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A Comparative Study of Sustainable and Commercial Stain Removers on Textiles

*Nisha Jangra, Harinder Pal & Sagarika Pal
Dept. of Fashion Technology, Bhagat Phool Singh Mahila Vishwavidyalaya, Sonepat, Haryana

Abstract

This research investigates the effectiveness of different stain removal agents on fabric stains using a combination of grey scales and spectrophotometer analyses. Fabric swatches were stained with various substances, and each stain removal treatment was evaluated based on factors such as stain set time, stain removing time, temperature, fabric type, and the type of stain remover used. The results indicate that a longer stain remover application time of one hour and thirty minutes leads to improved stain removal efficacy. Water treatment without mechanical agitation proves effective in removing stains while preserving fabric integrity. Furthermore, in this research compared the performance of commercial detergent, baking soda mixed with apple cider vinegar, baking soda mixed with water, and apple cider vinegar alone. Each treatment showed varying degrees of effectiveness based on the stain type. Commercial detergent performed well in all type of stains, while baking soda mixed with apple cider vinegar was effective against oxidizable and enzymatic stains. Baking soda mixed with water exhibited lower efficacy, and apple cider vinegar demonstrated proficiency in removing pigment-based stains. These findings contribute to a better understanding of stain removal techniques, aiding in the enhancement of fabric care practices and protect the environment from the excessive use of chemical based detergents.

Key words: Detergent, Environment, Lightness, Stain, Stain Remover

1. INTRODUCTION:

In modern society, the demand for effective stain removal and laundry detergents has surged due to the constant battle against tough stains and the desire for immaculate clothing and fabrics. Traditionally, chemical-laden stain removers and detergents have been the go-to solutions for achieving spotless laundry results. However, the growing awareness of the detrimental impact of synthetic chemicals on the environment and human health has led to a shift in consumer preferences towards more sustainable and eco-friendly alternatives [1]. Stains are very common and persistent problem in our daily lives, affecting various materials such as fabrics, carpets, and surfaces. They can be caused by a wide range of substances, including food, beverages, oils, inks, and chemicals. The presence of stains not only affects the appearance and aesthetics of objects but also poses challenges in maintaining their functionality and durability. To address this issue, stain removers have become essential tools in our cleaning routines, offering effective solutions for stain removal [2].

However, while stain removers provide convenience and efficacy, their use raises concerns about the environmental impact associated with their production, usage, and disposal. Many conventional stain removers contain chemicals that can be harmful to the environment, potentially leading to pollution of water bodies and soil, as well as posing risks to human and animal health [3]. As our society becomes increasingly aware of the importance of sustainability and environmental stewardship, it is crucial to examine the environmental implications of stain removers and explore alternative approaches that minimize their ecological footprint [4].The primary objective of this research paper is to investigate the relationship between stains and stain removers. By conducting a comprehensive research of existing literature and employing scientific methodologies, Baking soda and vinegar are widely used as safe and eco-friendly ingredients that may offer an effective solution for stain removal. This research aims to compare the performance of baking soda mixed with apple cider vinegar and water with that of a standard detergent in removing stains from cotton fabric swatches. Furthermore, we will explore alternative stain removal methods that can mitigate the negative effects on the environment [5].

2. LITERATURE REVIEW:

As early as 1921, Elledge and Wakefield conducted a comprehensive study detailing the use of various acids, alkalis, and other laboratory reagents for stain removal from fabrics [6]. Prasad (1982) explained the slightly acidic nature of Reetha solution,

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which allows for gentle washing of delicate natural fabrics without damaging the fibers or colors [8]. In 1992, Singh et al. explored the effectiveness of certain chemicals combined with Japanese tissue paper in removing stains from Thangka paintings [7]. Csiszar (1998) found the impact of Cellulase enzyme in combination with scouring chemicals, observing a bleaching effect on cotton fabric with consecutive Cellulase treatment and alkaline scouring [9]. Additionally, Diller et al. (1998) emphasized the effectiveness of Glucose oxidize as a bleaching agent when used in combination with Cellulase or protease enzymes [10]. Mohamed et al. (2018) demonstrated that using laundry greywater for irrigation negatively affects soil characteristics and poses potential risks to soil quality and human health. Proper management and treatment of greywater are essential to mitigate its harmful impact on the environment and maintain soil fertility [4]. Mohite, M.S. (2017) the study demonstrated the potential of herbal stain removers containing natural ingredients in effectively tackling various types of stains. The F3 solution, with a higher content of eucalyptus oil, proved to be the most successful in removing stains, offering promising prospects for eco-friendly and efficient stain removal solutions.

3. EXPERIMENTAL WORK:

Fabric swatches used in this study were prepared from plain weave, undyed cotton fabric. Each fabric swatch measured 10 cm x 10 cm in size. Details regarding the specifications and properties of the cotton fabric used are presented in the accompanying table 1.

Table 1: Specification of the fabric:

S.NO.	Property	Value	Standard
1.	**Condition**	Bleached and washed fabric	---------
2.	**GSM**	75gm/m^2	ASTM D 3776
3.	**Blend**	100% cotton	---------
4.	**Weave plan**	1/1 plain	---------

To conduct the experiment, fabric swatches were initially stained with common substances, including turmeric, ink, katha, mobil oil, chocolate, food color, coffee, and beetroot. The application of the stain on each fabric sample was constant. A circular area with an approximate diameter of 5cm was marked at the center of each cloth swatch measuring 10cm x 10cm. using a dropper; 1-2 drops of each stain were carefully applied within the marked circle on the fabric samples. The application of the stain was stopped once it began spreading towards the edges of the circle.To ensure the absorption of the stains into the fabric, the stained fabric samples were left overnight before proceeding with the cleaning process using a textile stain remover. This approach was designed in accordance with **ASTM International D4265-14, the Standard Guide for Evaluating Stain Removal Performance in Home Laundering.**

Table 2: Types of stains

S.NO.	Types of Stain	Stains
1.	**Enzymatic stains**	Chocolate, food color
2.	**Oxidisable stains**	Coffee, Beetroot
3.	**Pigment and dye**	Ink, katha, turmeric
4.	**Greasy or oily stains**	Mobil oil

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Treatment Groups: The fabric swatches were divided into six treatment groups: **Group A -** Control (untreated), **Group B -** Distilled water, **Group C -** Baking soda mixed with apple cider vinegar solution, **Group D** – Baking soda mixed with water, **Group E –** Apple cider vinegar and **Group F** - Conventional detergent shown in table 3.

3.1 Stain Removal Procedure: Each stained fabric swatcheswas treated with the respective stain removal method. The control group (Group E) remained untreated. Each stain received a treatment with a total volume of 4 ml of the corresponding solution. The treatment solution was prepared by combining 1 gram of powder with 3 ml of liquid solvent. In this research study, the stain removal solutions were applied to the stained areas for two different time durations: 45 minutes and 1 hour 30 minutes. The aim was to investigate the effects of varying treatment times on the efficiency of the stain removal process. After allowing the treatment to sit for 10 minutes, the stained area was gently rubbed with bare hands.

Table 3: Stain Removers Application

S.NO.	Stain Remover	Sample ID	Amount of stain remover	Method of application
1.	**Untreated sample**	**OX**	**……..**	**.....**
2.	**Water wash**	**WX**	4ml	Rubbing evenly on stain by hand
3.	**Baking soda with apple cider vinegar**	**BVX**	1gm powder 3ml liquid	Rubbing evenly on stain by hand
4.	**Baking soda with water**	**BWX**	1gm powder 3ml liquid	Rubbing evenly on stain by hand
5.	**Apple cider vinegar**	**VX**	4ml	Rubbing evenly on stain by hand
6.	**Detergent**	**DX**	1gm powder 3ml liquid	Rubbing evenly on stain by hand

3.2 Experimental Design: The experimental samples were subjected to room temperature conditions at approximately 28°C. Stain exposure times were tested for two different durations: 45 minutes and 1 hour 30 minutes. To observe any potential variations in stain development based on the different stain removers and exposure times, the stains were left on the fabric swatches overnight.In addition to comparing the stain removal efficacy with a synthetic detergent, the results were assessed using the grey stain scale under a color matching cabinet with D65 illuminant lighting. The color difference values (L*, a*, b*) of the various stained samples were measured using a data color spectrophotometer and data color software interfaced with the computer. The illuminant used was D65, the observer angle was set to 10°, and the CIE 1976 color space was used for analysis.
By employing these methods, the study aimed to comprehensively evaluate the effectiveness of different stain removers and exposure times in removing stains from the fabric samples. The use of advanced color measurement techniques allowed for a precise comparison of the stain removal results and provided valuable insights into the performance of the stain removers under the specified conditions.

Table 4: Evaluation by Grey Stain Scale:

Stain Type	Stain Remover Applying (time)	DX	BVX	BWX	VX	WX
Ink	45min.	1.5	2	2.5	1.5	1
	1:30 min.	2.5	1.5	2.5	2.5	1
katha	45min.	1.5	2	2.5	1.5	1.5
	1:30min.	3	1.5	3	3	1.5
Chocolate	45min.	4.5	2.5	4	4	1.5

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	1:30 min.	4.5	2.5	4.5	4	1.5
Coffee	45min.	4.5	3.5	3	3.5	1.5
	1:30 min.	4.5	4	4	3.5	1.5
Turmeric	45min.	2	1.5	2	1.5	1.5
	1:30 min.	3	1.5	2	2	1.5
Beetroot	45min.	4.5	2	2.5	2.5	1.5
	1:30 min.	4.5	2.5	2.5	2.5	1.5
Food color	45min.	4.5	3.5	4.5	4	2
	1:30 min.	4.5	4.5	4.5	4	2.5
Mobile oil	45min.	4.5	2	1.5	1.5	1
	1:30 min.	4	2	2	1.5	1

Table 5: Evaluation by Spectrophotometer CIA lab* values:

Stain Type	**Stain Removing**	**Appling Time**	**l***	**a***	**b***
Ink	**Original**		28.63	2.777	-26.59
	WX	45min.	30.499	4.976	-31.487
	DX	45min.	56.484	-10.225	-31.241
		1:30min.	60.022	-10.937	-24.789
	BVX	45min.	55.962	-11.764	-22.602
		1:30min.	54.696	-12.131	-22.847
	BWX	45min.	48.811	-4.18	-34.409
		1:30min.	49.451	-5.621	-36.736
	VX	45min.	44.297	-2.538	-35.059
		1:30min.	43.746	-3.583	-35.288
Katha	**Original**		73.952	6.085	17.097
	WX	45min.	65.845	7.24	16.571
	DX	45min.	67.998	6.32	9.653
		1:30min.	68.645	6.247	12.353
	BVX	45min.	58.928	9.894	19.346
		1:30min.	58.507	10.273	18.607
	BWX	45min.	55.693	11.566	14.672
		1:30min.	55.21	11.517	15.073
	VX	45min.	65.486	6.576	17.89
		1:30min.	67.275	5.594	16.893
Chocolate	**Original**		42.58	10.297	15.788
	WX	45min.	67.017	4.984	9.84
	DX	45min.	77.696	0.249	-2.811
		1:30min.	79.089	0.823	-3.853
	BVX	45min.	64.832	2.979	7.215
		1:30min.	72.204	2.221	5.509
	BWX	45min.	65.762	3.67	7.546
		1:30min.	66.11	3.305	7.692
	VX	45min.	70.528	2.734	4.519
		1:30min.	71.906	1.631	3.215
Coffee	**Original**		34.804	4.215	3.27
	WX	45min.	69.076	0.288	20.35

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	DX	45min.	77.721	0.361	-3.565
		1:30min.	78.131	1.161	-2.455
	BVX	45min.	74.837	-0.095	5.866
		1:30min.	73.51	-0.17	7.34
	BWX	45min.	77.16	-0.17	0.506
		1:30min.	79.638	-0.163	9.403
	VX	45min.	72.393	0.327	8.381
		1:30min.	73.107	0.219	7.693
Turmeric	**Original**		65.021	12.873	62.784
	WX	45min.	68.477	5.514	65.605
	DX	45min.	74.302	-7.428	42.863
		1:30min.	75.94	-8.588	32.819
	BVX	45min.	66.701	4.571	59.694
		1:30min.	68.026	3.753	55.28
	BWX	45min.	58.998	13.294	45.879
		1:30min.	61.585	10.7	41.917
	VX	45min.	73.017	-6.224	54.299
		1:30min.	72.827	-5.278	56.186
Beetroot	**Original**		52.542	12.929	7.809
	WX	45min.	67.017	4.984	9.84
	DX	45min.	75.471	0.498	-0.448
		1:30min.	75.986	0.923	-1.969
	BVX	45min.	70.344	0.405	7.058
		1:30min.	69.281	0.629	7.249
	BWX	45min.	68.926	0.56	6.467
		1:30min.	66.11	3.305	7.692
	VX	45min.	70.528	2.734	4.519
		1:30min.	68.979	0.589	6.462
Food Color	**Original**		38.4	36.344	19.141
	WX	45min.	58.889	25.799	21.915
	DX	45min.	77.463	2.006	-4.413
		1:30min.	76.806	2.949	-4.676
	BVX	45min.	76.181	6.895	-3.079
		1:30min.	75.137	6.637	0.947
	BWX	45min.	72.753	11.1	0.788
		1:30min.	74.914	10.438	0.682
	VX	45min.	73.183	4.901	-0.677
		1:30min.	74.22	7.267	-0.096
Mobil Oil	**Original**		55.868	1.281	6.268
	WX	45min.	58.097	0.926	6.031
	DX	45min.	74.586	0.344	-1.715
		1:30min.	73.715	5.571	-1.674
	BVX	45min.	66.248	0.234	5.478
		1:30min.	68.541	0.097	6.598
	BWX	45min.	61.395	-0.014	2.222
		1:30min.	65.127	0.584	5.998
	VX	45min.	65.114	-0.076	6.296
		1:30min.	67.596	0.369	5.83

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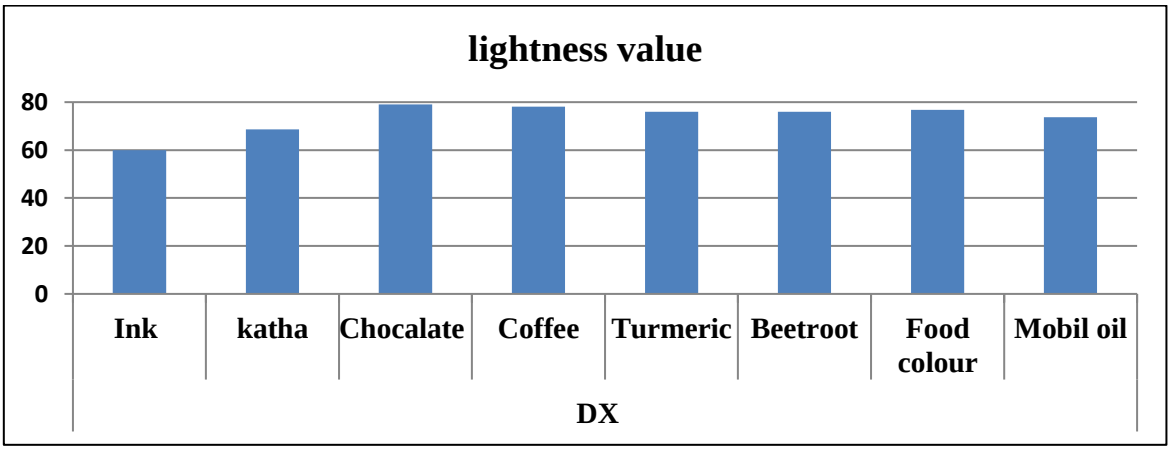
4. RESULT AND DISCUSSION:

Table 4 and Table 5 display the results obtained from the application of the grey stain scale and spectrophotometer, respectively. Based on these results, the efficiency of stain removal was evaluated, and a comparison was made to determine which stain remover exhibited greater effectiveness across all types of stains.The data from the grey stain scale and spectrophotometer analyses allowed assessing the performance of each stain remover in removing different types of stains. By quantifying the degree of stain removal and analyzing the color difference values (L*, a*, b*), we found valuable insights into the effectiveness of each treatment. A significant improvement in stain removal efficacy was observed when the stain remover was applied for duration of 1 hour and 30 minutes. This extended application period resulted in better results compared to shorter treatment times. The stains showed greater signs of being effectively lifted and removed from the fabric, demonstrating the effectiveness of the stain remover with the longer exposure time.

4.1 Water treatment: The stained fabric samples were immersed in distilled water for 45 minutes to facilitate the penetration and loosening of the stains. Subsequently, gentle hand rubbing was employed to remove the superficial layer of the stain. To ensure the safety of fabrics, no mechanical agitation was used during the process. Afterward, the treated samples were laid flat to dry.

4.2 Effect of Detergent:

Stain Remover	Stain Type	L*
DX	Ink	60.022
	Katha	68.645
	Chocolate	79.089
	Coffee	78.131
	Turmeric	75.94
	Beetroot	75.986
	Food Color	76.806
	MobilOil	73.715



The table represents the test results obtained by the Spectrophotometer, it shows the Lightness (l*) value. Cotton fabric stained with different substances such as chocolate, food color, katha, ink, turmeric, Mobil oil coffee, and beetroot. The fabric was washed using a commercial detergent. Based on the findings presented in this table 6, it is evident that the highest observed L* value was associated with chocolate (79.06), followed by coffee (78.131), food color (76.806) and the lowest value was observed with ink (60.022) under control conditions. The detergent facilitates the easy breakdown of enzyme-based chocolate stains. Specifically, surfactants of detergents target the components found in chocolate stains, effectively breaking them down and aiding in their removal from the fabric. In the case of coffee and beetroot stains, they are categorized as oxidizable stains. To eliminate such stains, bleach proves to be helpful due to its oxidizing agents. These agents react with the molecules of the

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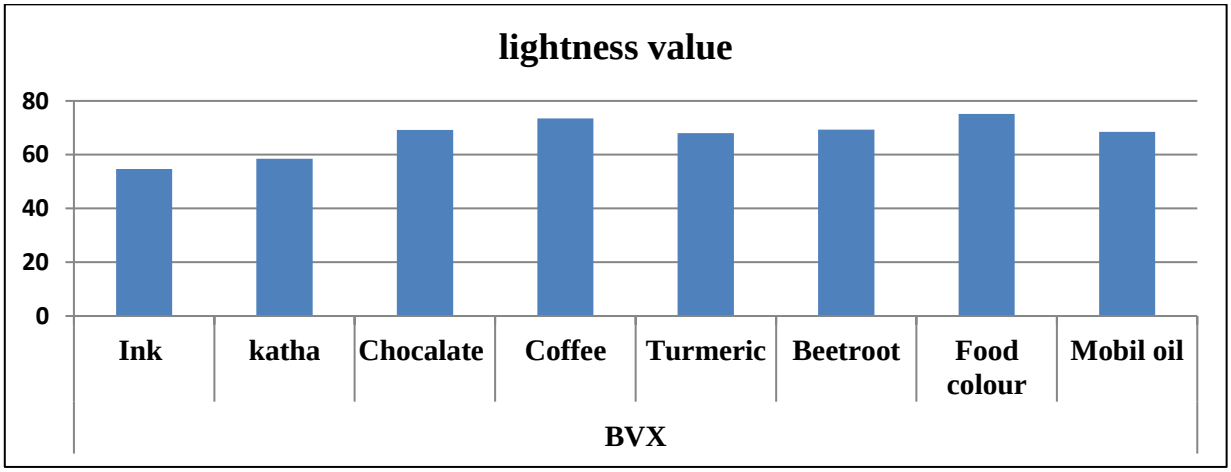
stains, causing changes in their chemical structure and rendering them more soluble in water. Consequently, the oxidation process breaks down the components responsible for the stains' color, resulting in their successful removal from the fabric. Mobil oil is comes to the oily stain category to this types of stains, surfactants play the important roles. As for katha and ink stains, they fall into the pigment stain category. In such instances, the detergent may contain specific additives that assist in breaking down these stains. These additives specifically target the pigment molecules present in the stains and aid in dispersing or solubilizing them. [11].

4.3 Effect of baking soda and apple cider vinegar:

Stain Remover	Stain Type	L*
BVX	Ink	54.696
	Katha	58.507
	Chocolate	72.204
	Coffee	73.51
	Turmeric	68.026
	Beetroot	69.281
	Food Color	75.137
	MobilOil	68.541



Based on the result of spectrophotometer the highest value of lightness by this treatment is found in food color (75.137) followed by coffee (73.51), chocolate (72.204) beetroot (69.281) and the lowest value of katha (58.507), ink (54.696) under the room temperature. Baking soda is also known as sodium bicarbonate ($NaHCO_3$) when it mixed with apple cider vinegar are combined to treat fabric stains, a chemical reaction occurs that can help in stain removal. The reaction between baking soda and apple cider vinegar results in the formation of carbon dioxide gas, which creates a foaming action. This foaming action aids in the breakdown and loosening of stain particles from the fabric. Apple cider vinegar is acidic, while baking soda is a base. When these two substances come into contact, they undergo an acid-base reaction, leading to the formation of carbon dioxide gas (CO_2) and water (H_2O), which is also known as a neutralization reaction.

CH3COOH (Acetic acid in vinegar) + $NaHCO_3$ (Baking soda) → CO_2 (Carbon dioxide) + H_2O (Water) + CH3COONa (Sodium acetate)

The production of carbon dioxide gas creates bubbles in the mixture, causing the solution to foam. This foaming action helps to agitate the stain particles, allowing them to be lifted and loosened from the fabric fibers.Baking soda has mild abrasive properties, which can help in absorbing and lifting certain types of stains, such as grease or oil-based stains, off the fabric [12].

4.4 Effect of baking soda and water:

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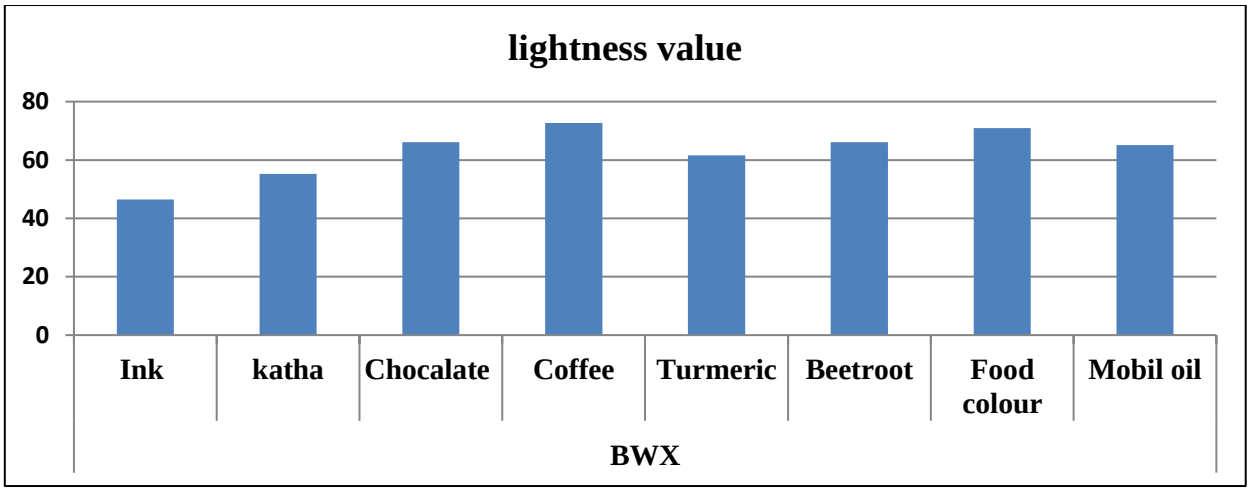
Stain Remover	Stain Type	L*
BWX	Ink	46.451
	Katha	55.21
	Chocolate	66.11
	Coffee	72.638
	Turmeric	61.585
	Beetroot	66.11
	Food Color	70.914
	MobilOil	65.127



In this case the highest lightness value found was of coffee stain (72.638) followed by food color (70.914), chocolate and beetroot value was same (66.11) and the lowest value was of ink (46.451). Baking soda with water was not given higher value than baking soda with apple vinegar. When baking soda (sodium bicarbonate) was mixed with water to treat fabric stains, it creates a mild alkaline solution that can help in stain removal. It dissociates into sodium ions (Na^+) and bicarbonate ions (HCO_3^-). The bicarbonate ions act as a weak base, which can help neutralize acidic components of the stains. The alkaline solution of baking soda can help dislodge the stain particles from the fabric fibers, loosening their grip and allowing them to be lifted and removed.Many stains, such as those from coffee, chocolate, food color, and turmeric, contain acidic components. The alkaline nature of baking soda helps in neutralizing these acidic substances, making them less adhesive to the fabric fibers.For oil-based stains like mobil oil, the alkaline solution of baking soda can help in emulsifying the oil. Emulsification breaks down the oil into smaller droplets, making it easier to disperse and remove from the fabric [13].

4.5 Effect of apple cider vinegar:

Stain Remover	Stain Type	L*
VX	Ink	43.746
	Katha	67.275
	Chocolate	71.906
	Coffee	73.107
	Turmeric	72.827
	Beetroot	68.979
	Food Color	71.22
	MobilOil	62.596

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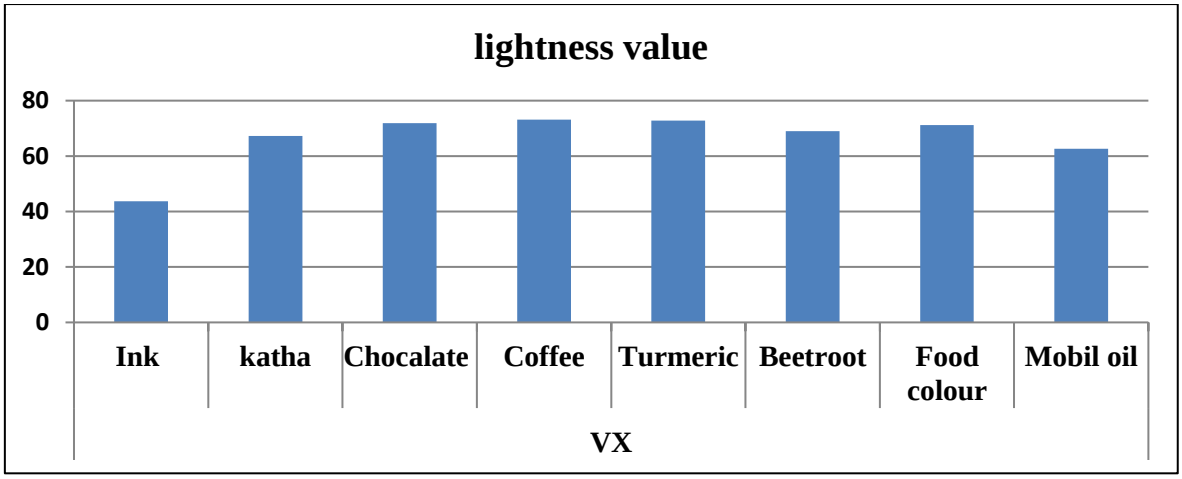

Apple cider vinegar can also be used to treat fabric stains, and its acidic nature contributes to its stain-removing properties. Based on the current findings highest lightness value was found on coffee stains(73.107) followed by turmeric (72.827), chocolate (71.906) and the lowest value of ink (43.746). Apple cider vinegar contains acetic acid. Acetic acid acts as a mild acid that can help break down certain types of stains.The acidic nature allows it to dissolve and weaken the chemical bonds of various stains, such as coffee, chocolate, food color, turmeric, katha, and ink. This dissolving action loosens the grip of the stain particles on the fabric fibers. Apple cider vinegar also possesses mild bleaching properties. This can be particularly helpful for stains like beetroot, where the acidic nature of ACV can help lighten the stain color and improve its removal. It has natural antimicrobial properties due to its acidic nature. This can help in treating stains caused by organic matter, such as food color or ink, and prevent the growth of microbes [14].

5. CONCLUSION:

The findings of this study offer valuable insights for consumers to enhance their home laundering practices and understand how to create effective stain removers using readily available, cost-effective home ingredients. The combination of apple cider vinegar and baking soda demonstrated excellent stain removal capabilities on cotton fabric, particularly for coffee, chocolate, and food color stains. Similarly, baking soda mixed with water showed notable stain removal efficacy. Meanwhile, the commercial detergent exhibited effective stain elimination on fabric surfaces. Notably, apple cider vinegar outperformed other homemade treatments in removing various stains. While homemade textile stain removers may have limited performance compared to commercial products, they present a viable option for individuals seeking to reduce their reliance on store-bought cleaning agents, leading to a healthier lifestyle and reduced environmental impact.

6. CONCLUSION

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