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# OPTIMIZATION OF PROCESS CONDITIONS OF SILK FABRIC DYEING WITH GALINSOGA PARVIFLORA LEAF EXTRACT FOR ANTIBACTERIAL APPLICATION.

**MUSINGUZI Alex[1, 2], MWASIAGI, J. Igadwa[1], NIBIKORA Ildephonse[2]
NZILA Charles[1]**

[1] Moi University, Faculty of Engineering, Department of Manufacturing, Industrial and Textile Engineering, P.O. Box 3900-30100, Eldoret, Kenya.

[2] Busitema University, Faculty of Engineering, Department of Polymer, Textile and Industrialisation Engineering, P.O. Box 236, Tororo, Uganda.

Corresponding author: Musinguzi, Alex, E-mail:musinguzialexb1@gmail.com

***Abstract:*** *Silk being one of the organic natural fibers, is susceptible to microorganisms attack thus leading to loss of physical aesthetic and mechanical properties. The present study was focused on optimizing the dyeing process parameters (Extract concentration and dyeing temperature) of dyestuff extracts from the Galinsoga Parviflora plant and analyzing the antibacterial activity of the dyed silk fabric. The Pad-dry method was used for the application of herbal dye extract onto selected silk fabric and the AATCC 100:2019 test method was used in assessing the treated fabric quantitatively against Staphylococcus Aureus and Pseudomonas Aeruginosa bacterial strains. Dyeing conditions obtained using Central Composite Design (CCD) indicated that dye concentration and temperature of 39.14 percent and 70$^0$C respectively could be deemed as optimum. Also, the Analysis of Variance (ANOVA) results showed that extract concentration has a statistically significant effect on bacterial count whereas the effect of temperature was not so much influential. Silk fabric dyed with optimized values demonstrated a 99.33% and 99.15% reduction in the bacterial count against Staphylococcus Aureus and Pseudomonas Aeruginosa bacterial strains respectively. Also, its fastness properties to light, washing, and Rubbing ranged from very good to excellent (4-5 to 5). Thus, in general, this research confirmed that Galinsoga Parviflora plant leaves, abundantly available in most parts of Uganda can be used as an antibacterial finish on silk fabric for improved bacterial resistance.*

***Keywords:*** *Antibacterial activity, Central Composite Design, Silk fabrics, leaf extract, Fastness properties.*

## 1. INTRODUCTION

Textile fibers and fabrics are well known to be excellent media for the generation and propagation of various micro-organisms which cause adverse fiber properties that include; unpleasant odor, staining, and health-related infections to the users [1]. In a bid to improve the functional ability of the clothing materials, several antibacterial agents can be applied [2],[3]. Recently, there has been an increase in the use of natural-based medicinal plants as antibacterial agents due to their eco-friendly nature and non-allergic properties [4],[5]. Galinsoga Parviflora is a well-known traditional plant belonging to the Asteraceae family, good at treating wounds and beetle bites, and grows on fertile soils which are uncultivated. It also contains several phytochemical and pharmacological properties which help it to resist microbes [6]. Apart from antibacterial activities, medicinal plant extracts can also be used to provide several colours to the fabrics although their colourfastness properties are relatively low but improve significantly when applied using a cross-linking agent [7]. However to effectively achieve the desired satisfaction of these natural dyes, dye application methods vary which can be optimized using different techniques [8]. Therefore, the present study was aimed at extracting the dye from *Galinsoga Parviflora* plant leaves and optimize dyeing parameters using Central Composite Design, a model fitting tool of Surface Response Methodology on silk fabrics for antibacterial applications.

## 2. MATERIALS AND METHODS

### 2.1 Materials

Pre-treated woven silk fabric was bought from Kawanda Silk Research Center, Kampala-Uganda. Mature plant leaves of *Galinsoga Parviflora* were collected from the wild in Biharwe, Mbarara District – Uganda. Sodium Hydroxide, Distilled water, Pestal, and a motor, Digital measuring balance, and Whatman No. 1 filter papers all were bought from INDO Kenya Enterprises, Eldoret-Kenya.

### 2.2 Methods

#### 2.2.1 Preparation of medicinal dye extract

The dried plant leaves of *Galinsoga Parviflora* were grounded into a moderately coarse powder, weighed, and subjected to an aqueous extraction process keeping material to liquor ratio at 15:250 w/v [9]. After 8 hours on a shaker, the extract was filtered and stored at $4^0$C degree in an airtight container.

#### 2.2.2 Microorganisms and culture condition

ATCC Gram-positive and Gram-negative pathogenic bacteria viz. *Staphylococcus aureus* and *Pseudomonas aueruginosa* were recovered from the storage media following the Standard Operating Procedures and maintained on Muller Hinton (MH) medium.

#### 2.2.3 Dyeing of the selected fabrics and testing for their antibacterial efficacy

After dye extraction, silk fabric samples were dipped in the bath with material to liquor ratio of 1:40, 3g/l concentration of Alum at $70^0$C for 30 minutes. Thereafter, the excess dyes were removed by padding mangles and dried under the shade [10]. To optimize the dyeing process, extract concentration and dyeing temperature were done at 15, 25, and 35%, and 60, 70, and $80^0$C respectively. These values were considered basing on the literature survey and preliminary trials. The dyed fabric samples were tested for bacterial efficacy against selected bacterial strains. The combination that yielded the lowest bacterial count was selected as the optimum condition.

#### 2.2.4 Response Surface Methodology

Basing on the bacterial resistance properties demonstrated by dyed silk fabric samples, dyeing conditions for *Galinsoga Parviflora* plant extract were optimized using Central Composite Design (CCD) of Response Surface Methodology [11]. The experimental variables were extract concentration and dyeing temperature. Their coded and actual levels are stated in Table 1.

***Table 1.*** *Experimental variables and their levels*

| Variables | Levels | | | | |
|---|---|---|---|---|---|
| | -α | -1 | 0 | 1 | α |
| Concentration (%) | 10.86 | 15 | 25 | 35 | 39.14 |
| Temperature ($^0$C) | 55.86 | 60 | 70 | 80 | 84.4 |

Then the response variable was the bacterial count values obtained from testing dyed silk fabrics against selected bacterial strains. All the design and analysis of experiments were performed using the Design Expert 7.0 software package [12].

#### 2.2.5 Statistical Analysis

With the help of ANOVA, the statistical significance of the regression coefficients and adequacy of the developed model was checked. Response surface plots were drawn to analyze the interaction among the different independent process factors and their effect on the bacterial count.

#### 2.2.6 Assessment of Antibacterial resistance and fastness properties of dyed fabric with optmized values.

As per AATCC Test Method-100:2019, dyed and undyed (Control), silk fabrics were tested for antibacterial activity against Gram-positive and Gram-negative bacterial strains. After inoculation and incubation, the microbial inhibition was calculated as a percentage reduction in the number of Colony Forming Units (CFU) with respect to untreated control samples following the formula below;

R = [(B-A)/B]*100. Where; R- Percentage reduction in Microbial colonies, A – CFU/ml for the treated fabric samples after 24hrs incubation, B – CFU/ml for the untreated fabric samples after 24hrs incubation under the same conditions.

For fastness properties, the dyed silk fabrics were analyzed following the ISO standard methods viz ISO 105-X12:2016, ISO 105-E04:2013, ISO 105-B02:2014, and ISO 105-C10:2006 for rubbing, perspiration, light, and wash fastness respectively.

## 3. RESULTS AND DISCUSSION

### 3.1. Response Surface Methodology

The bacterial count values of silk fabric samples dyed with *Galinsoga Parviflora* extracts at different dyeing conditions are illustrated in Table 2. An increase in extract concentration and dyeing temperature results in a decrease in bacterial count. However, the reduction in bacterial count majorly depended on the bacterial strains used and the concentration applied. This may have been attributed to the differences in the bacterial structures [3].

***Table 2.*** *Bacterial counts at varying dyeing parameters*

| No.of Runs | Conc. Of Extract (%) | Temp. ($^O$C) | Bacterial Count (CFU/ml) Silk fabric | |
|---|---|---|---|---|
| | | | Staphylococcus aureus | Pseudomonas Aeruginosa |
| 1 | 25 | 70 | $5.20 \times 10^4$ | $9.60 \times 10^4$ |
| 2 | 25 | 70 | $5.36 \times 10^4$ | $9.20 \times 10^4$ |
| 3 | 15 | 60 | $9.52 \times 10^4$ | $2.35 \times 10^5$ |
| 4 | 35 | 80 | $9.60 \times 10^3$ | $3.68 \times 10^4$ |
| 5 | 10.86 | 70 | $1.81 \times 10^5$ | $3.12 \times 10^5$ |
| 6 | 39.14 | 70 | 00 | $4.80 \times 10^3$ |
| 7 | 25 | 84.14 | $4.16 \times 10^4$ | $8.16 \times 10^4$ |

| | | | | |
|---|---|---|---|---|
| 8 | 25 | 70 | $4.96 \times 10^4$ | $9.76 \times 10^4$ |
| 9 | 25 | 55.86 | $6.24 \times 10^4$ | $1.00 \times 10^5$ |
| 10 | 25 | 70 | $5.12 \times 10^4$ | $9.36 \times 10^4$ |
| 11 | 25 | 70 | $5.04 \times 10^4$ | $9.68 \times 10^4$ |
| 12 | 15 | 80 | $8.24 \times 10^4$ | $2.08 \times 10^5$ |
| 13 | 35 | 60 | $1.12 \times 10^4$ | $6.24 \times 10^4$ |

### 3.2 Analysis of Variance (ANOVA)

The ANOVA results for bacterial count values of treated silk against *Staphylococcus aureus* and *Pseudomonas Aeruginosa* are illustrated in Table 3. It can be seen that both models (‘$Y_{ss}$’ & ‘$Y_{sp}$’) are significant having p-values = 0.001and 0.000. Also, the effect of extract concentration on bacterial count is statistically significant with a p-value of 0.000 on both models. Therefore, it can be deduced that a change in extract concentration has a significant effect on dyeing silk fabrics for bacterial resistance whereas, the dyeing temperature did not significantly affect the bacterial count of the dyed fabrics.

***Table 3.*** *ANOVA for the bacterial count at different dyeing variables on silk*

| | | *Staphylococcus aureus* | | *Pseudomonas Aeruginosa* | |
|---|---|---|---|---|---|
| Source | DF | F-Value | P-Value | F-Value | P-Value |
| Model | 5 | 14.85 | 0.001 | 87.40 | 0.000 |
| A | 1 | 67.88 | 0.000 | 390.23 | 0.000 |
| B | 1 | 0.77 | 0.410 | 3.91 | 0.088 |
| $A^2$ | 1 | 4.43 | 0.073 | 42.32 | 0.000 |
| $B^2$ | 1 | 0.57 | 0.474 | 0.01 | 0.913 |
| A*B | 1 | 0.10 | 0.761 | 0.00 | 0.978 |
| Error | 7 | | | | |
| Lack-of-Fit | 3 | | | | |
| Pure Error | 4 | | | | |
| Total | 12 | | | | |

The second-order regression equations (1 & 2) were generated to model the relationship between bacterial count (Response ‘$Y_{ss}$’ & ‘$Y_{sp}$’) and dyeing variables of extract concentration (A) and Temperature (B) for silk fabric samples. The $R^2$ and adjusted $R^2$ were 91.39% and 85.23% respectively for the $Y_{ss}$ model and then for the $Y_{sp}$ model, $R^2$ and adjusted $R^2$ were 98.42% and 97.30% respectively. This implies that 91.39% and 98.42% variations in the data sets can be explained by the models. For the unseen data sets, the adjusted $R^2$ for each model is 85.23% and 97.30% respectively. The interaction effects of the dyeing variables are represented on the three-dimensional graphs, response surface plots in Fig. 1.

$$Y_{ss} = 106932 - 14176\,A + 5864\,B + 141.2\,A^2 - 50.8\,B^2 + 28.0\,AB \quad \textbf{(1)}$$

$$Y_{sp} = 654883 - 27081\,A - 1865\,B + 344.0\,A^2 + 6.0\,B^2 + 2.0\,AB \quad \textbf{(2)}$$

Whereby;
$Y_{ss}$ & $Y_{sp}$ are bacterial count of dyed silk fabric against *Staphyloccocus aureus* and *Pseudomonas Aeruginosa* bacterial strains

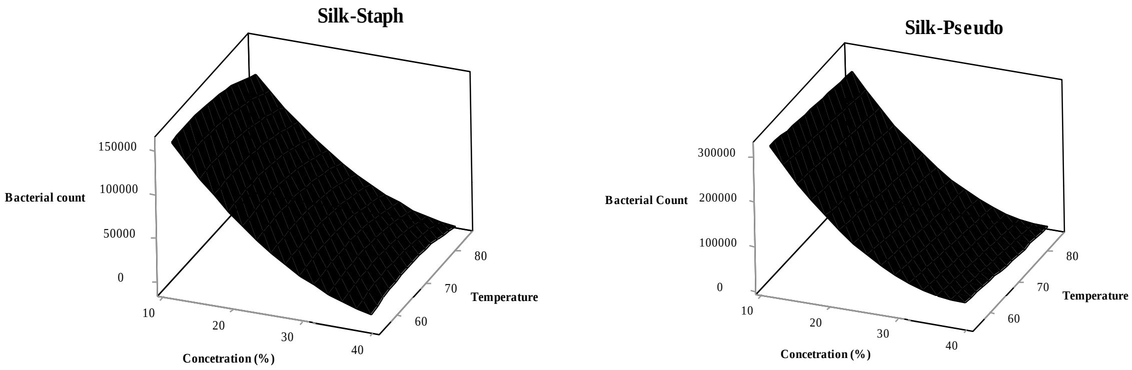


***Fig.1***. *Effect of extract Concentration and dyeing temperature on Bacterial count for dyed silk.*

As can be seen in Fig. 1, extract concentration demonstrated a vivid influence on bacterial count as opposed to dyeing temperature. The optimized values were found to be at 39.14% and $70^0$C. Also, it was noted that at lower extract concentrations and temperatures, there was a slight decrease in bacterial count. This could have been due to the low concentration gradient of the extract and the inability of the fibres in the structure of the fabrics to swell [8]. Then at very high concentrations and temperatures, the bacterial count values increase still due to dyed fabric saturation and decrease in dye molecule stability [13].

### 3.3 Assessment of Antibacterial resistance and fastness properties of dyed fabrics

***Table 4.*** *Antibacterial efficacy of dyed silk fabric*

| Plant extract | Reduction in Bacterial Count (%) Silk fabric | |
|---|---|---|
| | *Staphylococcus aureus* | *Pseudomonas Aeruginosa* |
| *GP* | 99.33 | 99.15 |

***Table 5.*** *Fastness properties of dyed silk fabric*

| Plant extract | Light fastness | Wash fastness | | Rub fastness | |
|---|---|---|---|---|---|
| | | CC | CS | Dry | Wet |
| *GP* | 5 | 4-5 | 5 | 5 | 4-5 |

GP- Galinsoga Parviflora, CC-Colour Change, CS-Colour Staining, 4- Good and 5- Excellent.

From the results in Table 4, dyed silk fabric using optimized values demonstrated a bacterial count reduction percentage of 99.33 and 99.15 against *Staphylococcus aureus* and *Pseudomonas Aeruginosa* bacterial strains respectively. This high percentage reduction in bacterial count may have been attributed to the presence of more functional groups on silk fabric structure and therefore the ability of more of these medicinal extracted dyes to form covalent bonds with it [3]. It was further revealed that due to differences in chemical compositions of their cell walls, the percentage reduction was much higher in the case of *Staphylococcus* compared to *Pseudomonas* bacterial strain. Then the results of colourfastness properties presented in Table 5 ranged from very good to excellent thus confirming the presence of good covalent binding linkages between the dye and the fibres in the silk fabric structure [14].

## 4. CONCLUSIONS

To achieve the dyed fabric quality for antibacterial applications, optimization of dyeing conditions is vital. The study revealed that dyeing parameters have a significant effect on the antibacterial properties of dyed silk fabrics. Optimized dyeing conditions were; extract concentration 39.14% and dyeing temperature 70$^0$C. The dyed silk fabrics with the optimized condition showed high bacterial count reduction against both bacterial strains (99.33% and 99.15%) and overall very good to excellent fastness properties (4-5 to 5) thus confirming that *Galinsoga Parviflora* plant extract can be a potential source of eco-friendly natural dye with remarkable antibacterial potency.

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