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PRODUCTION AND PERFORMANCE ENHANCEMENT OF TRANSPARENT AND SHADOW PUPPET SHOW LEATHERS

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Transparent leathers have attracted significant attention in the fashion industry due to their unique aesthetic appeal. Over recent decades, various companies have intermittently produced these materials; however, inherent performance limitations from the chemicals used remain unresolved. Despite their commercial appeal, the mechanical properties and durability of these leathers are often compromised; limiting widespread adoption. This study involved collaboration with international companies experienced in producing transparent leathers. A detailed exchange of technical knowledge aimed to address performance issues through modifications of existing production recipes. This approach focused on enhancing physico-mechanical properties such as tensile strength, elasticity, and durability while ensuring that alterations did not compromise transparency or visual appeal. Additionally, the dyeability of both leather types was thoroughly investigated, emphasizing the need for uniform and aesthetically pleasing coloration without affecting transparency for high-end fashion applications. The findings provide valuable insights into producing more durable and versatile transparent leathers, aligning with both performance and aesthetic requirements of the fashion industry. This study contributes to ongoing efforts to optimize the production of transparent and shadow puppet show leathers, making them more viable options for widespread use.

Keywords: transparent leathers, shadow puppet show leathers, transmittance

INTRODUCTION

Transparent leathers, appreciated for their aesthetic appeal, have gained attention in the fashion industry, although performance limitations have restricted widespread use (Yiying *et al.*, 2024). Today, transparent leathers are used in various applications, including the production of garments, footwear, bags, belts, wallets, watch straps, shoelaces, lampshades, drum coverings, and decorative household items, typically for accessories (China Arts, 2019). Also, transparent leathers have a longstanding tradition in shadow puppetry, serving as a medium for visually engaging representations. Shadow puppets, made from flat, transparent cut-outs of leather or paper, are affixed to a supporting stick and manipulated with at least two slender rods, allowing for intricate movements and storytelling (Orr, 1974). To ensure the quality of raw hides/skins intended for transparent leather production, specific characteristics must be present. These include low fat content, the absence of defects such as scars or irregularities, a tight structural composition, a high inter-fibrillar angle, and a predominance of the reticular layer compared to the papillary layer (Bayraktar *et al.*, 2005). Over the past two decades, companies have experimented with production, but challenges related to chemical treatments persist, particularly affecting durability and mechanical strength.

This study seeks to refine the production recipes of transparent and shadow puppet show leathers to mitigate current performance deficiencies. By optimizing essential properties, including mechanical strength and aesthetic clarity, this research endeavors to enhance both the functional and visual characteristics of these leathers. The ultimate aim is to render them more suitable for a range of applications within the fashion industry and other sectors where durability and visual appeal are of utmost importance.

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EXPERIMENTAL

Materials and Methods

The production of transparent leather involved the use of six pickle (pH 2.5) goat skins and two pickle kid skins as raw materials. These skins were processed using six distinct recipes (Table 1). All recipes are clearly detailed below (Tables 2-7), and information regarding the commercial chemical products used in this study, which were sourced from Güvener Company (Türkiye), is provided in this section.

Table 1. Recipes and their codes

Recipes	Code
1. Glycerin	A
2. Fatliquor with Special Tanning Effect	B
3. Fatliquor with Special Tanning Effect + Dyeing	C
4. Bleached and Glycerin	D
5. Bleached and Glycerin+ Dyeing	E
6. Shadow Puppet Show Leather	F
Shadow Puppet Show Leather (Yellow)	F1
Shadow Puppet Show Leather (Red)	F2

In Table 2, the skins underwent depickle, washing, and pickle, followed by controlled drying to form transparent leather. Despite treatment with “Transparent Leather Tanning Agent” without auxiliary chemicals after depickle, moisture retention issues persisted, leaving the skins vulnerable to ambient humidity.

Table 2. Recipe A, Glycerin

Material	Pickle Goat Skin						
Weight	Pickle + %50						
Process	%	Material	Time (min)	Speed (rpm)	Temp (°C)	pH	Description
	300	Water	15	18	20		
	1.5	NaCOOH	3 × 15			5	
Depickle	1.5	Microbial Protease	60				Drain, cold water wash
	4	Ecological Degreasing Agent	60				Drain, wash
	4	Ecological Degreasing Agent	60				Drain
Washing	150	Water	30				Drain
	400	Water					Salt-free float
Pickle	1.5	Formic acid	5 × 25				3h + overnight rest
	40	Trnsp. Leat. Tan. Agent	120			3.5	Drain, buck
Drying	Controlled toggle drying						

In Table 3, skins undergo depickle, washing, pickling, and tanning with specialized fatliquor and tanning agents to enhance flexibility and durability. Controlled drying on a toggle drying ensures the desired texture and transparency. Formic acid is used in the pickle stage for controlled swelling, followed by “Transparent Leather Tanning Oil”. To prevent moisture absorption and achieve non-hygroscopic properties, “Moisture Stabilizer (Polyalcholes)” and “Moisture Stabilizer (Silicone Base)” are added. Finally, “Anti-Adhesive Agent” is applied to eliminate the sticky texture common in transparent leathers.

Table 3. Recipe B, Fatliquor with Special Tanning Effect

Material Weight	Pickle Goat Skin Pickle + 50%						
Process	%	Material	Time (min)	Speed (rpm)	Temp (°C)	pH	Description
Depickle	300	Water	15	16	20		
	1	NaCOOH	3 × 15			4.2	
	1.5	Microbial Protease	60				Drain, cold water wash
	1.5	Microbial Protease	60				Drain, cold water wash
	4	Ecological Degreasing Agent	120				Drain, wash
	3	Ecological Degreasing Agent	120				Drain
	1	NaCOOH	3 × 15			4.2	
Washing	150	Water	30		20		Drain
Pickle	400	Water			20		Salt-free float
	1.2	Formic Acid	4 × 30			3.5	3 hours + overnight rest Drain in the morning
Tanning	40	Trnsp. Leat. Tan. Oil					
	4	Moisture Stab. (Polyalcholes)					
	0.4	Moisture Stab. (Silicone Base)					
	0.01	Mold Preventive Fungicide	180	8			Drain, wash
	300	Water		20			
	2	Anti-Adhesive Agent	20				Drain, buck
Drying	Controlled toggle drying						

In Table 4, the skins processed according to Recipe B were treated with an acid dye, which was precipitated onto the surface using formic acid. After swelling the skins with formic acid, they were subjected to fleshing, washed, and dried to achieve the desired dyed appearance. This method not only enhanced the visual characteristics of the leather but also ensured a uniform distribution of color throughout the surface.

Table 4. Recipe C, Fatliquor with Special Tanning Effect + Dyeing

Material Weight	Pickle Goat Skin Pickle + 50%						
Process	%	Material	Time (min)	Speed (rpm)	Temp (°C)	pH	Description
Depickle	300	Water	15	16	20		7 Be °
	1	NaCOOH	3x15			4.2	
	1.5	Microbial Protease	60				Drain, cold water wash
	1.5	Microbial Protease	60				Drain, cold water wash
	4	Ecological Degreasing Agent	120				Drain, wash
	3	Ecological Degreasing Agent	120				Drain
Washing	150	Water	30		20		Drain
Pickle	400	Water			20		Salt-free float
	1.2	Formic Acid	4 × 30			3.5	3 hours+overnight rest, drain
Tanning	40	Trnsp. Leat. Tan. Oil					
	4	Moisture Stabilizer (Polyalcholes)					
	0.4	Moisture Stabilizer (Silicone Base)					
	0.01	Mold Preventive Fungicide	180	8			Drain, wash
	300	Su			20		
	2	Anti-Adhesive Agent	20				Drain, wash
Dyeing	300	Water	20				
	0.01	Dyestuff	30				
	1	Formic Acid	2x15				Check for swelling, if there's swelling, drain it. Fleshing (tight), wash, drain, buck
Drying	Controlled toggle drying						

In Table 5, pickled goat leather was bleached with hydrogen peroxide and treated with "Transparent Leather Tanning Agent". However, without auxiliary agents, the leather failed to retain moisture after drying, leaving it sensitive to humidity and persistently damp. This underscores the need for appropriate auxiliary agents in leather processing.

Table 5. Recipe D: Bleached and Glycerin

Material	Pickle Kid Skin						
Weight	Pickle + 50%						
Process	%	Material	Time (min)	Speed (rpm)	Temp (°C)	pH	Description
Depickle	300	Water	15	16	20		7 Be °
	1	NaCOOH	3x15			5.5	
	2	Microbial Protease	60				Drain, cold water wash
	3	Ecological Degreasing Agent	60				Drain, wash
	4	Ecological Degreasing Agent	60				Drain
Washing	150	Water	30		20		Drain
Pickle	100	Water			20		Salt-free float
	1	H_2O_2	60				
	1.5	H_2SO_4	5x15			3.5	Drain
Washing	150	Water	3x15		20		Drain, Fleshing
	30	Trnsp. Leat. Tan. Agent					Anhydrous float
			6h+overnight				Automatic. Remove in the morning.
Drying					35°C		Buck, toggle drying

Recipe E in Table 6 is derived from Recipe D with the addition of an acid dye. The dye was precipitated formic acid, followed by swelling, rinsing, and fleshing to tight setting on the surface. This process gave the leather a dyed appearance while eliminating moisture retention issues and imparting a rigid, plastic-like texture.

Table 6. Recipe E, Bleached and Glycerin+ Dyeing

Material	Pickle Kid Skin						
Weight	Pickle + 50%						
Process	%	Material	Time (min)	Speed (rpm)	Temp (°C)	pH	Description
Depickle	300	Water	15	16	20		7 Be °
	1	NaCOOH	3x15			5.5	
	2	Microbial Protease	60				Drain, cold water wash
	3	Ecological Degreasing Agent	60				Drain, wash
	4	Ecological Degreasing Agent	60				Drain
Washing	150	Water	30		20		Drain
Pickle	100	Water					Salt-free float
	1	H_2O_2	60				
	1.5	H_2SO_4	5×15			3.5	Drain
Washing	150	Water	3x15		20		Drain, Fleshing (tight)
	30	Trnsp. Leat. Tan. Agent					Anhydrous float, 6 hours+overnight Automatic. Remove in the morning.
Drying	Buck, toggle drying						
	300	Water					
	0.01	Acid Dyestuff	30				
	1	Formic Acid	2x15				Check for swelling, if there's swelling, drain it. Fleshing (tight), wash

In Table 7, glycerin was omitted as soft leathers were not desired. Instead, semi-transparent, rigid leathers for shadow puppet shows were produced by swelling the leather with acid and toggle drying to bond collagen fibers. Yellow (F1) and red (F2) dyes were added to create colored shadow puppet show leathers.

Table 7. Recipe F, Shadow Puppet Show Leather

Material	Pickle Goat Skin						
Weight	Pickle + 50%						
Process	%	Material	Time (min)	Speed (rpm)	Temp (°C)	pH	Description
Depickle	300	Water		16	25		
	1	NaCOOH	60			4.5	
	1.5	Microbial Protease	60				Drain, cold water wash
	4	Ecological Degreasing Agent	60				Drain, wash
	3	Ecological Degreasing Agent	60				Drain
Washing	150	Water	30				Drain
	100	Water			20		Salt-free float
	1	HCL	2x10				
	0.01	Bactericide	100				Drain
Drying	Controlled toggle drying						

Spectrophotometric Color Measurement and Light Transmittance Determination

To accurately evaluate the colorimetric properties and light transmittance characteristics of leather specimens, a Konica Minolta CM 3600D spherical spectrophotometer, interfaced with a computer, was used. This instrument facilitates precise measurements across a wide spectrum, ensuring reliable data for subsequent analysis.

Physical Tests

All physical tests followed TS EN ISO 2418, 2006 standards for sample preparation. Samples were conditioned as per TS EN ISO 2419, 2006 at 23 ± 2°C and 50% ± 5% relative humidity. Leather thickness was measured using a Satra Thickness gauge according to TS 4117 EN ISO 2589, 2006. Tensile strength, percentage of elongation and double edge tear strength of samples were determined by using Shimadzu AG-IS Tensile Tester and Trapezium-2 software according to TS EN ISO 3376, 2012, TS EN ISO 3377-2, respectively. The distension and strength of surface tests were done according to TS EN ISO 3379, 2016.

RESULTS AND DISCUSSIONS

The Lab* color values measured using a spectrophotometer are shown in Table 8. The “L*” value ranges from near black (0) to white (100), while the “a*” and “b*” values indicate red-green and yellow-blue tendencies, respectively. Upon examining the “L*” values, it is observed that leathers treated with glycerin (A) exhibit a darker coloration, whereas the shadow puppet show leather samples (F, F1, F2) display a lighter appearance.

Table 8. Spectrophotometer color measurements of leathers

Code	L*	a*	b*
A	33.22	1.49	6.63
B	41.06	1.49	8.54
C	44.58	2.85	2.13
D	40.02	1	5.46
E	36.32	-16.29	1.44
F	78.79	1.3	8.51
F1	66.22	1.49	40.57
F2	67.32	13.99	6.61

The photographs depicting the leathers processed in accordance with the specified recipes are presented in Figure 1. Each image is accompanied by its corresponding identification code, which serves to enhance the clarity of reference and facilitate comprehensive analysis of the visual characteristics associated with each treatment method.

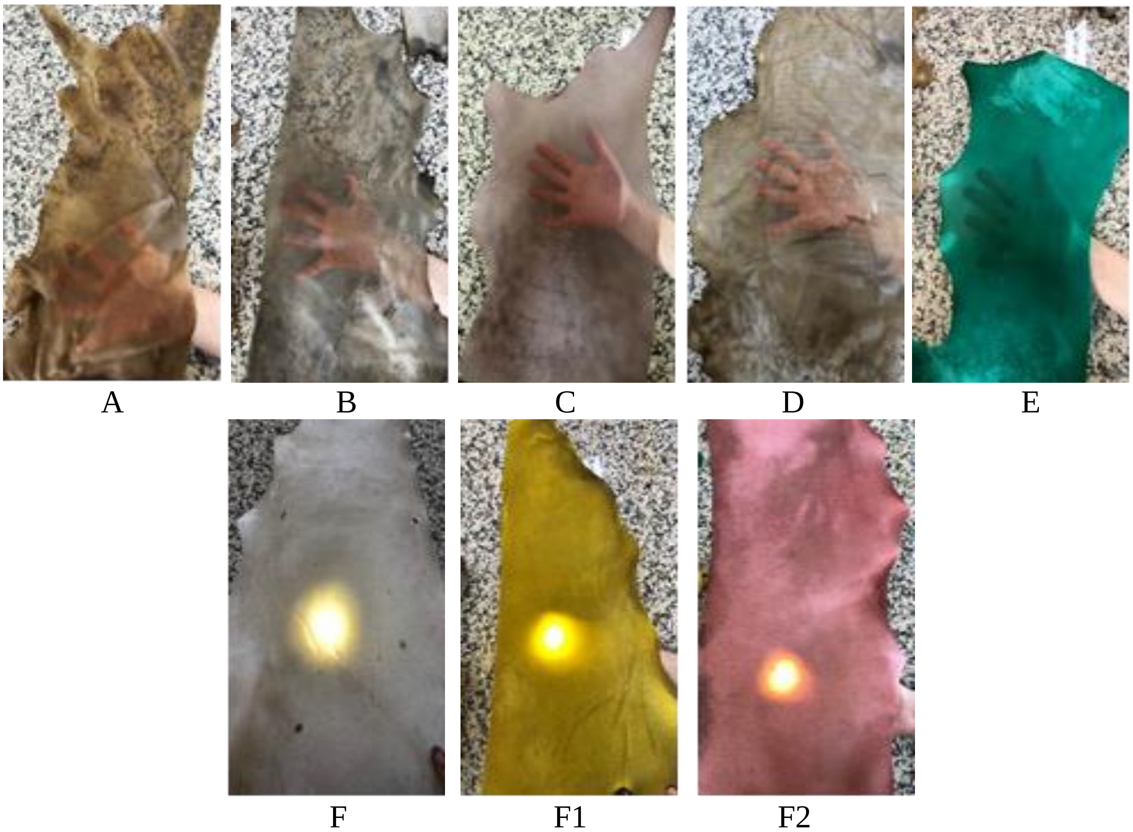

Figure 1. Photographs of the transparent and shadow puppet show leathers

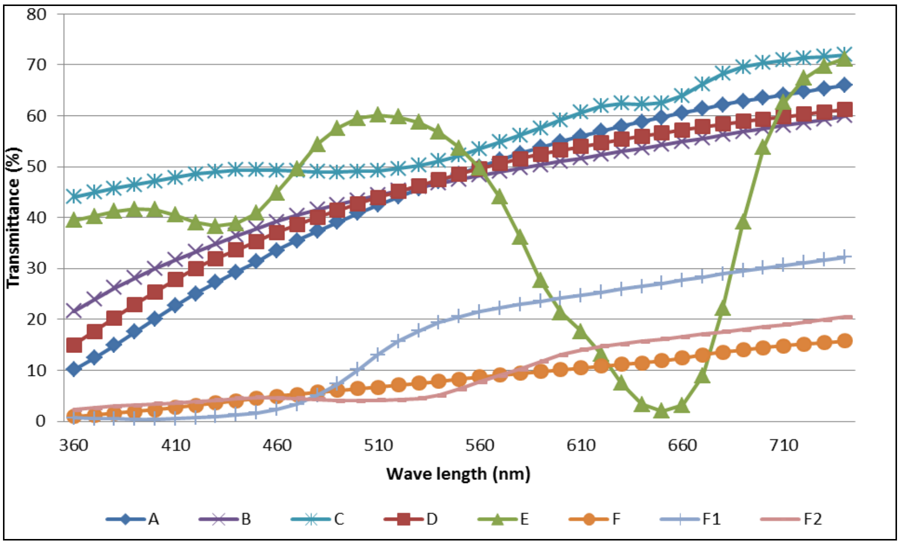

Figure 2. Transmittance spectra of transparent leathers

The percentage transmittance values measured by the spectrophotometer are illustrated in Figure 2. Upon analyzing the graph, Recipe C demonstrates the highest transparency in the visible spectrum, followed by B, D, and A. Leathers processed with E show relatively high transparency, but a decline is seen between 510 and 710 nm due to the light-reflective properties of the green dye. The lowest transparency values were recorded for F1, F2, and F. The reduced light transmittance of these leathers is attributed to the intended semi-transparency. Furthermore, these leathers require rigidity due to their use as show curtains, a property achieved by omitting glycerin treatment, which preserves their semi-transparent nature. Similar trends were reported about some materials by An *et al.* (2017), Alam *et al.* (2016), and Qiang *et al.* (2019). Based on the reviewed literature, the transparency characteristics of leathers processed with recipes C, A, D, and B in this study can be deemed satisfactory.

One key factor in determining leather suitability is its tensile and tear strength, which are influenced by the three-dimensional structure of the fibers and the treatments they undergo. Table 9 shows that leather treated with recipe E had the highest tensile strength (83.87 N/mm²), followed by recipes C, F1, F2, and F, with strengths ranging from 82.82 to 71.6 N/mm². Recipes D and B showed moderate values, while recipe A had the lowest tensile strength at 5.38 N/mm², falling below the United Nations Industrial Development Organization (UNIDO), (1996), minimum of 20 N/mm² for goat leathers. Recipe A also had the highest elongation (115%), while recipe F showed the lowest. The highest tear strength was recorded for recipe D (73.14 N/mm), and recipe A again had the lowest value (18.20 N/mm), below the UNIDO standard of 40 N/mm.

Table 9. Mean values some mechanical tests of leathers

Code	Thickness (mm)	Tensile strength (N/mm^2)	Elongation (%)	Tear Load (N)	Tear strength (N/mm)
A	1.53	5.38	115	26.02	18.20
B	0.89	20.33	104	46.62	52.98
C	0.24	82.82	18	14.92	57.39
D	0.71	25.35	83	49.73	73.14
E	0.27	83.87	20	15.73	65.58
F	0.42	71.6	17	29.94	69.64
F1	0.32	82.53	21	22.61	68.52
F2	0.34	81.4	20	25.57	71.03

In the leather production process, all materials come into contact with grain side, which can lead to a loss of flexibility in over-tanned leather sections. According to the data obtained from Table 10, leathers from recipes E, F, F1, and F2 burst without cracking in the grain layer. The highest bursting load values were seen in recipes F2, F, and F1, with minimal variation, while recipe A had the lowest. The longest bursting length was 15.63 mm for recipe B, and the shortest was 6.61 mm for recipe E.

Table 10. Mean values of distension and strength of surface test of leathers

Code	Thickness	Cracking		Bursting	
	mm	kgf	mm	kgf	mm
A	1.60	7.80	10.91	4.72	11.27
B	0.88	14.00	13.33	20.37	15.63
C	0.24	7.00	5.76	29.50	7.29
D	0.68	14.25	11.58	23.00	13.50
E	0.25	-	-	25.00	6.61
F	0.34	-	-	31.75	7.02
F1	0.31	-	-	31.25	7.15
F2	0.38	-	-	33.00	7.29

CONCLUSION

This study provides a comprehensive examination of leather produced according to formulated recipes, focusing on their dyeability and transparency. The findings indicate that the use of direct acid dyes and specific mechanical processes effectively enhances the dyeing capabilities of transparent leathers. Notably, Recipe C, which employed a pink dye with the special tanning effect fatliquor, exhibited the highest transmittance percentage, as visually corroborated by captured photographs. In contrast, leather samples processed under Recipes F, F1, and F2 showed significantly lower transmittance values, aligning with their intended application in shadow puppet shows, where semi-transparency is obscured while allowing for shadow projection.

Furthermore, physical testing results indicate that dyed leather samples generally possess higher strength values, although those treated with glycerin exhibited lower performance metrics. It is crucial to emphasize the importance of researches aimed at enhancing the strength and performance characteristics of transparent leathers, facilitating the development of innovative techniques that improve the quality and utility of leather in various applications.

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