



# Ecoprint Motif Analysis Using Young Teak Leaves with Tungjung Fixation Applied to Artificial Fibers

Farihah<sup>1\*</sup>, Winda Hastuti<sup>1</sup>, Halimul Bahri<sup>1</sup>, Yudhistira Anggraini<sup>1</sup>

<sup>1</sup>fashion design study program, Universitas Negeri Medan, Medan, Indonesia

Received: February 03, 2026

Revised: April 14, 2026

Accepted: May 25, 2026

Published: May 31, 2026

Corresponding Author:

Farihah

[dist.tira@gmail.com](mailto:dist.tira@gmail.com)

DOI: [10.29303/jppipa.v12i5.14506](https://doi.org/10.29303/jppipa.v12i5.14506)

 Open Access

© 2026 The Authors. This article is distributed under a (CC-BY License)



**Abstract:** This study aims to analyze the effect of tunjung (ferrous sulfate) fixation duration on the color quality and motif clarity of ecoprinted fabrics made from young teak (*Tectona grandis*) leaves applied to artificial fibers. The research supports the development of eco-friendly natural dye applications and innovation in textile and fashion education. A descriptive quantitative method was used, employing trend and percentage analyses based on evaluations from three textile experts. The assessment covered five aspects: color brightness, motif clarity, motif arrangement neatness, cleanliness, and overall appearance. The results showed that fixation durations of 10, 30, and 60 minutes did not significantly influence color brightness or motif quality, indicating that the dye-fiber bonding equilibrium was achieved within 10 minutes. However, qualitative observations revealed that samples fixed for 30 minutes exhibited slightly clearer motifs due to mild oxidation and pigment redistribution during steaming and drying. These findings suggest that a 10-minute fixation duration is sufficient for efficient dye bonding, while a 30-minute duration may enhance visual definition. The study contributes to sustainable textile innovation by demonstrating that teak leaf pigments combined with tunjung mordant can produce eco-friendly, visually appealing fabrics suitable for fashion and textile learning.

**Keywords:** Artificial Fibers; Ecoprint; Textile motif; Tunjung Fixation; Young teak leaves

## Introduction

Indonesia possesses abundant biodiversity resources that can support the development of sustainable textile innovations through the utilization of natural dyes. One plant with strong potential for eco-friendly textile coloration is young teak leaf (*Tectona grandis*), which contains tannin and anthocyanin pigments capable of producing distinctive dark natural tones on fabric surfaces (Fazruza et al., 2018; Puspaningtyas & Ratyaningrum, 2022; Qomariah et al., 2022). The increasing environmental concerns associated with synthetic dyes, including water pollution and toxic chemical residues, have encouraged the textile industry to adopt more sustainable dyeing alternatives (Alegbe et al., 2024). Natural dyes are biodegradable, renewable, and environmentally safer, making them increasingly

relevant to the implementation of sustainable textile production aligned with Sustainable Development Goal (SDG) 12 concerning responsible consumption and production (Dey, 2024; Leha & Khayati, 2022).

One environmentally friendly textile coloration technique currently attracting attention is ecoprinting. Ecoprint is a natural dyeing method that transfers the shape, color, and texture of plant materials directly onto fabric surfaces through steaming and pressure processes (Maharani, 2018; Santosa & Hidayati, 2020). Unlike conventional dyeing, ecoprinting produces unique motifs while minimizing the use of hazardous chemicals and synthetic colorants. Previous studies reported that teak leaves can generate stable natural coloration due to their tannin and anthocyanin contents, particularly when combined with metallic mordants such as ferrous sulfate ( $\text{FeSO}_4$ ) or tunjung (Kurniawidi, 2023; Setiawan

## How to Cite:

Farihah, Hastuti, W., Bahri, H., & Anggraini, Y. (2026). Ecoprint Motif Analysis Using Young Teak Leaves with Tungjung Fixation Applied to Artificial Fibers. *Jurnal Penelitian Pendidikan IPA*, 12(5), 74–80. <https://doi.org/10.29303/jppipa.v12i5.14506>

et al., 2022). In textile dyeing, ferrous sulfate functions not only as a fixative agent but also as a color modifier capable of producing darker and more contrasted tones through metal-pigment complex formation (Burkinshaw & Kumar, 2009).

Several studies have investigated ecoprint applications on natural fibers such as cotton, silk, and linen because these fibers contain hydroxyl groups that facilitate interactions with natural pigments (Cristea & Vilarem, 2006; Widiawati et al., 2009). However, limited studies have explored the application of teak leaf ecoprint on rayon-based artificial fabrics and the influence of fixation duration using ferrous sulfate. Rayon-based fabrics possess semi-cellulosic characteristics that differ from natural fibers in terms of dye absorption and mordant interaction, potentially affecting motif clarity and color stability during ecoprint processing. Furthermore, although tunjung fixation is widely applied in natural dyeing, the effectiveness of different fixation durations has not been thoroughly examined in ecoprint production using teak leaves.

The fixation stage is an important process in ecoprinting because it influences the formation of mordant-pigment complexes on the fabric surface. Ferrous sulfate ions interact with tannin compounds to produce darker shades and improve color durability (Rahmawati & Mulyadi, 2021). Nevertheless, prolonged fixation duration may not always enhance visual quality because mordant reactions can reach saturation within a relatively short period. Excessive fixation may also increase oxidation effects that influence surface appearance and color uniformity. Therefore, optimizing fixation duration is necessary to achieve efficient, environmentally responsible, and visually acceptable ecoprint results.

Based on these considerations, this study aims to analyze the effect of tunjung fixation duration (10, 30, and 60 minutes) on the visual quality of ecoprint fabrics produced from young teak leaves applied to rayon-based artificial fabrics (Karabulut, 2020; Klančnik et al., 2024). The novelty of this research lies in the investigation of fixation duration optimization on rayon-based ecoprint fabrics using teak leaf pigments within the context of sustainable textile innovation. This study is expected to contribute to the development of eco-friendly textile dyeing techniques and sustainable fashion practices.

## Method

### *Research Design*

This study employed a quantitative experimental design to analyze the effect of tunjung (ferrous sulfate) fixation duration on the visual quality of ecoprint fabrics

using young teak leaves (*Tectona grandis*). According to Creswell (2015), an experimental design is appropriate for examining the influence of controlled treatment variables on observed outcomes. The independent variable in this study was fixation duration consisting of 10, 30, and 60 minutes, while the dependent variables included color brightness, motif clarity, motif arrangement neatness, cleanliness, and overall appearance of the ecoprint results. The experiment was conducted under controlled laboratory conditions to maintain consistency in steaming temperature, fixation concentration, and drying conditions.

### *Materials and Tools*

The material used in this study was rayon-based artificial fabric with a smooth surface suitable for ecoprint application. Rayon-based fabrics were selected because their semi-cellulosic properties allow better interaction with natural pigments compared to fully synthetic fibers (Widiawati et al., 2009). Young teak leaves (*Tectona grandis*) were used as the natural pigment source due to their tannin and anthocyanin contents, which are commonly utilized in natural dyeing processes (Fauzi et al., 2023; Fazruza et al., 2018). Ferrous sulfate ( $\text{FeSO}_4$ ), locally known as tunjung, was used as the mordant and color modifier during fixation because iron ions can form stable complexes with plant pigments and produce darker color tones (Burkinshaw & Kumar, 2009). Neutral detergent and clean water were used during the fabric preparation and rinsing processes.

The equipment used in this study included a fabric steamer, measuring cups, digital scale, pH meter, iron rod, rubber ties, brush, digital camera, and drying rack. The pH meter was used to measure the acidity level of the fixation solution because pH conditions influence the stability of anthocyanin-based natural dyes (Gecchele et al., 2021; Larasati & Murwanti, 2023).

### *Procedure*

The research procedure consisted of four stages: fabric preparation, pigment transfer process, fixation, and documentation. In the first stage, the rayon-based fabric was washed using a neutral detergent solution to remove impurities and residual finishing chemicals that could interfere with pigment absorption during ecoprinting (Indrayani et al., 2020). The fabric was then rinsed thoroughly and air-dried at room temperature.

In the second stage, young teak leaves were arranged directly on the fabric surface according to the desired motif composition. The fabric was subsequently rolled around an iron rod, tightly bound using rubber ties, and steamed for 90 minutes to facilitate pigment transfer from the leaves onto the fabric surface. After steaming, the fabric rolls were allowed to cool naturally

before being opened. This steaming method follows the ecoprint procedure described by Pandansari et al. (2022), in which heat and pressure assist the transfer of natural pigments and leaf patterns onto textile materials.

In the third stage, the fixation process was carried out using a ferrous sulfate (FeSO<sub>4</sub>) solution with a concentration of 5 g/L. The ecoprinted fabrics were immersed in the fixation solution for 10, 30, and 60 minutes to evaluate the effect of fixation duration on the visual characteristics of the ecoprint motifs. Ferrous sulfate was applied because metallic mordants are known to improve color durability and modify color intensity in natural dyeing systems (Rahmawati & Mulyadi, 2021). After fixation, the fabrics were rinsed using clean water and air-dried for 24 hours at room temperature.

In the final stage, all ecoprint samples were documented using digital photography for visual analysis and comparison among treatments.

*Data Analysis*

The visual quality of the ecoprint fabrics was evaluated using an organoleptic assessment conducted by three textile experts. The assessment aspects included color brightness, motif clarity, motif arrangement neatness, cleanliness, and overall appearance. Each aspect was rated using a four-point scale ranging from 1 (poor) to 4 (excellent).

The collected data were analyzed using descriptive statistical techniques including mean score, percentage, and standard deviation to identify trends in visual quality across different fixation durations. Descriptive analysis is appropriate for systematically describing observed phenomena in small-scale experimental studies without inferential statistical testing (Sugiyono, 2019). The mean (M) was calculated using the Formula 1.

$$M = \frac{\sum X}{N} \tag{1}$$

Where:

M = Mean score

$\sum X$  = Total Score obtained

N = Number of sample

The standard deviation (SD) was calculated as Formula 2.

$$SD = \sqrt{\frac{\sum(X-M)^2}{N}} \tag{2}$$

Where:

SD = Standard deviation

X = Individual score

M = Mean score

N = Number of samples

The percentage score was calculated using the Formula 3.

$$P = \frac{f}{N} \times 100\% \tag{3}$$

Where:

P = Percentage

f = Frequency and Percentage

N = Total number of observations

The analysis results were interpreted descriptively to determine the most efficient fixation duration for sustainable ecoprint production on rayon-based fabrics.

**Result and Discussion**

*Result*

This study investigated the effect of fixation duration using tunjung (ferrous sulfate) on the color characteristics and motif quality of ecoprint produced from young teak leaves (*Tectona grandis*) applied to synthetic fabric. Three fixation durations – 10, 30, and 60 minutes – were applied to evaluate differences in color brightness, motif clarity, cleanliness, and overall visual appearance.

The results indicated that there was a slight variation in ecoprint quality across different fixation durations. Although all treatments produced generally acceptable ecoprint outcomes, differences in visual characteristics were observed in terms of brightness, motif definition, and surface uniformity.

The 10-minute fixation treatment tended to produce relatively brighter color tones. The 30-minute treatment resulted in the most balanced appearance, showing clearer leaf motifs and more stable coloration. Meanwhile, the 60-minute treatment produced darker tones with minor surface irregularities such as faint dark spots in some samples, which may be associated with extended exposure to iron ions and oxidation processes. Overall, the differences among treatments were not drastic, but a clear trend in visual quality changes was observed depending on fixation duration.



Figure 1. Preparation of teak leaves for eco-printing

To provide a comprehensive overview of the process, the following figures illustrate the stages of ecoprint production from raw material preparation to final results.



Figure 2. Fixation and steaming process using tunjung



Figure 3. final ecoprint results from 10, 30 and 60 minutes of fixation

Table 1 shows the distribution of color brightness scores for the 10-minute fixation treatment. The results indicate that most samples fall within the moderate category, with a tendency toward brighter tones compared to longer fixation times.

Table 1. Color brightness distribution (10 minutes)

Score	Frequency	Percentage %
4 (Very appropriate)	3	30
3 (Appropriate)	4	40
2 (Less appropriate)	3	30
1 (Inappropriate)	0	0

Table 2 presents the results for the 30-minute fixation treatment. The data show a relatively balanced distribution, indicating stable coloration with slightly reduced brightness compared to the 10-minute treatment.

Table 2. Color brightness distribution (30 minutes)

Score	Frequency	Percentage %
4 (Very appropriate)	3	30
3 (Appropriate)	3	30
2 (Less appropriate)	3	30
1 (Inappropriate)	1	10

Table 3 shows the results of the 60-minute fixation treatment. The data indicate that most samples are in the “appropriate” category, although some samples show lower scores due to minor surface irregularities.

Table 3. Color brightness distribution (60 minutes)

Score	Frequency	Percentage %
4 (Very appropriate)	1	100
3 (Appropriate)	6	60
2 (Less appropriate)	2	20
1 (Inappropriate)	1	10

Across all treatments, ecoprint quality shows a gradual change pattern rather than a drastic difference. The 10-minute treatment tends to produce brighter results, while longer fixation durations lead to darker tones and slightly improved motif stabilization, particularly at 30 minutes. However, excessive fixation time (60 minutes) may introduce minor surface irregularities due to prolonged exposure to iron ions and oxidation effects.

Discussion

The variation in ecoprint coloration across different fixation durations is closely related to the interaction between natural pigments in young teak leaves and ferrous ions (Fe<sup>2+</sup>) from tunjung. Tannins and anthocyanins present in plant leaves are known to form coordination complexes with metal ions, producing stable pigment compounds that influence final color expression (Arora et al., 2017; Jabar et al., 2023).

In this study, the observed reddish-brown to purplish tones indicate partial complexation between plant pigments and iron ions. However, the expected dark iron-tannin complex (typically black or dark gray) was not fully dominant. This phenomenon may be associated with limited concentration of ferrous sulfate and insufficient oxidation time during the fixation and drying stages.

According to natural dye chemistry principles, Fe<sup>2+</sup> ions can oxidize into Fe<sup>3+</sup> under exposure to air, leading to darker and more stable color formations

(Indraningsih, 2014). Variations in fixation duration may influence the rate of diffusion and oxidation processes, which in turn affect motif sharpness and surface uniformity.

The results also show that a moderate fixation duration (30 minutes) provides the most balanced outcome in terms of color clarity and motif definition. Similar findings were reported by Baaka et al. (2023), who stated that optimal mordanting time plays a crucial role in stabilizing natural dye uptake and improving pattern clarity on textile substrates.

Meanwhile, the synthetic fabric used in this study limits dye absorption due to its relatively low polarity and lack of abundant hydroxyl groups. Unlike cellulose-based fibers, synthetic fibers show weaker affinity toward natural dyes, resulting in lower fixation efficiency and reduced color depth (Astuti et al., 2023; Mouro et al., 2023).

From an educational perspective, ecoprinting provides a meaningful context for integrating chemistry concepts such as redox reactions, metal-ligand complexation, and diffusion processes into project-based learning. This supports the development of environmental awareness and sustainable creativity in vocational education settings (Ahire et al., 2024).

## Conclusion

This study found that fixation duration using tunjung (ferrous sulfate) at 10, 30, and 60 minutes had no significant effect on the color brightness and motif quality of ecoprint produced from young teak leaves on synthetic silk fabric. Only slight variations were observed among treatments. All treatments produced relatively similar color outcomes, indicating limited variation in dye fixation under the same material and mordant conditions. The expected strong darkening effect of iron mordant was not fully observed, which may be related to the low dye affinity of synthetic fibers and partial pigment-metal complex formation. Although the 30-minute fixation showed the most balanced visual appearance, this difference is not strong enough to be considered statistically or practically significant. Therefore, from an efficiency perspective, shorter fixation time may also be used depending on production needs.

## Acknowledgments

The authors would like to thank the Fashion Design Education Study Program, Faculty of Engineering, Medan State University, for providing support and facilities for this research. They also thank LKP Mei Goom for providing the venue and assistance with the ecoprinting process. They also thank the supervisors and expert textile observers who

provided valuable guidance, input, and assessments throughout the research process.

## Author Contributions

All authors contributed equally to this research. Fariyah was responsible for the research design and manuscript preparation. Winda Hastuti and Halimul Bahri contributed to data collection, analysis, and interpretation. Yudhistira Anggraini assisted in reviewing, editing, and validating the manuscript. All authors have read and approved the final version of the manuscript.

## Funding

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

## Conflicts of Interest

The authors declare no conflict of interest. All authors have read and agreed to the published version of the manuscript.

## References

- Ahire, B. B., Kasabe, S. M., Mali, A. B., & Jadhav, R. B. (2024). Development of a sustainable dyeing process for cotton fabric utilizing natural dyes from *Punica granatum* L. and *Curcuma longa*. *Current World Environment*, 19(1), 123–134. <https://doi.org/10.12944/CWE.19.1.12>
- Alegbe, E. O., Akinlabi, S. A., & Madushele, N. (2024). A review of history, properties, classification, and applications of natural and synthetic dyes. *Heliyon*, 10(2), 33646. <https://doi.org/10.1016/j.heliyon.2024.e33646>
- Arora, J., Agarwal, P., & Gupta, G. (2017). Rainbow of natural dyes on textiles using plant extracts: Sustainable and eco-friendly processes. *Green and Sustainable Chemistry*, 7(1), 35–47. <https://doi.org/10.4236/gsc.2017.71003>
- Astuti, D., Purwanto, A., & Sari, R. (2023). Analysis of heavy metals concentration in textile wastewater in batik industry center. *Jurnal Penelitian Pendidikan IPA (JPPIPA)*, 9(3), 1176–1181. <https://doi.org/10.29303/jppipa.v9i3.3085>
- Baaka, N., Khiari, R., & Haji, A. (2023). Eco-friendly dyeing of textile materials with natural colourants from date palm fibre fibrillium. *Sustainability*, 15(2), 1688. <https://doi.org/10.3390/su15021688>
- Burkinshaw, S. M., & Kumar, N. (2009). The mordant dyeing of wool using tannic acid and FeSO<sub>4</sub>, Part 1: Initial findings. *Dyes and Pigments*, 80(1), 53–60. <https://doi.org/10.1016/j.dyepig.2008.05.008>
- Creswell, J. W. (2015). *Penelitian Kualitatif & Desain Riset*. Pustaka Pelajar.
- Cristea, D., & Vilarem, G. (2006). Improving light fastness of natural dyes on cotton yarn. *Dyes and Pigments*, 70(3), 238–245.

- <https://doi.org/10.1016/j.dyepig.2005.03.006>
- Dey, P. (2024). Sustainable and eco-friendly natural dyes: A holistic review. *Textile Research Journal*, 94(3), 1–14. <https://doi.org/10.1177/00405175231214783>
- Fauzi, S., Haryono, M. B., Hanapia, C., & Nurhasanah, S. (2023). Pengabdian kepada Masyarakat: Sosialisasi Teknik Ecoprint dengan Pemanfaatan Limbah Organik di Sekolah Dasar Desa Nyalindung, Kecamatan Nyalindung. *Celebes Journal of Community Services*, 2(1), 64–70. <https://doi.org/10.37531/celeb.v2i1.3013>
- Fazruza, M., Mukhlis, N., & Novita, R. (2018). Eksplorasi daun jati sebagai zat pewarna alami pada kain katun dengan teknik ecoprint. *Jurnal Ilmiah PKK*, 3(3), 45–52. Retrieved from <https://www.scribd.com/document/519168750/2-Eksplorasi-Daun-Jati-Copy>
- Gecchele, E., Negri, S., Cauzzi, A., Cuccurullo, A., Commisso, M., Patrucco, A., Anceschi, A., Zaffani, G., & Avesani, L. (2021). Optimization of a sustainable protocol for the extraction of anthocyanins as textile dyes from plant materials. *Molecules*, 26(22), 6775. <https://doi.org/10.3390/molecules26226775>
- Indraningsih, A. W. (2014). Natural dyes from plants extract and its applications in Indonesian textile small medium scale enterprise. *Eksplorium*, 11(1), 45–52. <https://doi.org/10.31315/e.v11i1.327>
- Indrayani, L., Triwiswara, M., Andriyati, W., & Nuraini, E. (2020). Peningkatan kualitas batik eco-fashion dengan pewarna alami jalawe menggunakan iradiasi berkas elektron. *Jurnal Aplikasi Isotop Dan Radiasi*, 16(2), 71–80. <https://doi.org/10.17146/jair.2020.16.2.5964>
- Jabar, A., Rahayu, S., & Ramasamy, M. (2023). Ethnobotanical study on plants used as natural dye by handwritten batik craftsmen in Cirebon, Indonesia. *Biosaintifika: Journal of Biology and Biology Education*, 16(2), 109–117. <https://doi.org/10.15294/biosaintifika.v16i2.10923>
- Karabulut, K. (2020). Dyeing of cotton knitted fabrics with extracts of 40 different dye plants without mordant usage. *Fibers and Polymers*, 21(10), 2308–2318. <https://doi.org/10.1007/s12221-020-9365-2>
- Klančnik, M., Šajn Gorjanc, D., & Simončič, B. (2024). Extraction of anthocyanin dye from staghorn sumac fruit for printing inks and textile applications. *Coatings*, 14(8), 1025. <https://doi.org/10.3390/coatings14081025>
- Kurniawidi, D. W. (2023). Characteristics of dyeing cotton thread using fine particle powder from teak leaves. *Jurnal Penelitian Pendidikan IPA (JPPIPA)*, 9(10), 3753. <https://doi.org/10.29303/jppipa.v9i10.3753>
- Larasati, A., & Murwanti, A. (2023). Teknik tritik dan sulam dengan zat pewarna alami pada tas denim. *Qualia: Jurnal Ilmiah Pendidikan*, 3(2), 44–51. <https://doi.org/10.21009/qualia.32.05>
- Leha, D. M., & Khayati, E. Z. (2022). Penggunaan Fiksator Alam Pada Ecoprint Daun Mindi (Melia Azedarach L.) Kain Satin Dan Sifon. *Prosiding Pendidikan Teknik Boga Busana*, 17(1). Retrieved from <https://jurnal.uny.ac.id/index.php/ptbb/article/view/59326>
- Maharani, A. (2018). *Motif dan pewarnaan tekstil di Home Industry Kaine Art Fabric "Ecoprint Natural Dye [Skripsi, Universitas Negeri Yogyakarta]*. Retrieved from <https://shorturl.asia/sWPUh>
- Mouro, C., Gomes, A. P., Costa, R. V., Moghtader, F., & Gouveia, I. C. (2023). The sustainable bioactive dyeing of textiles: A novel strategy using bacterial pigments, natural antibacterial ingredients and deep eutectic solvents. *Gels*, 9(10), 800. <https://doi.org/10.3390/gels9100800>
- Pandansari, P., Purwanti, R., & Alfianti, D. A. (2022). Analysis of steaming ecoprint techniques on various fabrics. *Formosa Journal of Social Sciences*, 1(4), 411–424. <https://doi.org/10.55927/fjss.v1i4.2049>
- Puspaningtyas, A. M., & Ratyningrum, F. (2022). Uji coba ecoprint daun pucuk merah dengan teknik pounding dan steam menggunakan fiksasi tawas dan tunjung. *Jurnal Seni Rupa*, 10(1. a), 41–49. Retrieved from <https://ejournal.unesa.ac.id/index.php/va/article/view/44380>
- Qomariah, U. K. N., Bashiroh, V. A., & Chusnah, M. (2022). Ekspresi Warna Ecoprint Daun Jati (Tectona Grandis) Pada Katun Primiissima Dengan Mordan Tawas, Tunjung Dan Kapur. *Agrosaintifika*, 5(1), 17–23. <https://doi.org/10.32764/agrosaintifika.v5i1.2972>
- Rahmawati, N., & Mulyadi, R. (2021). Natural dyeing process using metal mordants: Effects on color and fastness. *Materials Chemistry and Physics*, 276, 125461. <https://doi.org/10.1016/j.matchemphys.2021.125461>
- Santosa, W., & Hidayati, N. (2020). Development of eco-print techniques on textile design and its contribution to sustainable fashion education. *IOP Conference Series: Earth and Environmental Science*, 485, 12089. <https://doi.org/10.1088/1755-1315/485/1/012089>
- Setiawan, R., Pratama, I., & Dewi, N. (2022). Project-

based learning in eco-fashion design education. *Journal of Technical Education and Training*, 14(4), 129-139.

<https://doi.org/10.30880/jtet.2022.14.04.012>

Sugiyono. (2019). *Metode Penelitian Kuantitatif, Kualitatif dan R&D*. Bandung: PT Alfabeta.

Widiawati, D., Hidayati, N., & Setiawan, A. (2009). The revival of the usage of natural fibers and natural dyes in Indonesian textile. *ITB Journal of Visual Art and Design*, 3(2), 59-72. <https://doi.org/10.5614/itbj.vad.2009.3.2.2>