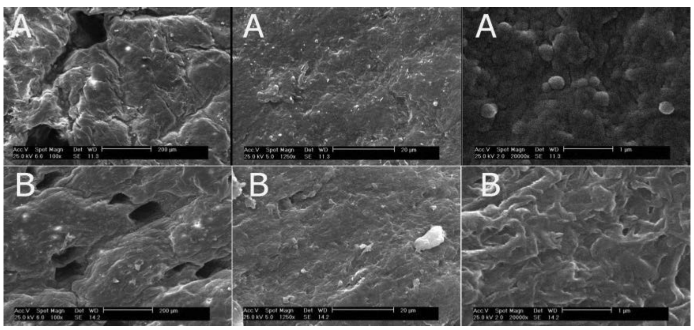

Figure 3. Grain surface SEM images of goat leather at 100, 1250 and 20000× magnification, respectively; **(A)** leather and **(B)** leather-Na^{+}Mt_3%.

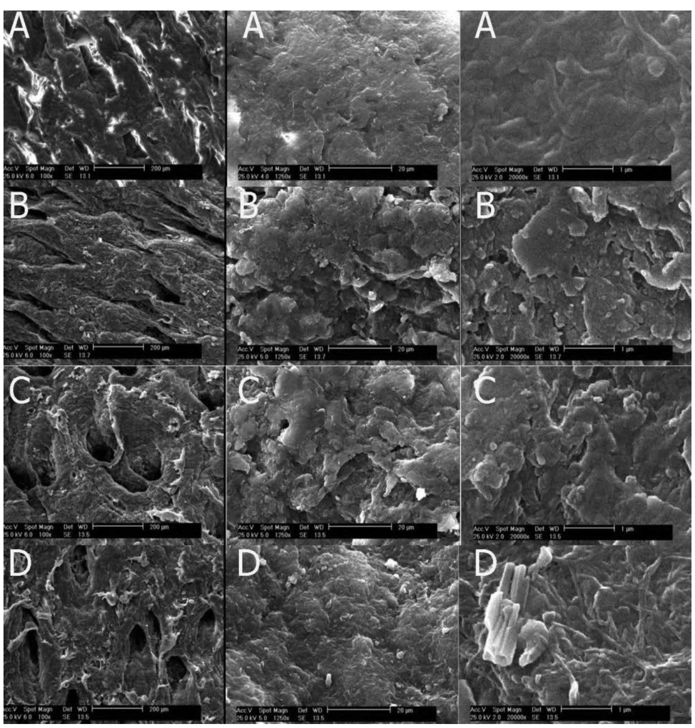

Figure 4. Grain surface SEM images of bovine leather at 100, 1250 and 20000× magnification, respectively; **(A)** leather, **(B)** leather-Na^{+}Mt_1%, **(C)** leather-Na^{+}Mt_3% and **(D)** leather-Na^{+}Mt_5%.

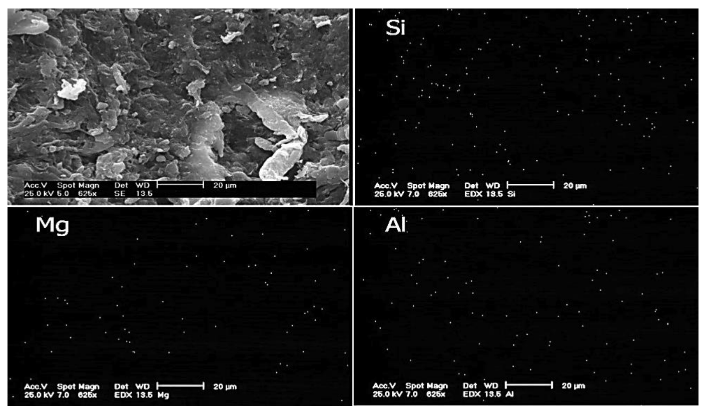

Figure 5. Elemental analysis of sample: leather-Na^{+}Mt_5%.

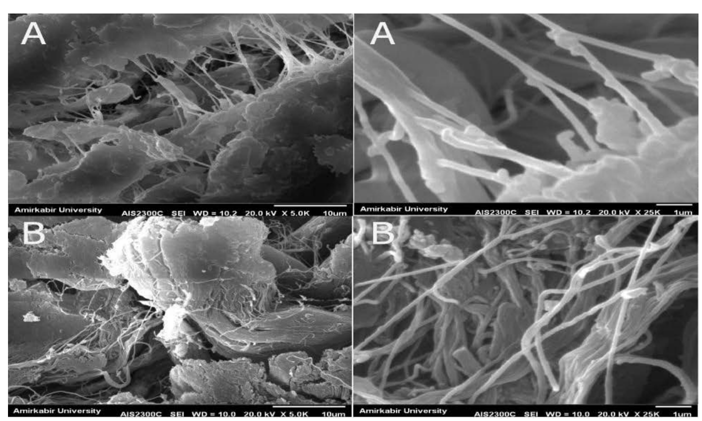

Figure 6. Cross sectional SEM images of goat leather at 500 and 2000× magnification, respectively; **(A)** leather **(B)** leather-Na^{+}Mt_3%.

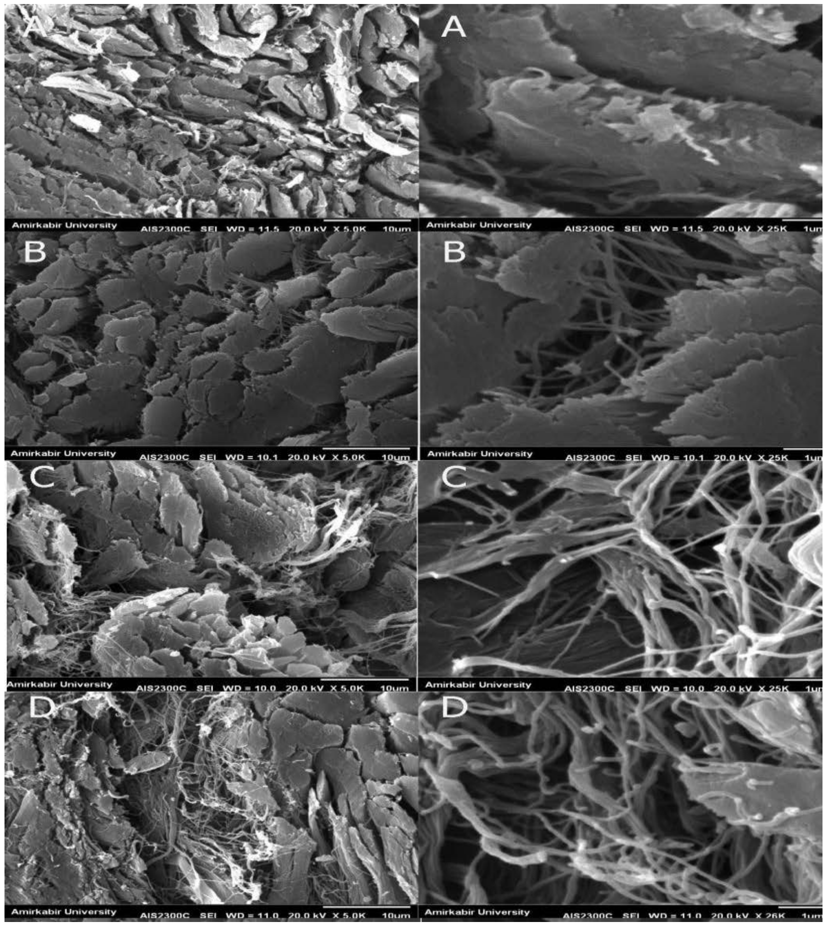

Figure 7. Cross sectional SEM images of bovine leather at 500 and 2000X magnification, respectively; **(A)** leather, **(B)** leather-Na^+Mt_1%, **(C)** leather-Na^+Mt_3% and **(D)** leather-Na^+Mt_5%.

According to the images of the electron microscope, it is observed that the size of samples' pores is microscopic. Because in the 100x magnification, these pores are well observed. Therefore, the distribution of clay nanoparticles in these pores is expected.

Fig. 5 represents the mapping of some elements found in the leather-Na^+Mt_5%. Si, Al and Mg, the main components of Na^+Mt, are homogeneously dispersed within the network of leather.[3]

Fig. 6 and 7 show cross-sectional SEM images of goat and bovine leather samples. Comparing the images of control and nanoclay containing samples, no significant agglomeration in the cross section of the samples can be observed.

According to the SEM images, it can be concluded that by increasing nanoclay percentage, the agglomeration of nanoparticles increases. However, this agglomeration is mostly seen on the grain of samples and images of samples cross-section do not show this agglomeration. Hence probably the clay nanoparticles have dispersed homogeneously within leather structure.

Tensile and tear strength

The tensile strength of leather depends on some factors such as the strength of the collagen fibers, the angle of the fibers with each other, the amount and type of material that is placed between the fibers, and so on.

By increasing the entanglement of collagen fibers, the modulus increases.

In order to investigate the effect of nanoclay on the strength of leather samples, tensile and tear strength of samples were evaluated using an Instron tensile testing machine.

Table III shows the mechanical properties of the leather samples.

As can be seen, by the addition of nanoclay, the modulus of the samples has increased, which indicates that the nanoclay performs as filler and increase entanglement of fibers and does not reduce the strength of the leather samples. In addition, the electrically-charged surface of clay that is negative due to the presence of

Table III

Mechanical properties of leather samples.

Sample	Average thickness (mm)	Tensile strength (MPa)	CV%	Average thickness (mm)	Tear strength (N)	CV%
Leather	2.04	13.17	26.37	2.22	63.02	11
Bovine Leather Na+Mt_1%	2.7	37.94	31.60	2.03	49.93	13
Bovine Leather Na+Mt_3%	2.43	20.18	43.19	2.02	61.55	15
Bovine Leather Na+Mt_5%	1.9	23.00	29.88	2.18	52.87	22

oxygen groups[17] creates a series of hydrogen bondings between collagen and nanoclay, which increases the tensile strength. However, the highest strength is related to the treated sample with 1% nanoclay. Increasing nanoclay amount to 3% and 5% may result in nanoclay agglomeration, which acts as a stress center and reduces the samples' strength. In addition, this increase in the amount of nanoclay probably reduces the entanglement of collagen fibers and reduces the strength of the leather compared to the treated sample with 1% nanoclay.

Tear strength actually shows the strength of the collagen fibers and the amount of adhesion bonding between them and is directly related to the quality of skin maintenance. If the skin is not kept properly, the tear strength will be low.

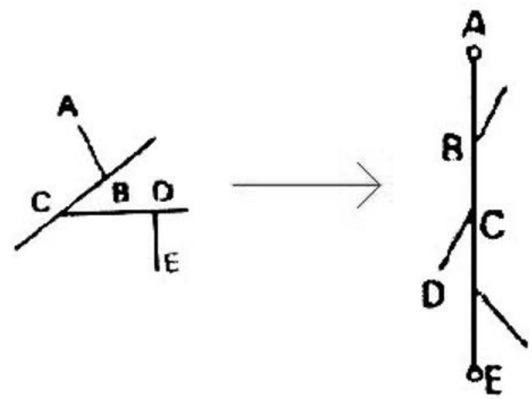

Figure 8. Formation of long fibers from entanglement short collagen fibers by applying force

Table IV

Burning Length of Bovine Leather

Sample	Average thickness (mm)	Average burn length (cm)	CV%	Average char from burning (%)	CV%
Leather	3	8.7	37.84	28.76	21.68
Bovine Leather-Na^+Mt_1%	2.4	5.9	14.77	14.32	6.78
Bovine Leather-Na^+Mt_3%	2.5	7.4	7.95	22.51	31.62
Bovine Leather-Na^+Mt_5%	2.3	7.3	24.25	26.40	30.43

Table V

Burning Length of Goat Leather

Sample	Average thickness (mm)	Average burn length (cm)	CV%	Average Char from burning (%)	CV%
Leather	1.2	6.1	38.41	42.28	36.39
Goat Leather-Na^+Mt_1%	1.4	4.9	8.89	9.57	33.78
Goat Leather-Na^+Mt_3%	1.4	4.7	8.66	6.77	9.51
Goat Leather-Na^+Mt_5%	1.4	5.3	28.14	12.25	48.13

By increasing the thickness of the leather, first increases its tear strength. However, if the empty spaces between the fibers are completely filled with solids, the thickness of leather increases too much and the tear strength will start to decrease. Because when we apply a force to stretch the fibers, short fibers cannot form the long fibers in the direction of force. Fig.8 shows the formation of long fibers from entanglement short collagen fibers by applying force.

The amounts of tear strength of samples can be seen in Table III. It can be said, the slight difference between the tear strength is due to the difference between the thicknesses of the samples.

However for more explanation about this slight difference, we can say that the presence of nanoclay between collagen fibers has reduced the tear strength of leather samples due to the reduction of the formation of longer fibers.

Flame retardancy properties

The vertical flammability test is one of the most important tests in terms of flammability. During a vertical flammability test, a material for its burning length (after the igniting flame is removed) and the amount of the char left is observed.

In order to investigate the effect of nanoclay presence on bovine and goat leather samples, the burning length of samples and their mass before and after burning were measured and the average of these lengths as well as the percentage of the average amount of char of the samples, are reported in Tables IV and V.

According to the data in Table IV and V, it can be concluded that the addition of nanoclay in the samples reduces their burning length and the average percentage of leather charcoal that can indicate the damage severity to a sample. In addition to the performance of nanoclay during fire, non-combustible gases, such as steam and carbon dioxide released by decomposition of collagen during burning, can also help to dilute the concentration of oxygen gas. This is confirmed by Jiang and his colleagues.[2]

As shown in Table IV, the average burning length and percentage of charcoal are the highest for control bovine leather, and the lowest for bovine leather with 1% nanoclay.

By increasing in the amount of nanoclay from 1% to 3% and 5% for bovine leather, the average burning length increased. It can be said that the leather treated with 1% nanoclay has a good distribution

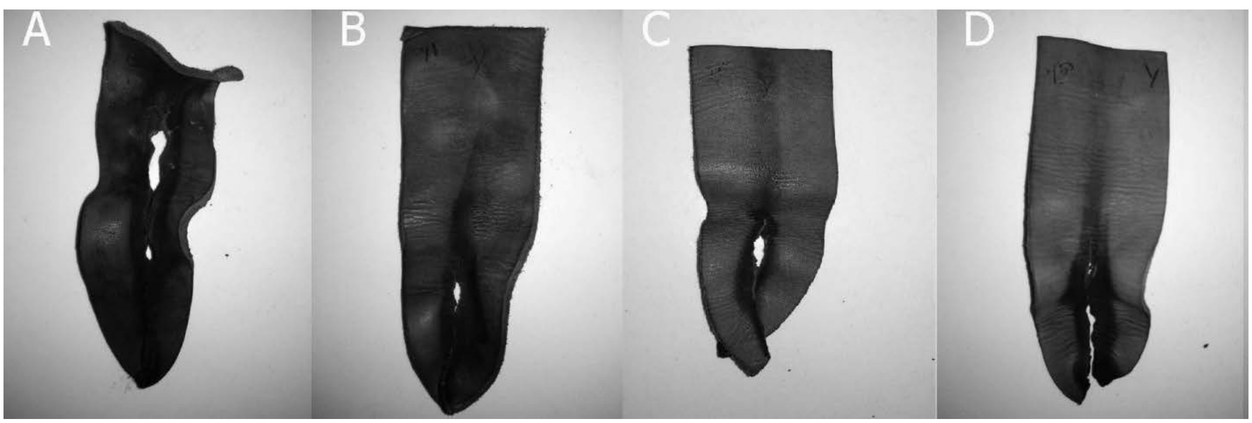

Figure 9. Bovine samples evaluated by flammability vertical test according to 14 C.F.R. Appendix F to Part 25 Part I (a) (1) (i). **(A)** leather, **(B)** leather- Na+Mt_1%, **(C)** leather- Na+Mt_3% and **(D)** leather- Na+Mt_5%.

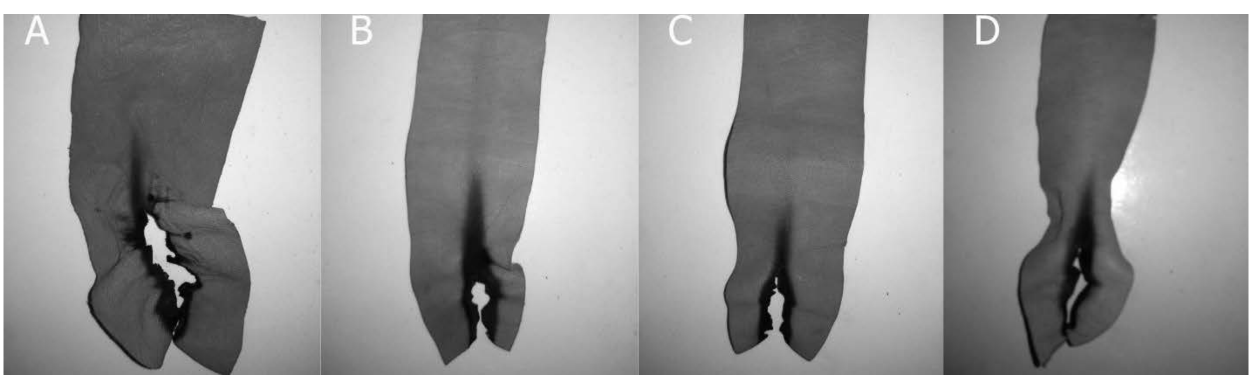

Figure 10. Goat samples evaluated by flammability vertical test according to 14 C.F.R. Appendix F to Part 25 Part I (a) (1) (i). **(A)** leather, **(B)** leather- Na+Mt_1%, **(C)** leather- Na+Mt_3% and **(D)** leather- Na+Mt_5%.

of this material between collagen fibers, however by increasing nanoclay percentage to 3% and 5%, clay nanoparticles probably agglomerate between collagen fibers and this agglomeration may not be in the burn path. Therefore, they do not reduce the burning length.

As can be seen in Table V, the highest burning length and charcoal are for control goat leather and the lowest are for goat leather with 3% nanoclay.

Since goat leather has more pores than bovine, the distribution of nanoclay in it, is better than bovine leather and more nanoclay is needed to achieve the optimal average burning length. Therefore, it has been expected that the optimal reduction of average burning length is obtained for goat leather with more nanoclay.

Also from the images of the burning length test, it can be concluded that the deformation and damage of the control samples of goat and bovine leather are higher than the other samples.

In Fig. 9 and 10, the comparison of the burning length of bovine and goat leather samples is possible.

Conclusion

In this study, the effect of clay nanoparticles on selected characteristics of bovine and goat leather was investigated. Sodium montmorillonite, a special type of clay, was selected for this study because it has no environmental hazards and its low price. It also improves flame retardancy by acting as a barrier and prevents the penetration of oxygen and heat into the samples and prevents the release of flammable products. In addition, it does not reduce the tensile strength of the leather. The final product also has an economical advantage. Some materials used in other studies are more expensive than nanoclay or have environmental hazards. In some cases they also reduce the tensile strength of leather. However, the main concern in this work was to figure out a process that can be applied in the leather production plants with only slight changes in the current machinery and chemicals.

In this study, clay nanoparticles by 1, 3, and 5 mass percent were added to wet-blue bovine and goat leather during the re-tanning process under the specified temperature and time conditions.

The result of TGA tests on bovine leather samples showed that samples with 5% and 7% nanoclay had higher thermal resistance than the control sample.

SEM images prepared from the grain and cross-sectional of bovine and goat leather samples showed that with a high percentage of nanoclay, particles agglomeration was partially visible. However, this agglomeration was not observed in samples with 1% nanoclay.

Tensile strength of bovine leather samples containing clay nanoparticles increased compared to control sample and the optimum amount of this increase was obtained with 1% nanoclay, so that the average modulus of control bovine leather samples and samples with 1% nanoclay were 13.17 and 37.94 MPa, respectively. However, the tear strength of the bovine leather containing nanoparticles did not differ significantly compared to the control samples.

The results of vertical burning test also showed that the presence of clay nanoparticles reduced the average burning length of leather samples. However, the optimum amount of this reduction was obtained for bovine and goat leather with 1% and 3% nanoclay respectively. The average burning length of bovine samples was 8.7 cm for control samples and 5.9 cm for samples with 1% nanoclay, and these values for goat control and leather- Na^+Mt_3%, were 4.9 and 1.6 cm, respectively.

Proper selection of materials used such as fatliquor, filler, dye, etc. can affect the flame retardancy of leather, so the process and materials of this research were designed and selected without changing the normal routine of leather factories. Therefore, only the effect of adding nanoclay can be examined. Since the results of this study indicate an improvement in the leather flame retardancy, without adversely affecting its strength, it is necessary to optimize the choice of materials and production conditions.

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