RENEWABLE RESOURCES FOR TEXTILE DYEING – TECHNOLOGY, QUALITY AND ENVIRONMENTAL ASPECTS

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ABSTRACT

In the last several years an increased interest in environmental technologies can be observed. This is also true for coloration purposes. Therefore the application of natural dyes for textile dyeing became more attractive.
Specific aspects mainly focused on industrial scale application will be discussed. Beside the traditional dye plants alternative sources for dyestuff extraction, derived from food and timber industry, were identified [1]. The coloration properties of selected vegetable material were evaluated in respect to color shade, color strength, availability and obtainable fastness level. The results will be summarized [2].
The light stability of dye/substrate-combinations was identified as key issue for enlarged use. Investigation of light-induced degradation and the knowledge of kinetics is essentially for the development of improvement strategies. A method for investigation is presented.
Dyeing experiments in laboratory are the basis for industrial scale application. Standardization approaches for commercial dyestuff formulations and requirements on the coloration technology are highlighted. Questions of reproducibility and level-ness that are state of the art of synthetic dyes have to be reconsidered for the natural ones. Possible strategies and practical experiences from a series of scale-up experiments are summarized [3].
The application of renewable resources does not result in "greener" products consequently [4]. Defined limitations for emissions have to be respected, addition of chemicals has to be considered and balances for energy and water have to be calculated.
As a conclusion a concept of environmental friendly plant dye application is presented.

INTRODUCTION

The textile industry is one of the biggest consumers of high quality water, energy and chemicals [5]. In terms of competition it is necessary to minimize expenses while maximizing effectiveness. Therefore critical consideration of resources especially water and energy are essentially. Beside the ethical responsibility for our environment increasing costs of waste- and wastewater treatment due to strict governmental regulations become a reasonable factor in cost analysis. The synthesis of colorants usually starts form simple oil based precursors hence the production costs are related to the raw oil price and the amount is limited on the global oil stock.
Natural dyes had been used up to the 19th century. By discovering a synthetic approach to obtain colorants at the beginning of the last century the situation changed. Synthetic dyes were designed in respect to coloration properties and application purposes. Compared the natural dyes they were deeper in color strength, more brilliant in appearance, easier to handle, higher in fastness level and offered a huge color gamut [6,7]. After a couple of years synthetic dyes replaced most of the application of natural dyes. But some survived in niche production, handicraft or special application fields.
Nowadays an increasing interest in the application of natural dyes can be observed. Based on different aspects our work is focused on the pros and cons of natural dyeing at an industrial scale and discusses the challenges that have to be overcome.

METHODS

Plant material – sources and preparation

All plant material used in this work was obtained from local or regional sources. Dyer's Chamomile was supplied from Thüringer Landesanstalt für Landwirtschaft, Germany. Berberine chloride comes from Fluka Chemie, Buchs. The dried plant material obtained was used without further preparation. Onion peels were obtained from Mr. Prischink, Austria.

Extraction step

Plant materials were extracted in stainless steel beakers with deionized water at a liquor ratio of 1:20 (For 1 g of plant material 20 ml of water was added). The average extraction time was 60 minutes at boiling temperature (90 – 95°C). After extraction the solution was filtered and used for dyeing experiments.

Dyeing procedure

Dyeing experiments were performed in a beaker by exhaust method using a liquor ratio of 1: 20 (For 1 g of substrate 20– 22ml of extract was applied). The dyeing temperature was held at 90-95 °C for about 1 hour. To investigate effect of mordants, alum ($KAl(SO_4)_2 \cdot 2H_2O$, puriss. p. a. Fluka, Buchs, Switzerland) and iron mordants ($FeCl_2$, 33 % aq. solution, BASF AG, Ludwigshafen/Main, Germany; and $FeSO_4 \cdot 7H_2O$, technical grade > 96 % purity, Riedl-de-Haen, Seelze, Germany) were added after 10 min at 90 – 95 °C. Dyeings experiments were performed on bleached wool yarn (Schoeller Wolle, Hard, Austria), bleached cotton fabric (Getzner Textil AG, Bludenz, Austria), viscose and lyocell fabric (Lenzing AG, Lenzing, Austria), and polyamide knitwear (tights, Wolford AG, Bregenz, Austria).

Dyeing experiments with Berberine chloride were done on cotton (Getzner Textil AG, Bludenz, Austria), viscose, lyocell and rainbow fabric (Lenzing AG, Lenzing, Austria) on a laboratory dyeing machine (Mathis Labomat BFA-8) at a concentration ranging form 0.0025 – 1 g/l. The liquor ration was 1:40. Dyeing was done at 30 °C for 30 minutes. After dyeing 3 times rising with deionized water at room temperature.

Technical scale dyeing experiments:

Package dyeing of wool yarns (Schoeller Wolle, Hard, Austria) on cones with Dyer's Chamomile was performed. The plant material was packet into cotton bags for extraction at a liquor ratio of 1:23 at 90-95 °C. The extract was diluted with water to reach required volume of the apparatus (14 L). Exhaust dyeing on a package dyeing machine (Thies) with addition of alum mordant after 10 minutes (final concentration = 1.5 g/L) at a liquor ratio of 1:30 was performed. Dyestuff application was performed at 95 °C for 30 minutes. Dyed wool was rinsed three times and dried.

Dyeing 50 m of bleached cotton fabric (Terra Verde Produktions GmbH, Vorchdorf, Austria) with Dyer's Chamomile was performed on a package dyeing machine (Jet/Thies). The 11 kg of plant material were extracted in three portions of 3.5 – 4 kg at a liquor ratio of 1:10. The extracts were combined and filled with water to the final apparatus volume of 127 L. Exhaust dyeing was applied at 95 °C for 45 minutes. After the first 10 minutes, the dissolved alum solvent was added (final concentration in dyebath = 5 g/L). Prior removing the dyed cotton fabric it was rinsed tree times with soft water. A few minutes of tumble drying and final air drying was performed.

Dyeing of 5 m fabrics of linen (Leinenweberei Vieboeck, Helfenberg, Austria) and cotton (Terra Verde Produktions GmbH, Vorchdorf, Austria) was preformed on a laboratory jig (Tischmodell 350) using different plant extracts. The procedure of extraction and dyeing were equal to laboratory parameters mentioned above. One onion peel extract was used up to three times. Three times of rinsing and air drying were done.

Polyamide dyeing was done following the standard procedure of laboratory mentioned above. The industrial scale dyeing was executed in the plant of Wolford AG, Bregenz, Austria.

A paddle dyeing machine was adapted. The volume of the machine is 220 l.

For garmet dyeing an extract of onion peel was applied to fabrics of linen (Leinenweberei Vieboeck, Helfenberg, Austria) and cotton (Terra Verde Produktions GmbH, Vorchdorf, Austria) in a garment dyeing machine (Mathis Fully fashion, TWA 1395). The goods were sewed in knitted washing bags for dyeing procedure. Extraction was done at 90 – 95°C for 1 hour using a liquor ratio of 1 : 20. The liquor ratio for dyeing was 1:58. After 10 minutes the mordant solution was added to reach a mordant concentration of 1 g/l in the final dyebath. Fabrics were rinsed three times with cold water and air dried

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<u>Quality evaluation of the samples</u>

The color appearance of the dyeings was characterized by determination of CIELab-coordinates with a tristimulus colorimeter (Minolta Chroma-Meter CR210, sample diameter 10 mm). Sample colours are given in CIELab-values, L* corresponding to brightness (100 = white, 0 = black), a* to the red-green coordinate (positive sign = red, negative sign = green) and b* to the yellow-blue coordinate (positive sign = yellow, negative sign = blue). Color differences were calculated.

The dyed samples were exposed to artificial xenon arc light (Xenotest Alpha LM, Hanau, Germany) and related to the standard scale of blue wool dyeings (grades 1-8, 1 = poor, 8 = excellent) [20].

Wet fastness was measured according to DIN 54006 [20]. The prepared test specimen were immersed with water, squeezed and placed with a certain weight (5 kg) in a laboratory oven at 37 °C for four hours. After air drying change in color of the samples and bleeding to adjacent material were evaluated. The changes were related to standard grey scales (grades 1-5, 1 = poor, 5 = excellent).

RESULT AND DISCUSSION

This part will be divided in three main sections addressing the following question:

- Why environmental friendly dyeing?
- What do we need for dyeing?
- Are natural dyes more ecological if industrial application is considered?

Answering these questions structures the topic and finally leads to a concept of environmental friendly coloration technology.

Why environmental friendly dyeing?

The answers we could identify for this question could be divided in four different categories: ethic reasons, economical reasons, personal reasons, and innovation.

Categories / Reasons	Ethics	Economics	Personal reasons	Innovation
limited recourses	■	■		
increasing oil price		■		
change in mind of costumers	■		■	
change in mind of society	■	■		
governmental regulations		■		
waste/waste water treatment		■		
health aspects			■	■
medicinal benefit			■	■
specific costumer group		■		
luxury product		■		■
fashion		■	■	
new products				■
new sources of income		■		
better range of price		■		■
resources for future generations	■	■	■	

protect environment				

In Table 1 some reasons were highlighted and within this four groups. Some of the reasons may belong to more than one category.

Table 1: Categories and reasons for environmental friendly techniques.

The results in the table show that there is a huge diversity in discussing reasons. While in some countries there may not be increasing costs due to a change in governmental regulation for emissions other countries will put much pressure on the industry. Another example is the attitude of the population of a certain area and as well their financial situation.
Anyway in industrial countries a trend towards more environmental friendly technology can be identified and seems to increase.
Environmental friendly techniques in the field of textiles are of growing importance. Not only from an ethic view but also form an ecological point of view. Before evaluating strategies for the improved eco balance of textile goods the production process has to be analysed. One important step in production is the coloration of goods.

What do we need for dyeing?

This step is going to be analysed in detail due to later discussion of plant derived dyestuff. Starting form an undyed substrate (wool, cotton, synthetics, regenerated cellulosics, linen, etc.) in different states of processing (fibre, yarn, fabric, etc.) the mainly needed components are dyestuff, water, chemicals and energy. For the coloration procedure itself specific equipments/machinery is needed.
Dyestuff and chemicals:

<u>Dyestuff</u>

Starting from the first synthetic dyes, Mauvein 1856 [8] and Fuchsin 1858 [9], intensive research on synthetic dyestuff production occurred. A huge number of new colorants were found; some of them – related to their coloration properties – were introduced into the market and applied in industrial scale, mainly without careful evaluation of their ecological impact and health risks. Later consideration of these aspects due to new diseases, allergic reactions and irritations as well as hazardous influences for environment lead to strict regulations and prohibition of specific dyes [9]. Today intensive testing of new products has to be done before enlarged application is permitted.
Dyestuff is mainly produced from refinery precursors. There is no general synthesis due to the high number of different colorant types and application fields. Therefore analysing of the specific production features for synthetic is questionable. Selected examples will not reflect the reality and generalization is hardly possible. Furthermore there is a big range of variations in coloration technology. The amount of dyestuff in liquor and the concentration of chemicals spread from a few grams up to several kilograms per batch.
There are different dyestuff groups that exhibit various application properties. Depending on the affinity of the colorant molecule in respect to the fibre the required amount of dyestuff for a desired colour depth varies. The fixation degree of dyes can be calculated by quantification of the dyestuff concentration in the dye bath before and after dyeing. According to this a relative sequence of the fixation degree for different dyestuff groups is given below:

Reactive dyes < indigo ~ sulphur dyes < direct dyes < vat dyes [5].

Unfixed dyestuff is of interested twice: this percentage of dyestuff is not available for the coloration process and the dye is present in waste water and has to be removed to avoid coloured effluents. Both aspects lead to a key factor for cost analysis.

Water

The water input for textile dyeing is considerable high. Water is used directly for preparation of dye liquors, washing and rinsing or various pre/after treatments as well as indirectly for thermal needs (heating and cooling of solutions). Direct use normally requires fresh while for thermal purposes mainly waste water or recycled water can be utilized.

Generally, the dyeing of 1 kg textile requires 100 – 200 l of fresh water [5]. An increased number of washing/rinsing steps or after/pre-treatment processes leads to higher water consumption.

The final volume is related to the equipment used and technique applied. While continuous coloration techniques deal with rather small volumes (liquor ratio = 0.7 – 0.8) for batch wise techniques the demand of water increases up to 40 l per kilogram of textile (e.g. paddle dyeing machine).

Optimization of the process and coupling of processing steps is essential for the eco-balance of the procedure.

Energy

In our study we focus on the energy input during the coloration process. The energy consumptions in terms of colorant production are neglected.

Especially heating and cooling of the high volumes in batch wise dyeing technology needs energy.

Considering a dyeing process of polyester based on a liquor ratio of 1:15 in a jet dyeing machine the following energy consumption for heating/cooling steps can be estimated. The volume of the machine is 300 l water. Rinsing is done with cold water. The energy to keep the different baths at a certain temperature was neglected.

Process step	**Δ T [°C]**	**Energy input [MJ]**
Wetting at 60 °C	40	50.2
Dyeing at 130 °C	70	87.8
	Total energy consumption	**138.0**

Table 2: Energy input for polyester dyeing

According to Table 2 the energy consumption during coloration of 20 kg of dyed polyester is calculated to 138.0 MJ. In other words around 7 MJ per kilogram. Minimization of the energy consumption can be done by ether changing the technique, decreasing the volumes or coupling of streams for reusing energy in heat exchangers.

Auxiliaries

Depending on the substrate-colorant combination a considerable amount of auxiliaries are needed. Table 3 highlights some examples.

Dyeing technology	**Required chemicals / additives**	**Consequence**
Direct dyes	salt	Increase affinity to substrate
Metal-complex dyes	Metal salts	Complex formation
Reactive dyes	Alkali, salt,	Chemical reaction in alkaline solution, sal increased affinity
Vat / Sulfur dyes	Alkali, reducing agent, disper agent, peroxide	Reduction of dyestuff, reduced form is sol in solvent
Mordant dyes	mordant	fixation
Natural dyes	eventually mordant	Fixation, shift in color shade, increa fastness properties

Table 3: Auxiliaries requirements for different dye classes

In many cases the addition of auxiliaries is imperative. For others it lead to improvement in handling or exhaustion of dyestuff. For example: increasing affinity, increasing wetting ability, adjustment of dyeing condition. They can also be part of the final colorant.
The existence of auxiliaries has to be considered in terms of waste water treatment.

Are natural dyes more ecological and can they be used in industry?
The general comparison of natural dyeing and conventional dyeing techniques leads to one major difference in the dyestuff itself. While the application of vegetable dyes for coloration purposes may be seen as more environmental friendly strategy there are several limitations in terms of dyestuff groups, coloration properties (color shade, color strength, availability of raw material and obtainable fastness level), dyeing techniques and fixation. Besides the processing of the dyestuff from renewable resources the consumptions of energy and water are comparable and can be optimized in both cases.

Raw material
Sources for dyestuff extraction can be widely found in flora and fauna. Due to ethic reflections our research is exclusively addressed to plant derived dyes. Therefore we identified two main streams of raw material. On the one hand cultivated dye plants were investigated, on the other hand wastes or byproducts of industry were found to be suitable for dyestuff extraction. Possible industry branches are food and beverage producers, timber industry, but also merchants of vegetables [1,10,11,12,14]. To achieve a price structure that is comparable to synthetic colorants the the majority of color shades should be derived from industrial production. Only in case of enlarging the color gamut the more expensive agricultural plant material is added. Table 4 shows some examples and the specific cost structure of these raw materials. The processing of the raw material includes drying, chopping/milling, packaging and standardizing. The prices in the Table 4 are calculated on the basis of 100 kg. By increasing the amount up to 1 t the prices are lowering due to batchwise standardization [1].

Source	Example	Raw material	Processing
Agriculture	Weld Madder	2 € 5 €	1 € 2 €
By-products	Bark Onions	0.1-1 € ~ 0.1 €	1 € -
Waste	Pomace	1-2 €	1 €
Others	Nut shells Vegetable	6 € 1 €	- 2 €

Table 4: Cost structure of raw material from different sources. The prices are calculated on a basis of 100 kg for each dyestuff.

Extraction
From an ecological and economical point of view only aqueous extraction can be performed. Particularly the utilization of organic solvents can lead to increase the yield but may increase the price and needs critical consideration of waste and waste water aspects []. For dry plants an average amount of solvent pick-up of 1 l per kilogram plant material is formed. Considering a batch of 10 kg dyed fabric, 10 kg of plant material has to be extracted. Assuming that the liquor ratio of extraction is calculated to 1:20 10 l of solvent are kept in the plant waste.
The big volume of water that is required for dyestuff extraction from plant material forces the strategy of a coupled extraction/dyeing process. This shows two ecological/economical advantages: avoid of two fillings [2]. The hot solution is used immediately after extraction thus the energy consumption is minimized [13]. In ideal case a combination of the two steps can be preformed like shown in Figure 1. Extraction and dyeing temperature is 95 °C. The liquor ratio of both steps is 1:20. Three rinsing steps were performed.

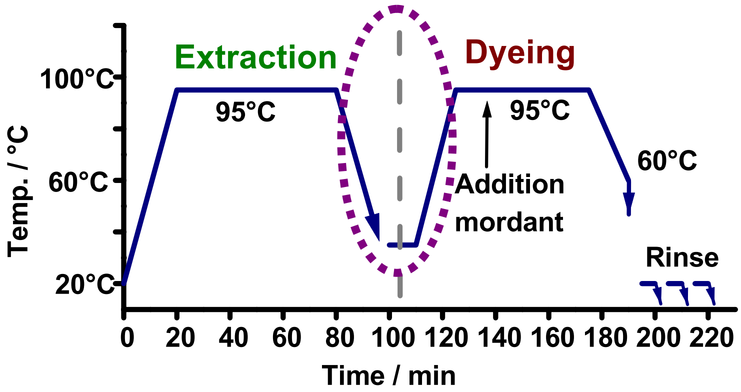

Figure 1: Temperature curve of dyeing and extraction. Purple ellipse highlights the option of combining the two steps.

Dyeing technique

Generally the dyeing technique of plant dyes is comparable to synthetic counterparts. From natural sources mainly direct dyes – eventually in combination with mordants – and Indigo can be found. Hence the coloration techniques are limited to exhaust dyeing and vat dyeing. Depending on the thermal stability of dyestuff dyeing temperatures lower than 100 °C are recommended. Especially anthocyane dyes show sensitivity to higher temperature [15].
The rather big volumes of extracts in case of plant dyeing favor batchwise dyeing techniques with lower liquor ratios. Suitable examples that already had been executed on laboratory scale experiments are jig and jet dyeing or cone dyeing on a package dyeing machine. The application of a concentrated solution in a foulard is not recommended for two reasons: firstly the extract has to be evaporated to obtain the concentrate. Secondly the affinity of natural colorants is limited thus the color uptake in a single step – even in high concentrated baths – is low. For example the exhaustion of berberine (CI Natural Yellow 18) for cotton and regenerated cellulose fibers is in the range of 30 – 55 %. That means that considerable amounts of dyestuff will be released into the waste water.

Wastes, effluents and emissions

In textile dyeing wastes, waste water and emissions are created. Wastes occur during the waste water treatment were dyestuff has to be removed. Strategies to achieve this are degradation of the dye molecule or filtration techniques. The solid waste can be burned or is deposit – in many cases as hazardous material. The big advantage of plant dyes is that they are non hazardous, normally equal to tea. Therefore after extraction process the plant material can be used for animal feed, burning or composting.
The amount of waste water released in conventional dyeing and natural dyeing is similar but the composition differs. Both have to fulfill the local governmental limits for effluents. For plant dyeing mainly mordants have to be carefully selected and the amounts should be optimized with respect to ecological aspects.

Mordant	**$c_{waste\ water}$ [mg/l]**		**Legal limits [mg/l]** (CWWT)
	$c_{dyebath}$ = 1g/l	**$c_{dyebath}$ = 5g/l**	
$FeSO_4$: $Fe^{2+/3+}$	50	251	*
SO_4^{2-}	86	431	200
$FeCl_2$: $Fe^{2+/3+}$	50	251	*
Cl^-	64	431	-
$KAl(SO_4)_2$: Al^{3+}	14	71	*
SO_4^{2-}	51	253	200
$CuSO_4$: Cu^{2+}	64	318	0.5
SO_4^{2-}	96	481	200
$SnCl_2$: Sn^{2+}	132	658	1
Cl^-	39	196	-

Table 5 gives an overview for some chemicals used for plant dyeing. Based on two variations the maximum concentration in waste water is calculated and legal limits for Austria are shown.

Table 5: Concentration of chemicals in waste water for selected mordants. (*limited by filter residue)

Due to their toxicity for environment and potential health risks copper- and tin mordants must not be used for application. Additional emissions in case of natural dyeing are not expected.

Dyeing results

Up to now we performed around 1800 dyeing in our laboratory and established a set of 70 shade cards of plants. However, only a few of them exhibit sufficient properties for industrial scale application. A rigorous selection with regard to fastness level, color appearance local availability and toxicity is necessary to evaluate promising candidates. Some of them are given in Table 6.

Plant material	Color	Color fastness to		Resource in Austria
		light	water	
Canad. golden rod	Yellow / olive	+	-	Collection / Agriculture
Onion peels	Orange / brown	+	+	Food industry
Nut peels	Brown	+	+	Agriculture / cosmetics
Barks	Brown / grey	+	+	Timber industry
Grapes pomace	Violet (tannin)	-	+	Wine production
Black elder	Rose / grey	-	+	Juice production
Tea	Beige / grey	+	+	Ice tea production

Table 6: Screening table: color in respect to visual impression, color fastness to light according to DIN 54004 and color fastness to water according to DIN 54006.

Even if all sources of plant material are combined there are still some color shades not received yet. The final goal would be to achieve a set of the basic colors: red, yellow, green, blue and black. Up to now brilliant green, blue and black color shades are still missing. The possibility of blue colorations derived from natural Indigo is hindered by the change in technology which is a vat dyeing process thus would lead to two different dyeing techniques. Research focused on cholorphyll as green natural dye was not successful in the past. Addition of iron mordant in combination with organic material containing tannins and gallic acids cause shifting to darker shades but no brilliant black.

One significant aspect that hinders enlarged application of plant dyes is the low dyestuff concentration in plant material. To obtain a comparable color shade of 1-2 % of synthetic dyes a plant to substrate ratio of 1:1 is required. This lead to huge amount of plant material that has to be handled in dye houses. Alternatively a plant-dyestuff-supplier could deliver plant extracts.

Fastness investigations

During our research and discussion with industrial partners we identified the light fastness as a key factor for enlarged application of vegetable dyestuff. Generally, natural dyes show weaker light fastness properties than synthetic colorants [2, 3, 4, 8, 9, 10], which some exceptions [5, 6, 7, 11, 12, 13]. For that reason specific investigation of light-induced dye degradation processes was performed. The dyeing of cellulose films offered the possibility to observe the change of the absorption spectra in consequence of light irradiation. The used technique provides spectrophotometric data that can be analysed in terms of kinetics. Berberine, a yellow natural dye, served as model system for these investigations. The irradiation experiments showed a consecutive two step reaction including the formation of an intermediate. Based on this degradation rate constants were estimated. The presented methodology to investigate the kinetics of a dye degradation reaction can be seen as the first step to improve the light stability of natural dyes. The developed method allows a systematic investigation of light degradation processes on cellulose substrates and can serve as efficient tool for quantification of the influence of specific parameters on light fastness.

Levelness / reproducibility:
Levelness and reproducibility are of major importance as far as textile dyeing is concerned. Unfortunately in the field of plant dyeing technology only very little research has been done since synthetic colorants have been invented. Examples are: stripes for jet dyeing, lighter color shades at the border for jig dyeing and filtration for cone dyeing. etc.

Scale-up experiments:

- **Yarn dyeing on a package dyeing machine:** An extract of Dyer's Chamomile was used to dye 2 kilograms of wool yarn on cones. The dyeing experiment leads to a light yellow color. Although color differences between the outer, the inner, and the middle part could be identified the results were satisfying. The reason for the unlevelled color appearance could be related to the parameters of the machine that have to be optimized. Filtration effects were of minor relevance. .
- **Fabric dyeing on a jet dyeing machine:** 50 meters of cotton fabric were dyed with an extract of Dyer's Chamomile. We received a brilliant yellow shade but light/dark stripes could be identified. One reason is for this can be found in the mordant addition technique as well as in the mordant concentration. Anyway, the formation of stripes during jet dyeing is a well known weak point of this type of machine. The average color difference $\Delta E = 1.4$ gives the fabric an uneven and flickering impression. This can be highlighted in terms of marketing natural dyed products.
- **Fabric dyeing on a jig:** Different plant extracts were use for dyeing cotton and linen fabric. Repeated use of one extract was done. The comparison of the results shows that there are only slightly differences in shade due to the low affinity of the dyestuff. Analysis of the 5 m fabrics showed that the variations in terms of color differences $\Delta E = 0.6$ in average and 1.8 maximum.
- **Polyamide dyeing in a paddle dyeing machine:** Following the pre-screening experiments from laboratory four suitable plant sources could be identified. The adaptation of the dyeing apparatus with an extraction unit is a prototype for plant dyeing in Austria. A ready-to-use concept for naturally dyes polyamide stocking was obtained.
- **Fabric dyeing in garment dyeing machine/washing machine:** Cotton and linen fabric was dyed with an extract of red onion peels and iron mordant. For this experiment a meta-mordanting technique was applied. The dyestuff shows higher affinity towards the linen substrate. For both cases uneven dyeing results were found due to wrinkles during the coloration process. Precipitation of iron components was not observed.

CONCLUSION

Plant dyeing techniques indicate a significant potential for future industrial application. However, using vegetable dyes does not lead consequently to environmental friendly coloration technique. A concept of ecological dyeing includes consideration of raw material, consumption of water, energy and chemicals during the total process and considers wastes, wastewater and emissions. For most of this aspects natural dyeing looks promising. A combination of dyestuff extraction and dyeing increase the eco balance in terms of energy and water input. Sophisticated use of mordants, auxiliaries and solvents will improve the ecological benefit.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the State Government of Vorarlberg for financial support; the Versuchsanstalt and HTL Dornbirn for the use of their equipment. We want to acknowledge all companies that supplied us material: Lenzing AG, Leinenweberei Vieböck, Getzner Textil, Schoeller Wolle; Mr. Prischink. We also thank the members of the Institute for Applied Ecology for their cooperation and want to acknowledge all partners of the project group (Programmlinie Fabrik der Zukunft). A part of this work is supported by the Austrian Federal Ministry for Transport, Innovation and Technology.

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