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Environmental Impact Analysis of Batik Natural Dyes Using Life Cycle Assessment

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Abstract. The use of natural dyes for batik dyeing is fewer than synthetic dyes because of its limitations in the application such complexity in manufacture and usage. For ease of use, natural dyes need to be processed into instant products. Extract of natural dyes are generally produced in liquid form that are less practical in long-term use. Dye powder obtained by drying the liquid extract using spray dryer. Production process of liquid natural dye is simpler and require less energy but need more energy for transporting. It is important to know which type of natural dyes should be produced based on their environmental impact. This research aim to compare environmental impact between liquid and powder natural dyes and also to find relative contribution of different stage in life cycle to total environmental impact. The appropriate method to analyze and compare the environmental impacts of powder and liquid natural dyes is Life Cycle Assessment (LCA). The "cradle to grave" approach used to assess environmental impact of powder and liquid natural dyes of Jalawe rind throughout production process of natural dyes, distribution and use of natural dyes for coloring batik. Results of this research show that powder natural dyes has lower environmental impacts than liquid natural dyes. It was found that distribution, mordanting and packaging of liquid dyes have big contribution to environmental impact.

INTRODUCTION

Using synthetic dye in process of coloring batik causes negative impact on environment as synthetic dyes are polluting agents that having carcinogenic properties and toxicity[1]. Natural dyes extracted from vegetative material and animal residues, claimed to be environmentally friendly, because it raises the lower level of emissions than synthetic dyes in the textile industry [2]. Additional benefit of natural dyes are antibacterial and deodorizing [3] and more than 60% of the coloring tests conducted acceptable in fastness properties [4]. Natural dyes suggested to be used for support sustainable batik production [5], [6].

Natural dyes for batik has long been used in this Indonesia. The dyes produced from wood, bark, rind, seeds, fruits, leaves, flowers, and roots of plants or trees from surrounding environment. Batik craftsmen's use various natural dyes extracted from the area around them, resulting in a unique color for each area. As an example, red color characteristics of batik Lasem derived from the root bark of the *Morinda citrifolia*. Blue color Tuban's batik is obtained from indigo plant. Yellowish brown to reddish brown are often found in Yogyakarta's and Surakarta's batik, derived from a mixture of jambal plants, steeper and tegeran [7]. Based on [8] the material chosen to produce a brown color is jalawe rind. Jalawe plant (*Terminalia bellirica*) is a lowland plant that has a height of up to 50 meters. Jalawe rind produce a tannin that can be used as textile dyes, leather and ink [9].

However, in practice the use of natural dyes for batik dyeing process is fewer than synthetic dyes. Limitations of natural dyes is that the process of dyeing with natural dyes are very long and time consuming. Besides that, the production capability gradation is also a major problem in dyeing with natural dyes as a traditional process [10].

Jalawe rind on the market are mostly available in the form of raw materials. Manufacture of natural dyes made of jalawe rind by batik craftsmen is still done traditionally, which is conducted by cut jalawe rind to a smaller size and then extracted using water media. Liquid natural dyes of jalawe rind less efficient in storage and less durable because it has a high water content. This problem make powder natural dyes be worthy to be developed [11]. Dye powder

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obtained by drying the liquid extract using spray dryer. The shelf life of powder natural dyes are expected to be longer than the liquid natural dyes because it has a lower moisture content [12]. In addition, powder natural dyes is more practical and easy to transport [13]. In other hand, production process of liquid natural dye is simpler and require less energy but need more energy for transporting. So It is important to know which type of natural dyes should be produced based on their environmental impact. This research aim to analyze and compare environmental impact between liquid and powder natural dyes and also to find relative contribution of different stage in life cycle to total environmental impact. Reference [5] measured the eco-costs and eco-efficiency rate of batik products, as well using LCA (Life Cycle Assessment) doped with SimaPro software. LCA is an approach that takes into account the product life cycle, from the extraction and collection of raw materials, production and manufacturing of energy and material, the use and handling end to disposal. Therefore, LCA method being used to analyze the environmental impact of liquid and powder natural dye products.

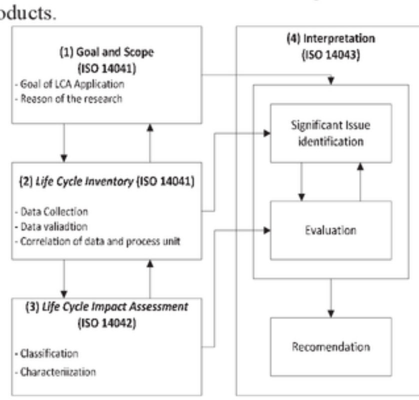

FIGURE 1. Stages of Life Cycle Assessment

RESEARCH METHODS

Stages of Life Cycle Assessment

Stages of LCA shown in Fig. 1. LCA analyze whether natural coloring products that have a large environmental impact of its product life cycle criteria [14]. Green product is a product that does not endanger the health of humans or animals, does not harm the environment throughout its life cycle, do not consume energy and resources that excess during manufacture, use and disposal and does not cause the waste of excess. So, green product not only in terms of the products but also life cycle of the product.

Eco Costs is a method used in Life Cycle Impact Assessment (LCIA) phase. The eco-costs method is used in LCIA to express the amount of environmental burden of a product or service, on the basis of prevention of that burden. Eco-costs are the costs which should be made to reduce the environmental pollution and material depletion in our economy to a level which in line with carrying capacity of our earth. As such, the eco-costs are virtual costs, since they are not yet integrated in the real life costs of current production chain (Life Cycle Costs) [15].

Scope of Life Cycle Assessment

The scope of LCA study is shown in Figure 2, from production of natural dye liquid or powder including packaging manufacturing, distribution, and use of natural dyes either liquid or powder for coloring batik. The production consist of extraction, evaporation, spray drying and packaging. Dyeing process comprising mordanting, coloring and fixation. Functional unit of the study was the number of natural dyes both liquid and powder used to do coloring 20 pieces of batik cloth with the size of 2,5 m x 1,05 m.

Limitations in this LCA study include: (1) Phase of cultivation, harvesting and transportation of Jalawe rind to production location are not included in the scope of the LCA. (2) Life cycle of machines and other facilities are not included in the calculation. (3) Production process consist of mordanting, dyeing surfactants, coloring and fixation.

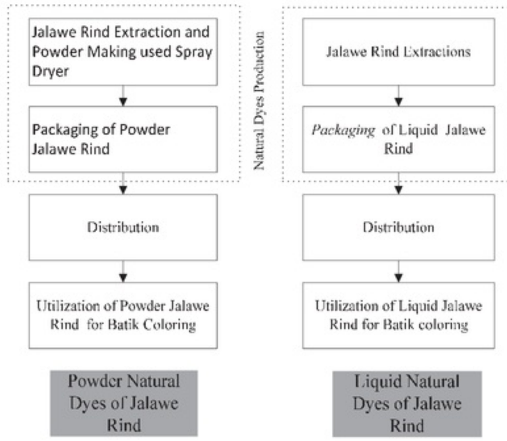

FIGURE 2. System limitations of Natural Dyes Products

LCA used l software v 7.1 Simapro, Ecoinvent database v 2.0 and impact assessment costs Eco 2012 v 3:03 method. The output of simapro results are types of environmental impact and the magnitude of the impacts from the life cycle of natural dyes jalawe rind powder and liquid, in the form of the cost of preventive often called by eco costs in the euro currency.

Life Cycle Inventory (LCI)

Life Cycle Inventory (LCI) is a stage in LCA and consists of activities related to the search, collection and interpretation of the data requirements for the measurement of environmental impacts observed in the system that is making natural dyes batik jalawe rind. Input data is in the form of material and energy used in a system consisting of raw material supplies, energy/ electrical energy, water and modes of transportation.

Sources of data in this study consisted of primary data and secondary data. The primary data obtained directly from SMEs Bixa Batik Natural Color either by collecting data on material, and energy that are needed in the production process of liquid and powder natural dyes. That were done by measuring and calculating the quantity of material and energy that being consumed. While secondary data obtained from scientific literature and v.20 ecoinvent database used as a source of background data contained in SimaPro 7.1 software.

The LCI of natural dyes consist of production, distribution and coloring batik.

1. *Production :* The production consist of extraction, evaporation, spray drying and packaging.

- *Extraction:* Extraction is done by inserting jalawe dried rind into boiling water, by comparison of jalawe rind and water each 1 kg: 5 liters. The mixture was then stirred, heated and boiled for 60 minutes, then was silenced for a moment before was filtered to separate the extraction and pulp. Since raw materials come from nature, then they do not cause emissions [16]. Water for extraction is obtained from groundwater that is pumped using a 250 Watt water pump with a capacity of 60 liters. The electrical energy required for pumping 5 liters of water per minute is 1250 Joule or equal to 0,347 Wh.
- *Evaporation:* The evaporation process is done to make the extraction become more concentrated. Jalawe rind extract was concentrated by evaporator to about 30-40% total solids before Spray Drying [17]. This is achieved by boiling the extract in a vacuum at a temperature below 720 C in a falling film on the inside of the vertical tube, and remove the water as vapor. Evaporator is used has a water evaporation capacity of 20 kg/hr, the heating surface area of 0.2 m2 with a power of 300 Watt. The time needed to evaporate 18,75 kg of water using the water evaporation that have capacity of 20 kg/h is 0,9375 hours. Thus, the energy needed by the evaporator is 281,25 Wh.
- *Spray drying :* Powder natural dyes manufacture by drying the extracted jalawe rind using spray dryer typed Anhydro A/S, Ostmarken 8, DK-2860. The energy required in the spray drying process includes the energy required for atomization, the energy required to circulate the hot air, and the energy needed to heat the air.

- *Packaging :* Powder natural dyes is packed per 100 grams by using HDPE plastic. Packaging 5 x 100 grams then packed with corrugated board which has dimensions of 18 cm x 18 cm x 5 cm with a weight of 100 grams. The packaging laminated with HDPE plastic. As for the packaging of liquid natural dyes using HDPE plastic bottles. HDPE plastic bottles used have dimensions of 20 cm x 9 cm x 6 cm with a weight of 90 grams. Using HDPE plastic bottle cap with a weight of 10 grams. Each bottle contains one liter of liquid natural dyes.

2. *Distribution :* Distance shipments of powder natural dyes factory in Rawa Kompeni, Benda, Banten to users in Jogjakarta is 555 km. The product carried by trucks. The same distance is assumed for the delivery of liquid natural dyes. Transport supplies ton.km calculated in units where 1 ton.km means transport one ton of material with a certain type of transport and associated with ecoinvent database developed for an average load of 3,5 to 7,5 ton truck for delivery from the factory to the user. Inventory transfers from the database ecoinvent process involves the operation of a vehicle; production, maintenance and disposal of vehicles, as well as the construction, maintenance, and disposal way.
3. Dyeing Process : Dyeing process comprising mordanting, coloring and fixation.

- *Mordanting:* Mordanting is process to make natural dyes easily attached to the fiber textile fabrics. Material used for mordanting on cotton fabric Primissima in SMEs Bixa Batik Natural Colour ie alum with alum composition of 100 grams and 15 liters of water to 500 grams of fabric. Alum put into water in a pan and then boiled at a temperature of 1000C. Wetted fabric put in a boiling water and stirring for 60 minutes. Fabric flame is turned off and left to soak for 24 hours. Once the fabric is rinsed and dried.
- *Decreasing Surface Tension Process* : This process is done by dipping mordanted fabric in detergents or surfactants like Turkey Red Oil (TRO). In this research, surfactant used is Palm Oil Sulfonate. This process is done before staining so natural dyes more easily absorb into the fabric. The composition between the surfactant and the water used is 1 gram to 1 liter of water.
- *Coloring* : coloring process is done by dipping fabric into dye solution jalawe rind. Dyeing is done three times or several times according to the brightness of the color desired. Functional unit used in the use phase is 10 pieces of batik fabric size of 2,5 m x 1,05 m with each sheet of fabric has a weight of 300 grams. For 10 pieces of batik cloth required rind powder and liquid jalawe each as much as 300 g and 12 liters. For coloring with rind powder jalawe added 4 liters of hot water per 100 grams of powder. To heat water that used to mix the powder dye using 0,3 kg of LPG to 12 liters of water.
- *Fixation* : Fixation is locking process color on cloth fiber compositions generally use alum with 70 grams of alum per 1 liter of water.

Life Cycle Impact Assessment (LCIA)

On Life Cycle Impact assessment (LCIA), types and amounts of environmental impact calculated using software Simapro Eco invent database v 7.1 and 2.0 as well as the impact assessment method Eco costs 2012 v 3.03. In the Eco costs method, LCIA calculation consists of several stages, among others, characterization, normalization and a single score from the resulting environmental impacts. Values and indicators generated from Eco costs in accordance with the standards of the World Business Council for Sustainable Development (WBCSD). The results of this indicator category is obtained by assigning the results of the Life Cycle Inventory for emissions to soil, water and air of the substances that are used to group representing environmental issues become a topic of concern so-called impact category. Normalization step in the Eco costs 2012 method is calculation in the preventive marginal cost of each impact category obtained by multiplying the result by a normalization factor indicator category which is the value of eco cost of each unit of emissions. For single stage score, based on the marginal cost of preventive obtained from normalization stage then summed from each category to a total eco-impact cost. Eco total cost is a measure for the amount of environmental burden of a product based on the prevention of the load. These costs must be incurred to reduce environmental pollution and decrease material reserves in the earth in accordance with the capacity of the Earth.

Life Cycle Interpretation

Life cycle interpretation is the last phase of the LCA process. Life cycle interpretation is systematic techniques to identify, measure, examine, and evaluate information from LCI and LCIA results.

RESULTS

LCA is calculated in a production lot where there are 10 pieces of batik cloth. The materials required such as cotton primisima with a size of 2,5 m x 1,05 m, equivalent to 0,3 kg. For 10 pieces of batik cloth dyeing, either powder or liquid natural dyes each requires 0,3 kg of powder and 15 liters of liquid colorant. Table 1 shows the inventory of natural dyes jalawe rind powder and liquid for 10 pieces of batik cloth.

TABLE 1. Life Cycle Inventory of Natural Dye Made From Jalawe Rind for 10 Pieces Batik Fabric

Process		**Quantity of Input**	
	Type of Input	***Powder***	***Liquid***
Extraction	Jalawe rind	3 kg	3 kg
Extraction	Water	15 liters	15 liters
Extraction	LPG	1,8 kg	1,8 kg
Extraction	Electrical energy	1,041 Wh	1,041 Wh
Evaporation	Electrical energy	168,75 Wh	-
Spray Drying	Electrical energy	2323,5 Wh	-
Packaging	HDPE	0,003 kg	1,2 kg
Packaging	Corrugated Board	0,06 kg	-
Distribution	Truck (vehicle)	0,1665 tkm	6,6 tkm
Mordanting	Alum	600 gram	600 gram
Mordanting	Water	90 liters	90 liters
Mordanting	LPG	3 kg	3 kg
Mordanting	Electrical energy	6,246 Wh	6,246 Wh
Decreasing Tension	Detergent	5 gram	5 gram
Decreasing Tension	Water	5 liters	5 liters
Decreasing Tension	Electrical energy	0,347 Wh	0,347 Wh
Dyeing	Water	12 liters	-
Dyeing	Natural dye	300 gram	12 liters
Dyeing	LPG	0,3 kg	-
Dyeing	Electrical energy	0,833 Wh	-
Fixation	Alum	350 gram	350 gram
Fixation	Water	5 liter	5 liter
Fixation	Electrical energy	0,347 Wh	0,347 Wh

TABLE 2. Comparation of Characterization Score of Powder and Liquid Jalawe Rind Natural Dye

Impact Category	**Characterization score**		
	Unit	***Powder***	***Liquid***
Climate Change	kg CO2 eq	5,807	13,039
Acidification	kg SO2 eq	0,035	0,062
Eutrophication	kg PO4 eq	0,003	0,008
Photochemical Oxidant Formation	kg C2H4 eq	0,001	0,002
Fine Dust	kg PM2.5 eq	0,002	0,004

Impact Category	Characterization score		
	Unit	*Powder*	*Liquid*
Human Toxicity, Cancer	CTUh	$3{,}56 \times 10^{-7}$	$6{,}00 \times 10^{-7}$
Eco toxicity	CTUe	4,607	7,745
Water Stress Indicator	Euro	0,046	0,062

TABLE 3. Eco Costs Life Cycle of Natural Dye made from Jalawe Rind

Impact Category	Eco Cost (Euro)	
	Powder	*Liquid*
Total	8,149	14,197
Climate Change	0,784	1,760
Acidification	0,288	0,510
Eutrophication	0,012	0,0309
Photochemical Oxidant Formation	0,012	0,0206
Fine Dust	0,065	0,136
Human Toxicity, Cancer	0,367	0,618
Eco Toxicity	6,587	11,076
Water Stress Indicator	0,035	0,047

The LCI results are assigned to the unit indicator category to get the category indicator for dye powder and liquid as shown in Table 2. The results of the LCIA phase in the form of a product's environmental impact costs (eco costs). Table 3 shows the value of eco costs of each life cycle of natural dyes made from jalawe rind powder and liquid.

DISCUSSION

Significant Problem Identification

Significant problem identification performed by the contribution analysis approach that aims to identify aspects that have contributed most to the results of impact indicators. Analysis of the contribution is used in order to determine the process or stage in the life cycle of natural dyes rind jalawe either powder or liquid that has dominant contributed. Analysis of the contribution made to the powder and liquid natural dyes jalawe rind based on the eco cost is generated for each unit process in the life cycle of natural dyes. Table 4 shows the contribution of environmental impact at this stage of the process / activity life cycle of powder and liquid natural dyes Jalawe rind.

TABLE 4. Comparation of Environmental Impact for each process in Life Cycle of Jalawe Rind (Powder and Liquid)

Process	Eco Cost (Euro)	
	Powder	*Liquid*
Extraction	0,948	0,948
Evaporation	0,088	-
Spray drying	1,210	-
Packaging	0,086	3,034
Distribution	0,118	4,673
Mordanting	4,070	4,070
Decreasing Tension	0,022	0,022
Dyeing	0,158	-
Fixation	1,451	1,451

Recommendation

Based on analysis of the contribution of environmental impact known that the main issues of concern to be improved is the distribution, mordanting and packaging of liquid natural dyes. The first priority is based on the problem of distribution and packaging of liquid natural dyes. Compared to dye powders, distribution and packaging of liquid natural dyes produced greater eco cost, it is mean greater environmental impact. This is due to the same functional unit for 10 pieces of fabric dyeing, coloring liquid used is much greater mass and volume. Alternative recommendation that can be done is by adding the evaporation process in the production of liquid natural dyes jalawe rind to make natural dyes deepened. So for staining 10 pieces of cloth, would require smaller mass and volume of liquid colorant. With a mass of liquid colorant per functional unit smaller can reduce material, energy and emissions associated with distribution and packaging of liquid natural dyes that will reduce the contribution of the impact on the environment.

The second priority is replacement of materials used in mordanting. Mordanting process generates large environmental impact similar to the natural dyes rind jalawe either powder or liquid. Mordanting process generates large environmental impact due to the use of materials of alum (aluminum sulphate). Improvement that can be done is using alum biomordant as a substitute for the mordanting process. Biomordant is a plant that can be used natural dyes bind to the fibers in the fabric. Biomordant can use one of them is pomegranates rind as it contains tannin. Reference [18] using pomegranate rind (Punica granatum Linn.) As a natural mordant in dyeing cotton fabrics. The advantage of using biomordant include a more secure and environmentally friendly.

CONCLUSION

Based on value of eco cost, it can be conclude that the powder natural dyes jalawe rind has smaller environment impact than the liquid natural dyes jalawe. Eco cost of powder natural dyes made of jalawe rind is € 14,197 while powder natural dye has eco costs value € 8,149 per 10 sheets batik cloth, while the value of eco cost incurred from the life cycle of liquid natural dyes is € 14,197 per 10 pieces of batik cloth.

Recommendation given to reduce the value of eco costs arising from natural dyes life cycle either powder or liquid carried by improvements to the most significant problem is the distribution of liquid dyes, mordanting and packaging of liquid dye. The first recommendation is done by adding the life cycle process of evaporation of liquid natural dye, while the second recommendation is substitution of alum with the skin of pomegranates as bio mordant.

Limitation of this research is (1) Phase of cultivation, harvesting and transportation of Jalawe rind to production location are not included in the scope of the LCA. (2) Life cycle of machines and other facilities are not included in the calculation. (3) Distance of shipments limited assumed by distance from the factory in Banten to Yogyakarta, it will be varies depends on location.

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REFERENCES

1. Nanthini, U. R., Athinarayanan, A., Singh, R. A. J. A., Dyeing Characteristics and Antimicrobial Efficacy Of A Natural Dye From The Flower Nyctanthesis arbortristis, Asian Journal of Science and Technology Vol. 4, Issue 09, 2013, pp. 227-230.
2. Narayanan, G. Badri, An Analysis of Long-run Environmental Impacts and Multi-criteria-based Prioritisation of the Natural Dyes in the Indian Textile Industry, Indira Gandhi Institute of Development Research Mumbai, India, 2003.

3. Rungruangkitkrai, N. & R. Mongkholrattanasit, Eco-Friendly of Textiles Dyeing and Printing with Natural Dyes, RMUTP International Conference: Textiles & Fashion 2012, Section III pp. 1-17.
4. Bechtold, T., A. Turcanu, E. Ganglberger , S. Geissler, Natural Dyes in Modern Textile Dyehouse - How to Combine Experience of Two Centuries to Meet the Demands of The Future?. Journal of Cleaner Production, Vol. 11, Issue 5, August 2003, pp. 499–509.
5. Sari, D. P., Hartini, S., Rinawati, D. I., Wicaksono, T. S., Pengukuran Tingkat Eko-Efisiensi Menggunakan Life Cycle Assessment untuk Menciptakan Sustainable Production di Industri Kecil Menengah Batik. *Jurnal Teknik Industri*, Vol. 14, No. 2, 2012, pp. 137-144.
6. Rinawati, D. I., Sari, D.P., Pramono, S. N. W., Muljadi, F., Lestari, S.P., Pengelolaan Produksi Menggunakan Pendekatan Lean and Green untuk Menuju Industri Batik yang Berkelanjutan. J@TI Jurnal Teknik Industri Undip Volume 8, 2013, No 1, pp. 43-50.
7. Widiawati, Dian. The Revival of the Usage of Natural Fibers and Natural Dyes in Indonesian Textile. ITB J. Vis. Art & Des., Vol. 3, No. 2, 2009, pp. 115-128.
8. Hartini, S., Nurmalasari S., Rinawati D. I., (2013). Model Pemilihan Bahan Pewarna Alam Coklat Batik Tulis Solo dengan Menggunakan Metode Analytical Hierarchy Process (AHP). Jurnal Teknik Industri Undip, Volume 9, No.2, Mei 2014, pp. 77-85.
9. Orwa C, A Mutua, Kindt R, Jamnadass R, S Anthony. Agroforestree Database: A Tree Reference and Selection Guide Version 4.0, 2009. Unpublished.
10. Saroj, Yadav., Rose Neelam., Singh Jeet Saroj and Khambra Krishna. Natural Dye Powder: An Easy Technique for Eco- Dyeing, Research Journal of Recent Sciences, Vol. 2 (ISC-2012). 2013, pp 308-311.
11. Anditasari, D., Potensi Daun Suji (*Pleomele angustifolia*) Sebagai Serbuk Pewarna Alami (Kajian Konsentrasi Dekstrin dan Putih Telur Terhadap Karakteristik Serbuk). Thesis. Unpublished.
12. Ngo et al., A Study of Soluble-Powdered Natural Dyes. Research Journal of Textile and Apparel ,Vol. 17 No. 1, 2013, pp 104 – 112.
13. Wibawanto, Produksi Serbuk Pewarna Alami Bit Merah (Beta Vulgaris L.) dengan Metode Oven Drying. Proceedings SNST 5th 2014 Faculty of Engineering, University of Wahid Hasyim Semarang, 2014, pp 38-43.
14. Siregar, Kiman, Perbandingan Penilaian Siklus Hidup (Life Cycle Assessment) Produksi Biodiesel Secara Katalis dari Crude Palm Oil dan Crude Jatropha Curcas Oil, Jurnal Teknologi Industri Pertanian, Vol. 23, No. 2, 2013, pp. 129-141.
15. McMillan, C. and S. Skerlos, An Introduction to Life Cycle Assessment with SimaPro, (2006), unpublished.
16. Mujumdar, Spray Drying of Foods, International Workshop on Drying of Food and Biomaterials, Bangkok, June 6-7, 2011.
17. Vogtländer, Joost G, LCA-Based Assessment Of Sustainability: The Eco-Costs/Value Ratio (EVR), Netherlands: VSSD Leeghwaterstraat 42, 2628 CA Delft, 2010.
18. Deshmukh, A. & M. Wath, Pomegranate Rind as A Natural Mordant in Dyeing of Cotton with Carissa Karandas Linn, Journal of Bionano Filter, Vol. 4, No. 2, July-December 2011, pp. 299-301.

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