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Investigating stingray skin as a novel material for high-performance textile items

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KEYWORDS

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Leather

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Abrasion Resistance

Cut Resistance

ABSTRACT

Fish skin leather is a sustainable alternative to traditional leather production. The goal of this study is to create a recipe for turning raw stingray leather into protective gloves for hands. The process flow of Stingray Leather Processing and optimization of each single step has been done. The technique is based on tanning agents, formulating new processing methods, conducting an extensive market analysis, and examining the environmental impact. The processed stingray leather was evaluated for resistance to abrasion, cur, and puncture resistance, and it was found that the stingray skin gloves showed better cut and abrasion resistance than the conventional gloves available in the market.

1. Introduction

The leather, a particular product, is the link between the world of fashion and small-town farmers. Compared to synthetic materials, natural materials such as leather have many advantages, including aesthetic appeal, handling, texture, and breathability. Clothing, shoes, and other leather goods are the primary uses of leather. Shoe manufacturing consumes more than 60% of leather produced. These processes are still in use in many developing countries to create leather, frequently squander water and chemicals. Leather production is an activity that helps utilize potential waste. Byproducts from the meat industry can be utilized by tanning hides or skins with basic chromium sulfate (BCS) or vegetable tannins. [1]

Tanners are becoming more interested in turning fish skins into leather because of their attractive and distinctive grain structure, which has high market value. Fish skin is generally regarded as weak, and uniform raw materials are difficult to obtain. Unlike other fish, stingrays belong to the cartilaginous family [Cartilaginous fishes (Chondrichthyes) represent the oldest surviving jawed vertebrates and, as the name suggests, have a skeleton made from cartilage. They include sharks, rays, skates, and chimeras [2], and can be found in both salt and fresh coastal waters, including some rivers. The raw skin thickness after green fleshing ranges from 2 to 5 mm with a beautiful grain structure, and it has historically been used to make decorative leather for ornamental goods. [3]

Stingrays are acquired as byproducts and sold at low prices, but they can also be processed into high-value raw materials for leather products with added appeal, such as beads and pearls. The skin of the mondol stingray and thorn stingray holds significant economic value when transformed into leather goods, while the meat can be utilized for interim food products. [4]

Stingrays are caught in large quantities and mostly sold in fresh form during the landing season. Stingray skin is often considered worthless; however, with technological advances and innovation, it can be utilized as a raw material for commercial products. [5]

Stingray skins have denticles rather than scales, which gives finished leather an appealing appearance. The stingray can grow to just over six feet wide, four feet long, and 100 pounds in weight, with females being larger than males. [6]

The skin of stingrays is composed of various types of cartilage surrounded by a fibrous perichondrium. The stiff material found in the skin of many chondrichthyan fishes is calcified cartilage, which is formed by calcification [the hardening of tissue or other material by the deposition of or conversion into calcium carbonate or some other insoluble calcium compounds] of Type II collagen. [4]

The goal of this study is to create a recipe for turning raw stingray leather into protective gloves for hands. The product will be evaluated based on the standards for hand-protection gloves. The findings of this study will determine the viability of using stingray leather as a material for hand protective gloves.

2. Materials and Methods

The use of untreated stingray skin in manufacturing is not feasible, thus the conversion to stingray leather through a sequence of chemical processes is necessary. Each step in this process plays a crucial role in creating the desired and usable leather. Tanning serves to safeguard the natural materials against bacterial activity, enhancing their durability and softness, ultimately achieving a more flexible and textile-like texture.

2.1 Application Procedure and Processes

The process flow to convert raw stingray skin into usable leather-like material is as per below.

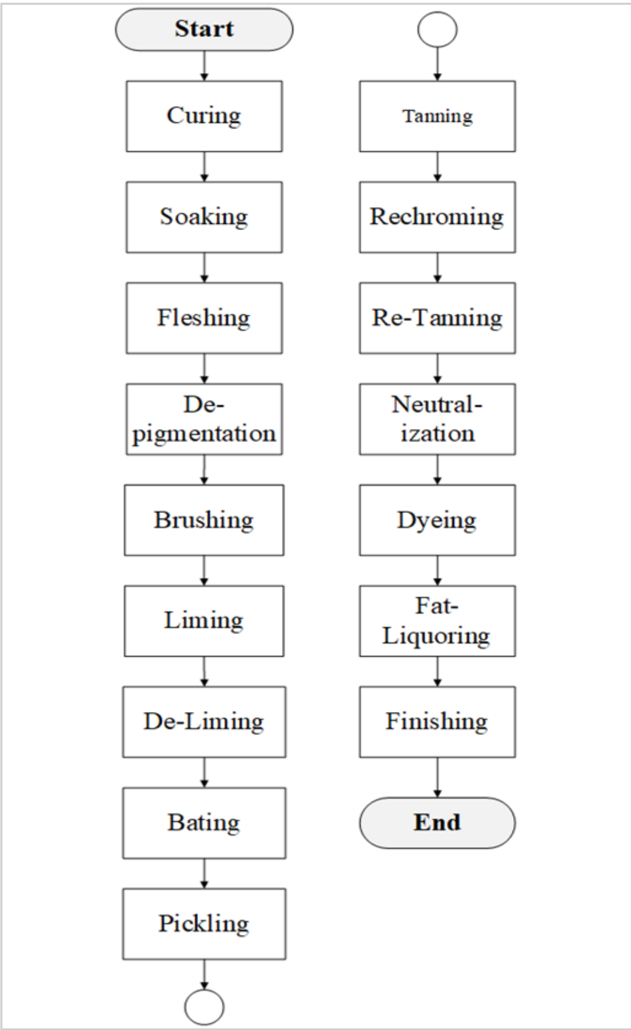


Fig. 1. Process Flow Of Stingray Leather Processing

The detail of each process is as follows:

2.1.1 Curing and preservation of hides of skin

To prevent deterioration, it is imperative to keep and maintain the fresh skin if tannery processing is not an option. Putrefaction is accelerated by bacterial development, rendering skin unfit for manufacturing leather. Skin storage is best done at a temperature of 4 to 7 °C. Fresh skin is frozen, wrapped in plastic, and kept in cold storage, which immediately halts the breakdown process and lengthens the shelf life of the skin. [9]

Skins and hides can be easily and conveniently preserved by salting. The salting procedure doesn't require chilling; thus, it needs to be done carefully to prevent the skin from rotting. The skin must be sufficiently saturated with salt to halt any bacterial growth. [10]

2.1.2 Soaking

The first step in the production of leather is known as soaking. The main objective of this procedure is to eliminate non-collagenous components of the skin, such as dirt, tissue, blood, and grease. The pH level required for this process falls within the range of 5.5 to 10. Enzymes are utilized in this process to improve softness and flexibility, as well as to reduce the manufacturing time by 10 to 20 hours. In addition, certain proteases aid in decreasing the reliance on liming chemicals, which are known to have detrimental effects on the environment. [11]

Salts such as sodium carbonate, sodium sulphide, sodium tetra-sulphide, and salts containing ammonia are employed in the soaking process. [11]

2.1.3 Dehairing or Fleshing

Dehairing refers to the act of extracting hair from the skin. Traditionally, this has been achieved through immersion in a sodium sulphide solution known as 'Hair Burning'. This process is widely considered to be one of the more unsanitary aspects of leather processing due to the unpleasant odor it produces. The primary component of skin is keratin, which sets it apart from other proteins due to its unique elemental composition.[7]

2.1.4 Liming

The liming step is not separated from the dehairing process because hair is removed by dissolving it in a solution of calcium hydroxide and sodium sulphide. Liming, one of the key steps in the leather-processing process, involves soaking skins in an alkaline solution while utilizing a drum and a paddle. [7]

2.1.5 Fleshing

The first mechanical operation to remove flesh tissues from the skin involves passing the skin between two rollers on the flesh side. [7]

2.1.6 Deliming

The deliming stage utilizes acid or acidic salts to remove excess liming chemicals from the earlier dehairing process. It is beneficial to consider deliming and bating separately even though they are both done in the same drum. Lime is extracted to neutralize any remaining alkali and decrease the pH before the bating process. Depletion of water causes the skin to become less transparent and the fiber color to become more visible. [7].

2.1.7 Bating

To prepare skins and hides for the tanning process, the procedure of bating is ultimately intended to make them more malleable. Proteases are used in this procedure to get rid of extra protein and scud. Enzymes are used to give skin a clean, smooth, and soft surface. The batting method yields the highest quality leather and cannot be substituted by any chemicals. The employment of enzymes in the initial stages of leather production is referred to as "bating," a general phrase. Its primary function is to disassemble skin components, typically a non-structural protein. The batting method is frequently used to create elegant leather from a variety of skin kinds. A method known as "bating" can further soften skin by removing grease, lime, and other pollutants [7].

2.1.8 Pickling

In order to prepare the skin for the tanning process, the pickling procedure is conducted. The conventional method of pickling, which takes into account the weight of the pelt, is outlined as follows:

- 100% float/skin
- 10% salt
- 1% sulfuric acid

The timeline for the pickling stage may vary depending on the thickness of the pelt and other external factors. Typically, it is left for approximately an hour before the addition of chrome tanning salt.

The purpose of the acid is to acidify the collagen structure by protonating the carboxyl groups, thereby increasing the reactivity of the acid. This is necessary for the chrome tanning reaction as it only involves ionized carboxyl groups. [7]

2.1.9 Degreasing

Prior to the tanning procedure, it is imperative to properly prepare the leather in order to facilitate the infiltration of tanning agents and dyes. This involves the removal of any fats and grease from the leather's surface, which is achieved through the use of lipases, detergents, and solvents. These substances also contribute to softening and increasing the pliability of the leather. [7]

2.1.10 Tanning

The process of tanning serves to mitigate the effects of protein on raw skin and prevent its decay. Tanning materials form crosslinks with the collagen structure, thus providing stabilization against all agents that degrade said structure. [8, 11]

Chromium is the most used tanning agent across the world. In the nineteenth century, all the tanners shifted from vegetable tannins toward chromium salts. But now again the world is reverting to natural vegetable tannins because of the environmental impact of chromium salts. [7]

2.1.11 Neutralization

During the tanning process, the acidic compounds penetrate the leather, making it imperative for them to be removed in order to achieve neutralized leather. However, attempting to attain a pH level of 7 is not advised as it can compromise the durability of the leather. Therefore, a pH range of 4-6 is deemed appropriate. This measure is crucial in allowing for the subsequent processes of fat liquoring and dyeing. [7]

2.1.12 Dyeing

The first property usually observed by a customer is dying. It is the most important step in the making of leather. He or she will make judgements briefly: color, depth of shade, uniformity. Multiple types of dyes are used in leather dyeing. [7]

a) Acid Dyes

Acid dyes are most common especially in the case of chrome tanned leather goods. [7]

b) Basic Dyes

The molecular structures of both basic and acidic dyes are identical. However, basic dyes possess a positive charge, while also containing anionic sites. The quaternary amino groups exhibit lower hydrophilicity compared to carboxylate groups, resulting in reduced water solubility compared to acid dyes. [7].

2.1.13 Fat liquoring

The main job is to save the leather from sticking during the drying stage. It is the most important task in fat liquoring, whereas softening of leather is also done in this process but it the secondary function of fat liquoring. When the leather is dried the moisture is removed which allows the fiber structure to contract [7].

2.1.14 Final drying

Initial leather drying involves surface water acting as a liquid, with evaporation rate depending on surface area, air temperature and humidity. If bound and structural water loss is prevented, fast drying is possible. After uniform drying, diffusion of moisture determines drying rate, with factors affecting diffusion controlling it. Higher drying temperature leads to stiffer leather, supporting belief of temperature's impact on stiffness. However, a two-stage drying process can result in softer leather. [7]

2.1.15 Finishing

Finishing aims to improve the leveling of color, covering grain defects, and controlling gloss, it further provides a protective surface with better resistance to water chemicals and abrasion. [7]

2.1.16 Final grading

Prior to sending the product to the customer, a grading process is conducted to evaluate color intensity and uniformity. Other significant factors for consideration in this process include the quality of leather, visual appearance, design effects, thickness, softness, and natural defects such as scratches. [7]

2.2 Manufacturing of The Gloves

Leather gloves have a long history and serve a variety of purposes, such as protection from debris, cold weather, dirt, and fashion accessories. The exceptional quality of leather gloves lies in the meticulous and time-consuming production process, which demands great attention to detail and rigorous quality control measures.

There are some simple steps for the glove manufacturing process:

1) Size
2) Choosing the material
3) Wetting back
4) Patch cutting
5) Sewing
6) Finishing

The sample with goat leather for developed having the same specifications as the gloves developed with stingray leather for the comparative analysis.

Fig. 2. Front View Of The Leather (Goat) Safety Gloves

Fig. 3. Back View Of The Leather (Goat) Safety Gloves

2.3 Evaluation of Finished Product

2.3.1 EN 388

The EN 388 standard, developed by the European Union, is primarily concerned with assessing the durability of various layered fabrics or a singular fabric in regards to resistance against harsh abrasion, cutting by sharp blades or objects, and puncturing and tearing by pointed objects. Each attribute is precisely evaluated in separate tests, with an assigned performance level determined by the results. As an example, a material with an abrasion resistance ranging from 100 to 500 cycles would be classified as level 1. [8]

2.3.2 EN 388 Abrasion resistance test

The Martindale tester is used to conduct the abrasion resistance test on a material. The test involves placing the material on a uniform bed and rubbing it with a standard abrasive material in a circular motion for a specific number of cycles. Generally, four samples are tested and the test result is determined by the number of cycles until the material breaks. A harsh abrasive material is used and a performance level of 3 is achieved if the material can withstand more than 2000 cycles. For layered materials, each layer is individually tested and the overall performance level is based on the resistance of the most durable layer. [8]

Table 1

Abrasion test standard values [8]

Cycles	Levels
100	1
200	2
2000	3
8000	4

2.3.3 EN 388 blade cut resistance test

A blade cut resistance test utilizes a rotating blade under pressure to determine the number of cycles needed to cut through a test specimen. Standard material is used to account for blade sharpness, and the final result is obtained by comparing the number of cycles on the sample to a few cycles on the standard material. This test can be performed on multi-layer materials, with a mean blade cut index calculated from five tests on two different samples. The lower mean blade cut index of two samples defines the performance level of the tested specimen. [8]

Table 2

Standard values for cut test index with EN 388 [8]

For Cut Resistance	
Index Value	Levels
1.2	LEVEL – 1
2.5	LEVEL – 2
5.0	LEVEL – 3
10.0	LEVEL – 4
20.0	LEVEL – 5

Table 3

Cut test with EN ISO 13997 standard values [8]

Performance Level	The amount of force (expressed in Newtons) required to penetrate a material using a blade that travels 200 mm.
A	>2
B	>5
C	>10
D	>15
E	>22
F	>30

2.3.4 EN 388 puncture resistance

This test is conducted by utilizing a standard rounded point that is penetrated through the material at a predetermined speed. The amount of force necessary for the point to fully penetrate the material serves as an indicator of the puncture resistance of the tested specimen. In cases where the test must be performed on a multilayer material, the layers are arranged and subjected to the test. The result of the lowest of the four tests dictates the performance level of the tested specimen. [8]

Table 4

Puncture test standard values [8]

Newtons	Levels
20	1
60	2
100	3
150	4

2.4 Sample Data

The PCSIR leather research center provided testing data of various animal leather for a comparative analysis between stingray leather and other types of conventional leather. This data includes commercially available leather and was tested for abrasion, cut, and puncture resistance according to EN388 standards. Results of the analysis are as follows.

Table 5

Data obtained from PCSIR leather research center

Samples	Abrasion Resistance	Puncture Resistance	Cut Resistance
Goat Crust Leather Gloves	Break at 945 cycles	103.30 N	2.39 Index
Corresponding Levels	2	3	1
Cow Full Grain Crust Leather Gloves	Break at 930 cycles	82.67 N	1.52 Index
Corresponding Levels	2	2	1
Goat Finished Leather Gloves	Break at 1025 cycles	102.34 N	1.97 Index
Corresponding Levels	2	3	1
Poly Urethane (PU) based Synthetic Leather Gloves	Break at 350 cycles	34.75 N	1.43 Index
Corresponding Levels	1	1	1

2.5 Experiment Design

Experiments were designed based on the weight of the skin obtained from the stingray vertebrate. Several trials were conducted with varying parameters to convert the raw stingray fish skin into usable leather materials. The recipe for each chemical is taken on the base of the weight of the vertebrate skin. Details of each chemical usage are mentioned below:

Table 6

Process information along with chemicals required with reference to the weight of the skin

S. No	Processes	Auxiliaries	% as per weight of the skin
1	Curing	Salt	-
2	Soaking	Detergent (Ni)	1%
		Biocide (z)	1%
		Water	300%
3	Fleshing	-	-
4	Depigmentation	Sodium Sulphide	As required
5	Brushing	-	-
6	Liming	Lime	6%
		Water	300%
7	Weighing	-	-
8	Deliming	Ammonium sulphate	2%
		Water	100%
9	Bating	Bate	2%
		Degreasing agent	1%
10	Pickling	Sulfuric acid	1%
		Formic acid	1%
		Water	100%
		Salt	10%
11	Tanning	Chrome	4%
		Water	100%
		Sodium formate	1%
12	Re-chroming	Chromigol	3%
		Water	100%
13	Re-tanning	Tannigan 08	3%
		Water	100%
14	Neutralization	Sodium Bicarbonate	1%
		Sodium formate	1%
15	Dyeing	Acid/Basic Dye	-
16	Fat-liquoring	Oil	15%
17	Finishing	-	-

Table 7

Trails of stingray leather

Process Flow	Process	Chemicals	Trails										
			Trail # 1	Trail # 2	Trail # 3	Trail # 4	Trail # 5	Trail # 6	Trail # 7	Trail # 8	Trail # 9	Trail # 10	Trail # 11
Weight of the skin (gm)			350	175	195	160	220	250	200	260	250	220	200
1	Curing	Salt	-	-	-	-	-	-	-	-	-	-	-
2	Soaking	Detergent (Ni) - ml	3.5	1.75	1.95	1.6	2.2	2.5	2	2.6	2.5	2.2	2
		Biocide (z) - gm	3.5	1.75	1.95	1.6	2.2	2.5	2	2.6	2.5	2.2	2
		Water - ml	1050	525	585	480	660	750	600	780	750	660	600
	Conditioning in a pit (days)		3	3	3	3	3	3	3	3	3	3	3
3	Fleshing/Dehairing	-	-	-	-	-	-	-	-	-	-	-	-
4	Depigmentation	Sodium Sulphide - gm	13	10	11	10	11	12.5	10	13	12.5	11	10
		Water - ml	13	10	11	10	11	12.5	10	13	12.5	11	10

5	Brushing	-	-	-	-	-	-	-	-	-	-	-	-
6	Liming	Calcium Hydroxide (lime) - gm	21	10.5	11.7	9.6	13.5	15	16	20.8	15	17.6	16
		Water - ml	1050	525	585	480	660	750	600	780	750	660	600
	Conditioning in a pit (days)		2	2	3	2	2	2	2	2	2	2	2
7	Weighing	-	297.5	148.75	165.75	136	187	212.5	170	221	212.5	187	170
8	Deliming	Ammonium sulphate - gm	7	3.5	3.9	3.2	4.4	5	4	5.2	5	4.4	4
		Water - ml	350	175	195	160	220	250	200	260	250	220	200
	Conditioning in a pit (hours)		2	0.5	1	1	1	1	1	1	1	1	1
9	Bating	Bate - gm	7	3.5	3.9	3.2	4.4	5	4	5.2	5	6.6	6
		Degreasing agent - ml	3.5	1.75	1.95	1.6	2.2	2.5	2	2.6	2.5	2.2	2
	Conditioning in a drum (hours)		1	1	1	1	1	1	1	1	1.5	1.5	1.5
10	Pickling	Sulfuric acid - ml	3.5	1.75	1.95	1.6	2.2	2.5	2	2.6	2.5	3.3	2
		Formic acid - ml	3.5	1.75	1.95	1.6	2.2	2.5	2	2.6	2.5	3.3	2
		Water - ml	350	175	195	160	220	250	200	260	250	220	200
		Salt - gm	35	17.5	19.5	16	22	25	20	26	25	22	20
	Conditioning (Drumming in hours + Ageing in days)		1+1	1+1	1+1	1+2	1+2	1+5	1+5	1+5	1+2	1+5	1+5
11	Tanning	Chrome - gm	14	5.25	9.75	9.6	13.2	15	14	18.2	15	17.6	12
		Water	350	175	195	160	220	250	200	260	250	220	200
		Sodium formate - gm	3.5	1.75	1.95	1.6	2.2	2.5	2	2.6	2.5	2.2	2
	Conditioning (Drumming in hours + Ageing in days)		2+2	2+3	2+5	2+2	2+2	2+2	2+2	2+2	2+2	2+2	2+2
12	Rechroming	Chromigol - gm	10.5	5.25	5.85	4.8	6.6	7.5	6	7.8	7.5	6.6	6
		Water - ml	350	175	195	160	220	250	200	260	250	220	200
	Conditioning in a drum (min)		60	60	60	60	60	60	60	60	60	60	60
13	Re-tanning	Tannigan 08 - gm	10.5	5.25	5.85	4.8	6.6	7.5	6	7.8	7.5	6.6	6
		Water - ml	350	175	195	160	220	250	200	260	250	220	200
	Conditioning in a drum (min)		60	60	60	45	30	60	60	60	60	60	60
14	Neutralization	Sodium Bicarbonate - gm	3.5	1.75	1.95	1.6	2.2	2.5	2	2.6	2.5	2.2	2
		Sodium formate - gm	3.5	1.75	1.95	1.6	2.2	2.5	2	2.6	2.5	2.2	2
	Conditioning in a drum (min)		60	45	50	45	45	45	45	45	45	45	45
15	Dyeing	Dye - gm	-	1.75	1.95	1.6	2.2	2.5	-	-	2.5	2.2	2
	Conditioning in a drum (min)		-	30	30	30	30	30	-	-	30	30	30
16	Fat-liquoring	Oil - ml	52.5	26.25	29.25	24	33	37.5	30	39	37.5	33	30
	Conditioning in a drum (min)		90	90	90	90	90	90	90	90	90	90	90
17	Finishing	Binder (ml)	-	-	-	-	-	-	-	-	-	10	10
		Pigment (ml)	-	-	-	-	-	-	-	-	-	2	2

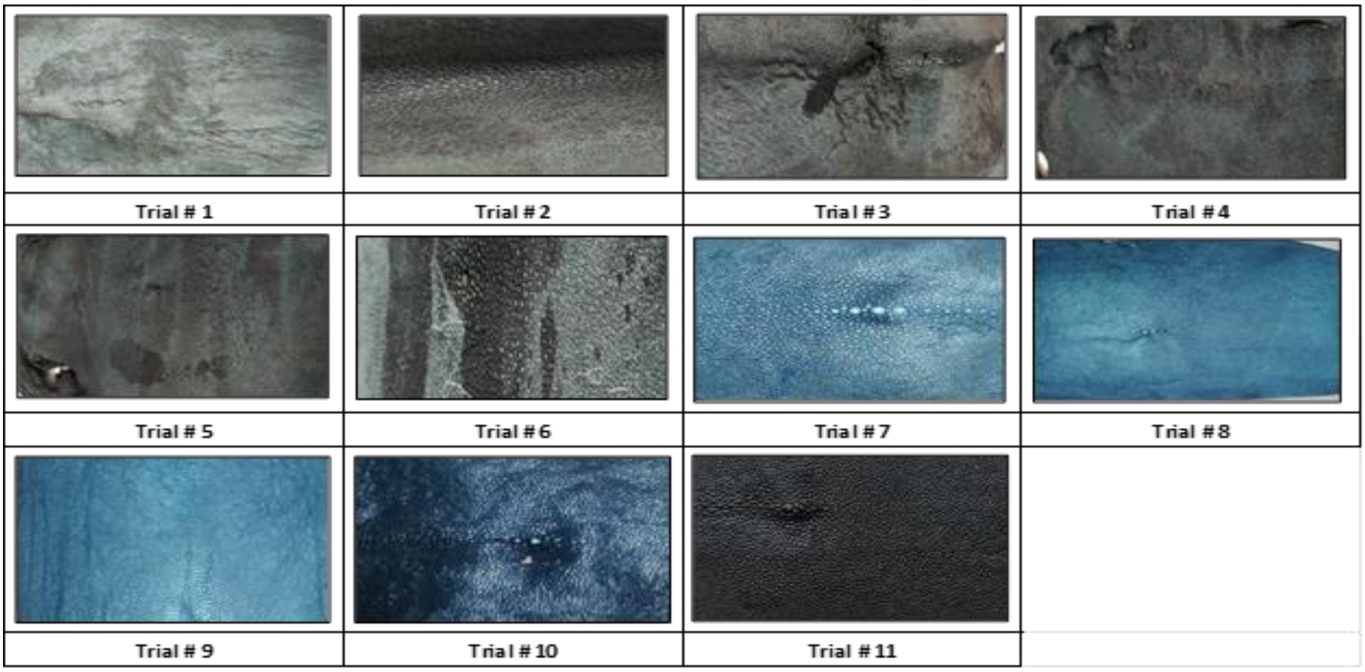


Fig. 4. Sample Trail Images of Stingray Leather

3. Results

For the conversion of the raw skin into usable material, a total number of eleven trials were conducted and the condition of the skin was visually inspected for further processing. The trails were adjusted in terms of the quantity/concentration of chemicals used and conditioning time. Following are the observations of each trial.

Table 8

Trails observations and suggested remedies

Trials	Sample Observations	Suggested Remedies
Trial 1	- Stiffness observed in the sample	- Increase tanning timings and amount of chrome.
Trial 2	- Stiffness observed in the sample	- Increase tanning timings and amount of lime and its auxiliaries.
Trial 3	-Poor Handle	- Opening of collagen is required.
Trial 4	- Uneven softness - Improper depigmentation	- Sulphide paste added for depigmentation. - Amount of chrome need to increase
Trial 5	- Grains on the skin are damaged	- Reduce gauge for better penetration of chemicals
Trial 6	- Patches are formed on the leather surface. - Uneven softness. - Veins were visible to the leather.	- Improve batting time. - Pickling chemicals need to validate
Trial 7	- Softness is improved from the middle portion of the skin.	- The process of fleshing should be performed with adequate protective measures in place to prevent any potential skin damage.
Trial 8	- Softness is adequate but the concentration needs to be reduced to avoid damage to beads.	- Removal of veins before tanning
Trial 9	- Beads are damaged due to long exposure to sulphide paste.	- To properly remove excess material, beads should be vigorously brushed.
Trial 10	-Softness improved. - Pickling problem.	- Beads are separated due to intense brushing.
Trial 11	- Sample seems feasible for the development of the product.	- Trail # s can be optimized for better performance and and productivity.

The sample is then attached with the hand protection gloves in the palm to analyze its performance as per EN388. A stingray leather patch is sewn on the palm side for the assessment.

Fig. 5. Stingray Safety Gloves Front (Palm) View

Fig. 6. Stingray Safety Gloves Back View

3.1 Abrasion Resistance

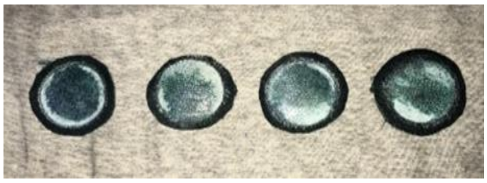
Three samples were tested, and the observation was same for all three of them:

Table 9

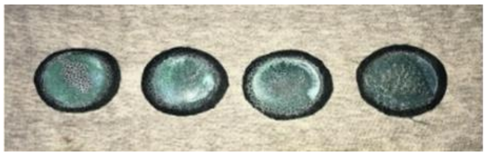
Abrasion resistance test result of stingray sample

Test	Test Results			Level
Sample # 1,2,3	Sample	Failure between per cycles	Observation	
Abrasion resistance	1 2 3 4	Greater than 8000	No Abrasion Impact Found	4

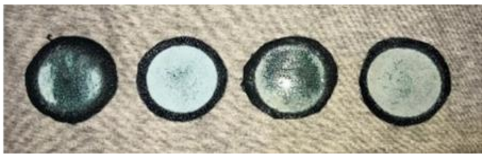
Abrasive paper with the product name Klingspor PL 31B Grit 180 and the tape with product number 3M 465.



Abrasion Resistance Test # 1



Abrasion Resistance Test # 2



Abrasion Resistance Test # 3

Fig. 7. Abrasion Resistance Tests of Sting Ray Leather

3.2 Cut Resistance

The sample was tested, and the observation was as per follows:

Table 10

Cut Resistance test result of stingray sample

Reading No.	Stroke per mm	Normalized stroke per mm	Load (N)
1	10.30	11.310	76
2	12.70	11.872	
3	14.30	13.394	
4	13.70	12.805	
5	25.11	23.503	
6	22.70	19.870	
7	26.82	25.103	75
8	21.34	19.952	
9	27.32	25.565	
10	22.26	20.833	
11	22.40	20.972	
12	24.61	23.001	
13	19.12	17.913	
14	25.23	23.634	
15	21.45	20.085	

The average of the last five values approximates the necessary force of 75 N needed to cut a 20 mm section of the sample.

The mean value of stroke/mm is recorded as 22.5.

The ultimate approximation for a 20 mm cut is calculated to be 75.00 N on the 'F' classification scale.

3.3 Puncture Test

Three samples were tested, and the peak force per newton is mentioned as per below:

Table 11

Puncture resistance test result of stingray sample

Test	Test Results				Level
Sample # 1,2,3	Sample	Peak force per Newton			
Puncture Resistance	1	124.903	104.20	119.83	3
	2	98.670	133.09	127.25	
	3	147.572	102.86	112.07	
	4	100.010	134.26	119.72	

The average puncture resistance values will be less than 150 Newtons but greater than 100 Newtons, therefore the level corresponding to puncture resistance for the stingray glove is Level 3.

The samples were assessed with the hand protection standardized testing standards to determine the performance of the gloves using stingray leather attached to the palm side. A total number of eleven trials were conducted and the observations after each trial were recorded. The samples that were obtained after trail # 11 were then attached to the palm side of the hand protection glove and then forwarded for the abrasion, cut, and puncture test according to EN388.

After completing the testing, the final sample was then compared and analyzed with the testing standard provided by the PCSIR leather research center as mentioned in table # 5. Below is a quick summary of the results obtained after the testing.

Table 12

Comparative analysis of abrasion resistance levels of different types of leather

S. No	Leather type	Breakage (# of cycles)	Abrasion Levels
1	Stingray Leather	>8000	4
2	Goat Finished Leather	1025	2
3	Cow Full Grain Crust Leather	930	2
4	Goat Crust Leather	945	2
5	Poly Urethane (PU) based Synthetic Leather	325	1

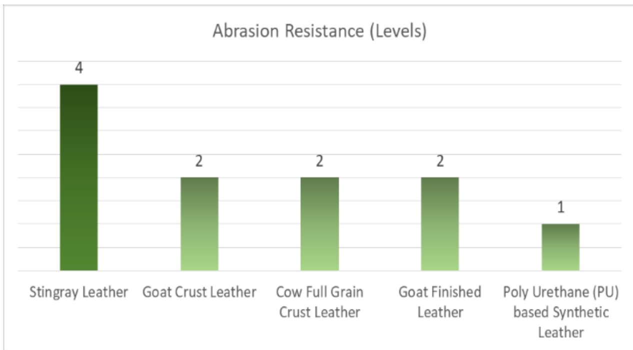


Fig. 8. Comparative Analysis Of Abrasion Resistance Levels Of Different Types Of Leather

As shown in Fig. # 8 and table # 12, the abrasion resistance properties of the glove incorporating stingray leather on the working side shows excellent abrasion resistance properties. Thus, we can conclude that for the application where a high level of abrasion resistance is required stingray leather can be a favorable choice.

Table 13

Comparative analysis of cut resistance levels of different types of leather

S.No.	Leather type	Index / Load	Cut Levels
1	Stingray Leather	75 N	F
2	Goat Finished Leather	1.962	1.0
3	Cow Full Grain Crust Leather	1.502	1.0
4	Goat Crust Leather	2.391	1.0
5	Poly Urethane (PU) based Synthetic Leather	1.413	1.0

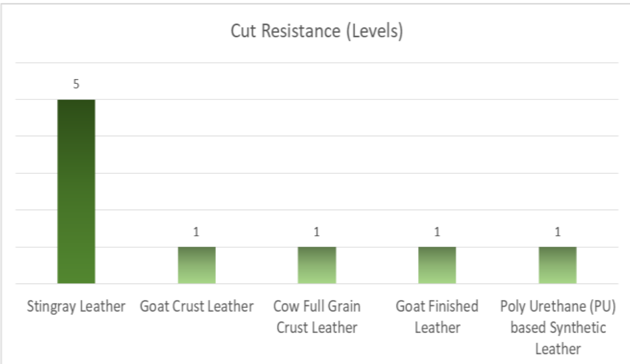


Fig. 9. Comparative Analysis Of Cut Resistance Levels Of Different Types Of Leather

As shown in Fig. 9, the cut resistance properties of the glove incorporating stingray leather on the working side show high-level cut resistance properties compared to the other type of leather. The evaluation of the protective capacity of gloves against cutting can be conducted using two distinct standards. The former approach gauges the extent of resistance with a load of 5N and grades the gloves from 1 to 5. The latter method measures a load of up to 100N and assigns grades from A to F. A thorough examination of stingray leather safety gloves revealed notable cut resistance, necessitating an average load of 75N to generate adequate incisions. Thus, we can conclude that for the application where a high level of cut resistance is required, stingray leather can be a favorable choice.

Table 14

Comparative analysis of puncture resistance levels of different types of leather

S.No.	Leather type	Peak force (Newton)	Puncture Levels
1	Stingray Leather	105	3
2	Goat Finished Leather	102	3
3	Cow Full Grain Crust Leather	82	2
4	Goat Crust Leather	103	3
5	Poly Urethane (PU) based Synthetic Leather	34	1

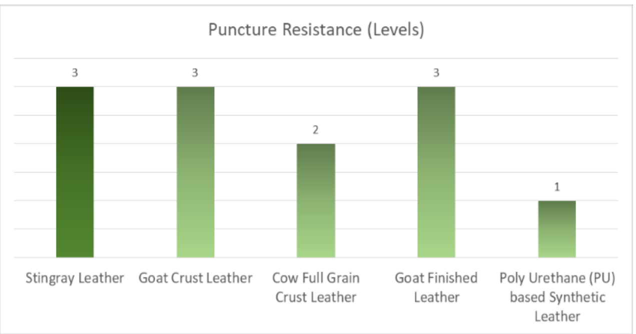


Fig. 10. Comparative Analysis Of Puncture Resistance Levels Of Different Types Of Leather

As shown in Fig. 10, the puncture resistance properties of the glove incorporating stingray leather on the working side shows similar results as compared to the goat leather (both crust and finished) whereas the puncture resistance performance is better as compared with the other samples.

4. Conclusion

The research presented in this paper highlight the development and application of stingray skin as a potential source of leather for textile products such as biker pants and safety gloves due to its enhanced mechanical properties. The study introduced a novel approach to protective textiles by incorporating stingray fish skin that shows substantial improvement in the cut, abrasion and puncture resistance of the gloves.

The key novelty of the research lies in its unique integration into the protective textile product using the conventional leather manufacturing techniques which enables the better performance. To make the leather more flexible, the results of recent experiments suggest that increasing the processing time of stingray skin with improved chrome concentration is recommended. Nevertheless, processing fish skins can be difficult, as they are not uniform in size and require specialized equipment. Additionally, optimizing fish skin processing methods and promote sustainability in leather production needs further investigation.

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