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EXTRACTION OF LEMON PEEL *(Citrus limon L.)* AS AN ORGANIC STAIN REMOVER FOR PARTICULATE AND OXIDIZABLE STAINS

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Abstract
Fabric plays a key role in modern society, used widely in fashion and home decor. Different fabrics, including synthetics like polyester, have unique properties that determine their applications. Stains, caused by foreign substances, are categorized into four types: enzymatic, oxidizable, greasy, and particulate. Stain removal often involves chemical-based products, which can be harmful. This study shows that Lemon Peel Extract (Citrus Limon L.) can remove oxidizable and particulate stains. With titrimetric and colorimetric analysis, it was found that 54.83% of particulate and 54.14% of oxidizable stains were removed. Promoting natural alternatives like lemon peel extract helps reduce harmful chemicals, supporting a healthier and more sustainable lifestyle.

Keywords: citric, discoloration, enzymes, oxalic, polyester

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INTRODUCTION

Fabric is a versatile material used in clothing, accessories, and home goods, with properties like thickness and texture varying by fiber type and weaving methods (**Turner, 2021**). Fabrics are classified into natural fibers, such as cotton and silk, and synthetic fibers like polyester, each serving different purposes due to their unique characteristics (**Abwonji, 2020).** Polyester, a popular synthetic fabric derived from petrochemicals, is known for its durability and resistance to wrinkles (**Sewport Support Team, 2019**). Stains on fabrics, including enzymatic, oxidizable, greasy, and particulate, require specific treatments. Enzymatic stains, involving proteins, are treated with enzymes, while oxidizable stains, caused by chromophores, are removed with oxidizing agents. Greasy stains are cleaned with surfactants, and particulate stains often need water softeners (**Brunning, 2015**; **Arnett, 2020**).

Stain removal techniques vary depending on the surface and type of stain. For instance, fabric stains might be treated with mild detergents, while metal stains may need rust removers. Natural substances like lemon peel, rich in acids and enzymes, can also aid in stain removal by breaking down organic components. Lemon peels, often discarded, can be repurposed for cleaning, offering a cost-effective and eco-friendly alternative to chemical stain removers. This approach not only reduces waste but also provides practical benefits, especially in regions with abundant lemon production (**Mir Khan, 2021; Limoneira, 2021**).

General Objectives

To determine the potential of lemon peel extract (Citrus limon L.) as an organic stain remover for particulate and oxidizable stains.

Specific Objectives

1. Characterize the compounds present in the extract of lemon peel (Citrus limon L.) specifically oxalic and citric content using titrimetric analysis.
2. To determine the percent removal and optimum conditions (amount of stain, dosage of lemon peel extract, and time) using colorimetric analysis.
3. To correlate the amount of stain, dosage of lemon peel extract, and time using Response Surface Methodology- Box-Behnken Design.

METHODS

PROCUREMENT OF MATERIALS

Experiments used lemon peel extract as a synthetic stain remover. The lemons were sourced from Nutrifres Philippines in Quezon City, Metro Manila, while 100% polyester fabric came from On Time Manufacturing Incorporated in Biñan, Laguna. Mud stains represented particulate stains, and a coffee-tea mix was used for oxidizable stains. The polyester fabric was cut into 7 cm x 7 cm samples, with a 3 cm diameter circle drawn in the center to control stain spread and differentiate stained from unstained areas. Additional lab equipment, including vials, beakers, a magnetic stirrer, FTIR, and a colorimeter, was provided by the Chemical Engineering Technology Department of the Technological University of the Philippines-Taguig Campus.

PREPARATION AND CHARACTERIZATION OF LEMON PEEL EXTRACT

The researchers used 4 kg of lemon peel that had been obtained from Triumph Upper Bicutan, Taguig City, Philippines, for the preparation of lemon peel extract. To obtain the lemon peel extract, the researchers used a manual compaction method with a mortar and pestle. Subsequently, the produced extract was transferred into vials for characterization. The produced lemon peel extract was characterized using the titratable acidity test method AOAC 942.15 to determine the compounds present in the extract, particularly the citric and oxalic acids. The testing was conducted at the Department of Science and Technology - Research Institute located at General Santos Avenue, Bicutan, Taguig City, Metro Manila.

STAINING AND APPLICATION OF LEMON PEEL EXTRACT ON FABRIC.

The 100% polyester fabric was cleaned and then stained with mud for particulate stains and a coffee-tea mix for oxidizable stains. Stains were applied using a dropper, and the process was stopped when the stains neared the circle. Lemon peel extract, rich in citric and oxalic acids, was used as a natural stain remover (**Nelofer et al.,**

2021). The extract was applied dropwise, from 5 to 15 drops, with its effectiveness enhanced by sunlight exposure during soaking (**Nur Syaliza, 2021**).

OPTIMIZATION AND ANALYZATION OF STAIN REMOVAL CAPABILITIES

After applying the extract, the fabrics were left for 5 minutes before washing. The swatches were separated based on stain duration—12, 18, and 24 hours—and washed in a magnetic stirrer for 15 minutes according to AATCC standards

(**Nur Syaliza Musa et al., 2021**). The fabrics were then line dried. Stain removal was analyzed using Response Surface Methodology (RSM) and a colorimeter to measure color differences before and after cleaning.

RESULTS and DISCUSSION

CHARACTERIZATION OF COMPOUNDS PRESENT IN LEMON PEEL

In collaboration with the Department of Science and Technology, a systematic and rigorously designed testing protocol was implemented to examine the chemical constituents of lemon peel extracts (Citrus limon L.), with a particular focus on the presence and concentrations of citric and oxalic acids. To assure the accuracy and strength of the findings, this project used a systematic method that included precise procedures, analytical apparatus, and statistical analysis.

Table 10

Titratable Acidity of Lemon Peel Extract

Test Parameter, Unit	Result	Test Method
Titratable Acidity (as Citric Acid), %w/v	3.29	AOAC 942.15
as Oxalic Acid %w/v	2.11	

Table 10 shows the titratable acidity results of lemon peel extract from DOST-PTRI. Two 300 mL samples were analyzed using the AOAC 942.15 method, revealing 3.29% citric acid and 2.11% oxalic acid. These results align with AOAC standards and studies by (**Jamil N. et al. 2021**), which report citric acid at 3.3±0.08% and oxalic acid at 2.12±0.03%. The presence of these organic acids supports their role in enhancing detergent effectiveness, as noted by (**Dhakite PA et al. 2021**).

Table 12

Percent Removal of Lemon Peel on Polyester Fabric

Test Requested	Test Results
P-12	49.53

O-12	49.12
P-18	49.84
O-18	49.72
P-24	51.62
O-24	51.85

In accordance with The Philippine Textile Research Institute (PTRI) the table shows the test results of removal percentage for particulate and oxidizable stains. The Philippine Textile Research Institute (PTRI) assessed stained polyester fabric for particulate and oxidizable stains, employing established textile testing protocols including the AATCC EP6 and the ASTM D4265-21 standard for stain removal measurement, commonly referred to as the Stain Removal Index (SRI). The report includes SRI values ranging from 0 to 100, where 0 indicates no stain removal and 100 denotes complete removal. Results indicated that lemon peel extract effectively removed a specific percentage of stains over 12, 18, and 24-hour durations.

DETERMINATION OF OPTIMUM CONDITION

PARTICULATE STAIN

Researchers optimized a procedure using lemon peel extract as a stain remover for polyester fabric, employing the Box Behnken Design. The study found that treatment times of 12, 18, and 24 hours removed stains at average rates of 49.53%, 49.84%, and 51.62%, respectively. While time affected stain removal efficiency, overall percentages were low, suggesting the need for further research to improve the effectiveness of lemon peel extract for particulate stains on polyesters

Table 14

Experimental Design and Results from Box-Behnken Design (BBD) with Percent Removal of Particulate Stain

Parameter	Name	Units	Low	High
1	Amount of Stain	drops	3	7
2	Dosage of Lemon Peel Extract	drops	1	3
3	Time	hour	12	24

		Amt. of stain	Dosage of lemon peel extract	Time	% Removal
Std	Run				
1	1	3	1	18	49.13
2	2	5	2	18	49.68
3	3	5	3	12	51.46
4	4	3	3	18	49.96
5	5	5	1	24	49.33
6	6	7	3	18	50.16
7	7	5	2	18	51.92
8	8	7	2	12	48.63
9	9	5	1	12	48.15

10	10	4	2	24	51.34
11	11	5	2	18	49.55
12	12	5	3	24	54.83
13	13	7	1	18	48.93
14	14	7	2	24	50.96
15	15	5	2	18	49.5
16	16	3	2	12	49.88
17	17	5	2	18	49.73

Table 14 presents the results of an experiment using the Box-Behnken Design (BBD) to study stain removal by the DOST-PTRI, following AATCC EP6 and ASTM D4265-21 standards. A chroma meter measured color changes to assess the treatments' effectiveness. The best stain removal occurred in run 12 with 5 drops of stain, 3 drops of stain remover, and 24 hours contact time.

OXIDIZABLE STAIN

The study on oxidizable stains used the Box-Behnken design to optimize the stain removal process with lemon peel extract. Results showed higher stain removal percentages for oxidizable stains (49.12%, 49.72%, and 51.85% at 12, 18, and 24 hours) compared to particulate stains, highlighting the importance of treatment time. These findings suggest tailored methods based on stain type and time can improve fabric cleaning efficiency.

Table 18

Experimental Design and Results from Box-Behnken Design (BBD) with Percent Removal of Oxidizable Stain

Parameter	Name	Units	Low	High
1	Amount of Stain	drops	3	7
2	Dosage of Lemon Peel Extract	drops	1	3
3	Time	hour	12	24

		Amt. of stain	Dosage of lemon peel extract	Time	% Removal
Std	Run				
1	1	3	1	18	49.13
2	2	5	2	18	49.68
3	3	5	3	12	51.46
4	4	3	3	18	49.96
5	5	5	1	24	49.33
6	6	7	3	18	50.16
7	7	5	2	18	51.92
8	8	7	2	12	48.63
9	9	5	1	12	48.15
10	10	4	2	24	51.34
11	11	5	2	18	49.55

12	12	5	3	24	54.83
13	13	7	1	18	48.93
14	14	7	2	24	50.96
15	15	5	2	18	49.5
16	16	3	2	12	49.88
17	17	5	2	18	49.73

Table 18 shows results from the Box-Behnken Design (BBD) used to assess oxidizable stain removal. Standards AATCC EP6 and ASTM D4265-21 were followed, and a chroma meter measured color changes for stain removal efficiency. The top three runs were run 12 (5 drops of stain, 3 drops of remover, 24 hours contact time), followed by runs 7 and 3 with slightly different conditions.

CORRELATION OF THE PARAMETERS USING RSM-BBD

The data highlights the effectiveness of lemon peel extract in removing particulate and oxidizable stains from polyester fabric. Using Design Expert software and the Box Behnken Design, researchers conducted 17 experimental runs to evaluate stain removal. After analyzing the results with multiple models, the software recommended a linear model for statistical significance.

Figure 11

Predicted vs Actual plot for Particulate stain.

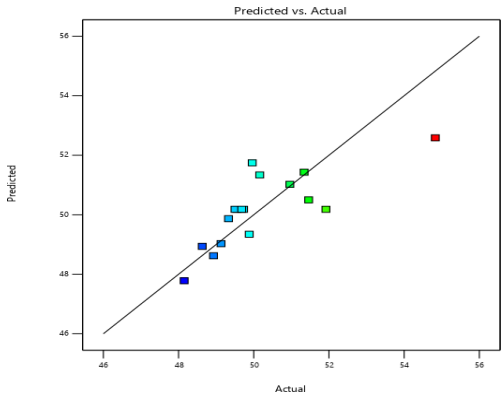

Figure 11 shows the plot of actual vs. predicted values, with data points closely aligning to the predicted line. This suggests the model is accurate, effectively capturing trends and relationships, confirming its reliability in forecasting outcomes.

Figure 12

(a) Contour and (b) 3D Response Surface Plots of the Interaction of (A) Amount of Stain and (B) Amount of stain remover for Particulate stain.

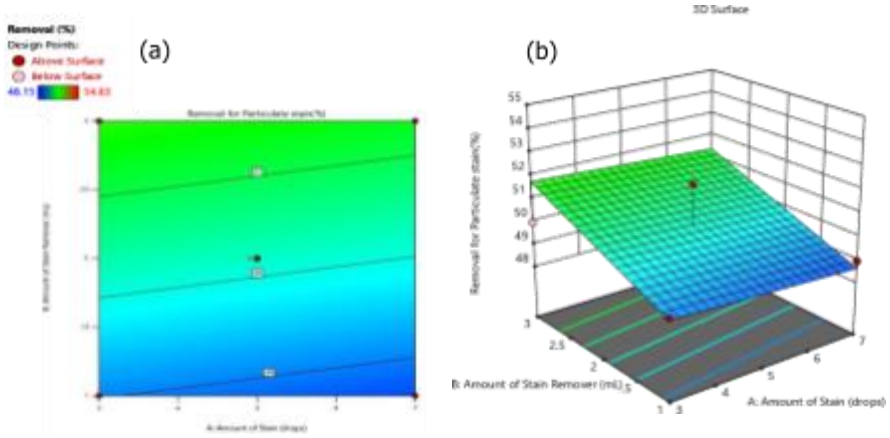

Figure 12 shows a color gradient from blue to red, representing stain removal percentages under different conditions. Figure 13 highlights how increasing the stain remover and contact time improves removal efficiency. The highest removal percentage (54.83%) occurs with 24 hours of contact time and 3 drops of remover, while the lowest (48.15%) is with 12 hours and 1 drop of remover.

Table 16

Confirmation Analysis for Optimized Conditions for Particulate Stain

Amount of Stain	Dosage of lemon peel extract	Time
5	3	24

Table 17

Confirmation analysis of the Model for Particulate stain

Analysis	Predicted Mean	Predicted Median	Observed	Std Dev	n	SE Pred	95% PI low	Data Mean	95% PI high
Removal	50.1847	50.1847		1.1027	6	0.523628	49.0535	49.9533	51.3159

Tables 16 and 17 present confirmation analyses from Design Expert v13. In Table 16, the optimized values were confirmed using 5 drops of stain, 3 drops of remover, and 24 hours contact time. Table 17 shows particulate stain removal with a mean of 49.9533 from 6 runs, closely matching the predicted 50.1847, with only a 0.2314 difference.

Figure 13

Predicted vs Actual plot for Oxidizable stain.

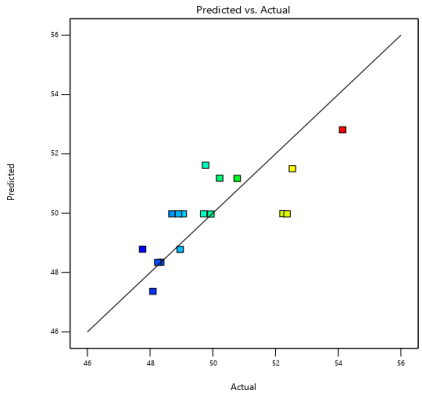

Figure 13 shows a plot of actual vs. predicted values, with data points closely aligning to the predicted line. This indicates the model's high accuracy, effectively capturing trends and supporting its reliability in forecasting outcomes.

Figure 14

(a) Contour and (b) 3D Response Surface Plots of the Interaction of (A) Amount of Stain and (B) Amount of stain remover for Oxidizable stain.

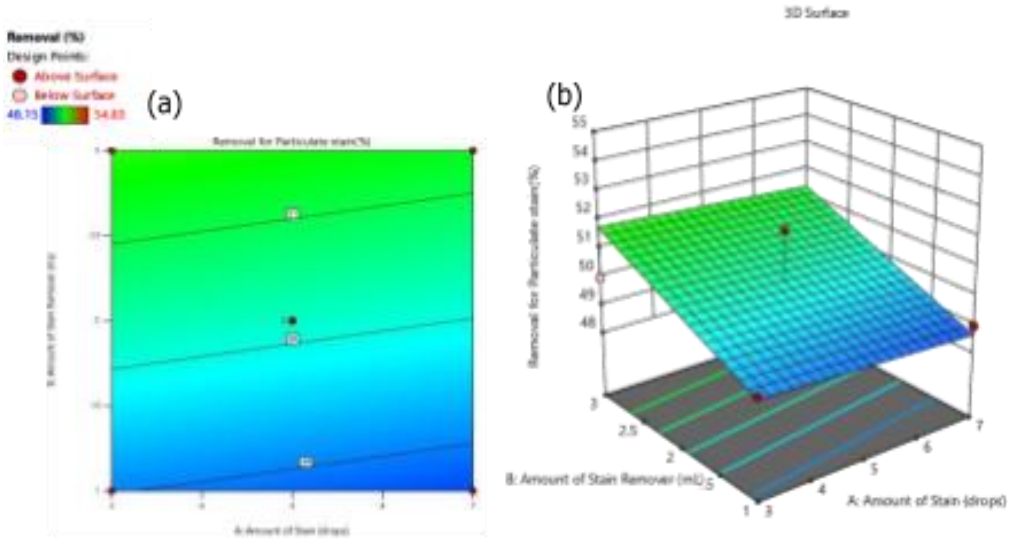

Figure 14 uses a color gradient to show removal percentages under different conditions. It reveals that increasing stain remover and contact time improves removal, with the highest percentage of 54.14% at 24 hours and 3 drops of remover, and the lowest of 47.76% at 12 hours and 2 drops.

Table 20

Confirmation Analysis for Optimized Conditions for Oxidizable Stain

Amount of Stain	Dosage of lemon peel extract	Time
5	3	24

Table 21

Confirmation analysis of the Model for Oxidizable stain

Analysis	Predicted Mean	Predicted Median	Observed	Std Dev	n	SE Pred	95% PI low	Data Mean	95% PI high
Removal	51.1802	51.1802		1.34292	6	0.905817	49.2233	50.0317	53.1371

Tables 20 and 21 present confirmation analyses from Design Expert v13. Table 20 confirms optimization with 5 drops of stain, 3 drops of remover, and 24 hours contact time. Table 21 shows an oxidizable stain removal mean of 50.0317 from 6 runs, close to the predicted 51.1802, with a 1.1485 difference.

CONCLUSION

In conclusion of this research, it is proven that Lemon Peel Extract (Citrus Limon L.) extract can eliminate a certain amount of oxidizable and particulate stain. Through the process of titrimetry, presence of oxalic and citric acid were detected on the extract thus hinting that the extract itself have the presence of compounds that may remove stains on clothes (specifically particulate and oxidizable stains). In addition to this, the process of colorimetry was performed by the Philippine Textile Research Institute (PTRI); through a standard calculation called Stain Removal Index (SRI), the efficiency of the extract was quantified. The results of the experimentation were clear; the time and amount of extract affects the efficiency of the stain removal capabilities. The fabric that was subjected with 3 drops of stain remover and was left for 24 hours yielded the most amongst all trials involving oxidizable stain with a percentage removal of 54.14%. On the other hand, fabric that was subjected with 3 drops of stain remover and was left for 24 hours yielded the most amongst all trials involving particulate stain with a percentage removal of 54.83%. In totality, the experiment proved that lemon peel extract has compounds present in it that makes it able to remove considerable amounts of particulate and oxidizable stains.

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