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Article

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The education of art culture at Sultanate of Oman through the multidisciplinary integration between graphic design and eco-friendly textile printing. Part 1: Standardization of extraction and dyeing with natural wastes products

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Abstract

Scientific research today is marked by a growing differentiation and specialization in the disciplines and interdisciplinary research. This paper investigates a number of challenges of Interdisciplinary collaborations in implementation of a circular economy approach within textile and graphic designs. These challenges range from achieving economy of scale required for commercial viability and finding secondary markets for the recycled materials to developing ‘resource efficient recycling processes’ that are especially tailored to the specific needs of eco-friendly textile products. Art Education Department at Sultan Qaboos University created interdisciplinary education strategy through an artistic relevant, and engaging the textile printing and graphic design courses in a project. The aim of this project is to apply some natural waste products which contain pigments to be served as recycling sources for natural dyes in textile coloration regarding their increasing interest due to their biodegradability and environmental awareness. The research project was divided in two parts; part one depends on studying the optimum condition of extraction with different co-solvent on different textile fabrics, as the extraction can be an energy, economic and environmental friendly by waste recycling. Part two deals on studying the mixing of the resulted extractions in producing a variety of hues under the effect of different pH values, mordants and mordanting methods to promote artistic printed textile patterns assisted by the graphic design. Therefore, students are introduced to different and integrated ways of thinking, aiming to make them more aware of circular economy and sustainability issues in all of their art activities, from personal to professional environments. As a result, this research is considered as a double scientific leap in terms of development strategies for teaching art curricula through the Multidisciplinary Integration in serving the community and the environment.

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1. Introduction

Education, as a field of study, is multidisciplinary. Globalization has certainly impacted the activities of educational institutions and educators, and of education researchers, and in the higher education sector in particular, with its core activities of teaching and research [1]. This is the world for which educators now groom their students towards creativity is differ from the world before. The meeting line mentality of the industrial world has morphed into a team-based approach whereby integrated concepts and skills are conducted across a wide range of courses. To excel in the professional environment, today's collegiate graduates should be prepared to go beyond the simple mastery of content and low level thinking. Through interdisciplinary education, creativity, critical thinking with the skills of communication and collaboration are disbursed within and across the syllabi. This enhances and increases the ability of students to take decisions and create knowledge beyond single disciplines. Also, increases the ability to recognize, assess, and convey significant information needed for problem solving, develop various perspectives, achieve a better overall comprehension of global interdependencies with values and points of view, and. From the educator point of view, interdisciplinary education is a technique to share pedagogical ideas with colleagues and to be energized by seeing one's own discipline from a fresh new perspective [2]. The aim of this strategy is to develop their critical thinking, creativity, collaboration and communication to prepare them to meet the challenges of the 21st century. As a result, it may be best suited to prepare students for real-world challenges as today's problems are not contained within discrete skills and concepts, but across a broad spectrum of skills and concepts best addressed through integrated competencies [3].

Nowadays, humans exploit natural resources that produce waste. In Latin, "residuum" means "that which remains", that is, a residue is what is discarded after taking advantage of something, which can be an energy, economic and environmental savings by waste recycling, where the circular economy constitutes a paradigm that will facilitate the transition of organizations to a more sustainable model. Recycling need not cost more than waste collection and disposal. In fact, recycling can make good economic as well as environmental sense [4]. Today's 'take-make-dispose' economy has long relied on inputs of cheap and available resources to create conditions for growth and stability. The concept of the circular economy is rapidly capturing attention as a way of decoupling growth from resource constraints. It opens up ways to reconcile the outlook for growth and economic participation with that of environmental prudence and equity. It is inspiring CEOs, politicians, engineers, designers and the next generation of leaders. The circular economy provides a framework to both challenge and guide us as we rethink and redesign our future [5].

Historically, Man has always been interested in colors. The art of natural dyeing goes back into prehistory since the Indus Valley civilization [6]. These dyes remain the main textile colorants up to the end of the 19th century, until synthetic colorants had increasingly replaced them in 1956 due to their lower specific cost, higher reproducibility, favorable dye affinity onto fabrics and their extensive range of colors [7]. Researchers have shown that most of synthetic dyes contain toxic raw materials and intermediates which have a negative impact towards the eco-balance nature, in addition to the serious health hazards [7]. In contrast, natural dyes are free from such problems [8]. As a result, there is a commonly inspiration towards the returning to the use of natural dyes, regarding the stringent environmental standards imposed by many countries towards the increased awareness to eco-safety and sustainable materials in textile coloration technology [9]. Regarding the economical point of view, there are limited researches conducted on the availability of organic wastes that could serve as sources for the extraction of natural dyes for textile coloration [10], hence the extraction of color is an important step for dyeing in order to evaluate and increase its dyeing characteristics on any textile substrate [11,12]. The standardization of the extraction process has commercial and technical importance on the cost and color yield of dyeing process. The conventional aqueous extraction is commonly solvent and time consuming, producing lesser amount of coloring component in comparison with the use of water co-solvent with acetone, ethanol and/or dimethylformamide (DMF) which are successfully promote rich extracts of natural dyes with minimum energy consumption with acceptable fastness properties [13,14].

There is now recognition on renewal and regeneration of art program to be increasingly aware of the human potential of a community, and to be applied as a mechanism to trigger individual and community development [15]. The mission of Art Education Department at Sultan Qaboos University is to prepare specialists in the field of fine arts who can serve the environment and society by developing the artistic and aesthetic taste of the community. This can be easily achieved by utilizing the integration of different disciplines to prepare projects among students in different courses that serve the community and environment.

As a result, a research project has been conducted to combine the benefits of both textile printing and graphic design courses and integrate their characteristics in producing art works that serve the Omani environment and economy. This research project consists of two parts, where in this part the beetroot peel, red cactus pear peel and *Ficus benjamina* leaves were studied in the course of textile printing as wastes sources of natural dyes of red, yellow and green colors respectively in order to determine the optimum extraction condition of plant using the most appropriate leaching solvent for pigments such as the aqueous solvent in comparison with the co-solvents of water/acetone, water/ethanol and water/ DMF. This was carried out at different concentrations, temperatures, pH values and time intervals to produce an optimum concentrated extract with high extraction capacity. The resulted standardization of extracts in this part will be utilized in part 2 with different percentages to dye silk and cotton fabrics with different color values to promote artistic textile patterns assisted by graphic design techniques.

2. Materials and methods

The students in the class of textile printing course were divided into groups to apply the following steps of work

2.1. The preparation of natural waste products

The beetroot peel, red cactus pear peel and *Ficus benjamina* leaves were washed under flowing water to remove dust particles and soluble impurities. The first two plants were dried by exposing to sunlight, and then were grinded into powders. The third plant was used without drying.

Beet (*Beta vulgaris* subsp. *vulgaris*) belongs to the Chenopodiaceae family. Its purple root is due to the presence of betalains which are comprised of two groups of two water-soluble pigments: the red–purple betacyanins and the yellow betaxanthins [16] as shown in Fig. 1.

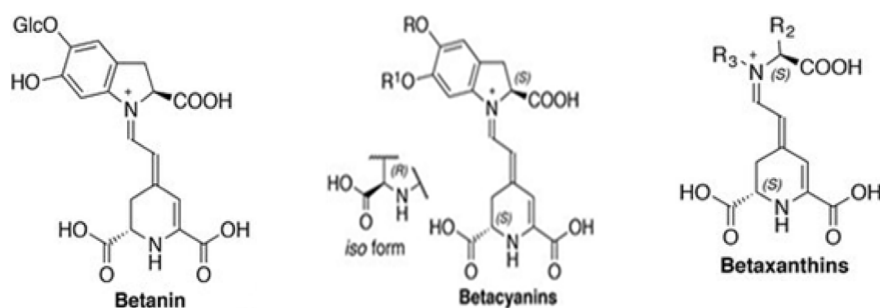


Fig. 1. Generic structures of Betanin, betacyanins and betaxanthins.

Cactus pear or prickly pear is a member of the Cactaceae family. It is characterized by the presence of betalain pigments which acts as a good potential for the use as a natural food colorant, in addition to the red–violet betacyanins and the yellow betaxanthins [17]. *Ficus benjamina*, has chlorophyll (Chl. a) and (Chl.b. b) as essential pigments [18]

2.2. Pigment leaching and estimation of extraction yields

To select the best extraction variable parameters, different amounts of powders (1–15)% (w/v) were dissolved in distilled water and other co-solvents [acetone, ethanol, dimethyl formamide (DMF)] as water–solvent mixtures were tested at different concentrations ranged from 5%–75% (v/v), at 80 °C, for 15–120 min, at pH values of 3, 5, 7.9 and 11. This was carried out with liquor ratio of 1:50 to determine the standardization method of extraction. It was recorded that the pH of beetroot peel, cactus pear and *Ficus benjamina* leaves are 4.99, 3.69 and 3, 84 respectively.

2.3. Spectral analysis

The color capacity of natural dye extract was evaluated by the absorption values in the wavelength range 300–700 nm. using UV-spectrophotometer (Model T60 spectrophotometer, United Kingdom).

3. Results and discussion

The color capacity of the extracts of beetroot peel, cactus pear peel and *Ficus benjamina* leaves was evaluated by the absorption values in the wavelength range 300–800 nm, giving maximum absorbance at 550/600 nm, 410/654.8 nm, and 427/578 nm λ_{max} , respectively. On dissolving 10% (w/v) of each plant powder in pure distilled water and (10% v/v of water/solvent) of each of [acetone, ethanol and dimethyl formamide (DMF)], at 80 °C for 60 min, using liquor ratio of 1:50 in order to determine the efficiency of solvent on absorbency and pigment leaching. It was denoted as shown in Fig. 2 that the maximum absorbance was achieved by using water/acetone with *Ficus benjamina* leaves.

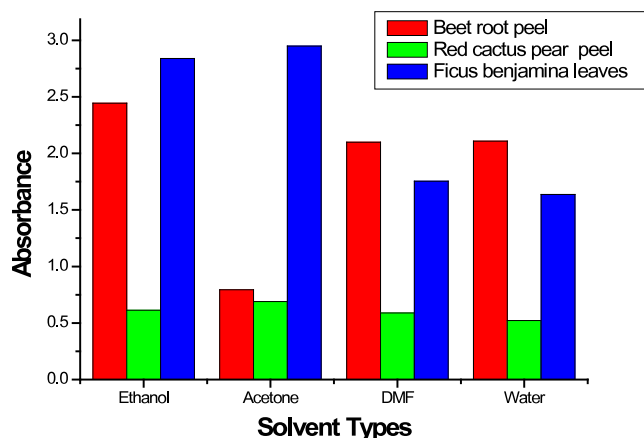


Fig. 2. Effect of different solvents on the absorbance of the studied plants.

The extracts are complex organic molecules which might carry charge centers and are thus prone to absorption changes in various media. Also, the absorbance values were influenced by the dielectric constant, dipole moment and refractive index values of solvents. Therefore, the change in values can be investigated to different types of interactions between the plants' powders and the solvents' types where the polarity of solvent can change emission band of molecules or the position of the absorption [19]. As a result, the absorbance values of plants' extracts were affected by the solvent type and the change in values with the different types of solvents can be noted as a probe for various types of interactions between the solute and the solvent. Water gave the lowest values of absorbance with the three examined plants, this is because water makes strong hydrogen-bonded nets in the water-rich region where it is preferentially interacts with itself rather than the plants' powders [12]. As shown in Tables 1a, 1b and 1c; The effect of water and the different concentrations from 5, 10, 15, 25, 50 and 75% (v/v) of DMF/water, acetone/water, ethanol/water and ethanol/water were studied at 80 °C for 60 min. to determine their effect on the absorbency of the three selected plants to detect the best solvent for pigment leaching. It was observed that the maximum value of absorbance was occurred on using 10% v/v ethanol/water solvent in extracting the pigment of beetroot peel, while in case of the Red cactus pear peel and *Ficus benjamina* leaves it was taken place when using 50% v/v water/DMF and 15% v/v acetone/water respectively. Water–ethanol co-solvent belong to HBD type of solvents where beetroot peel is preferentially solvated by the alcoholic component in all mole fractions in aqueous mixtures with ethanol.

Table 1a. Effect of solvent type and concentration on the absorbance of beetroot peel at 80 °C for 60 min at 80 °C for 60 min. [the pH of beetroot is 4.99].

Solvent conc. % (v/v)	Water/ethanol	Water/acetone	Water/DMF
0	2.109	2.109	2.109
5	2.289	1.992	2.114
10	2.444	0.795	2.099
15	2.123	0.782	2.057
25	2.050	0.687	1.998
50	1.901	0.742	2.002
75	1.902	0.668	1.952

Table 1b. Effect of solvent type and concentration on the absorbance of red cactus pear peel at 80 °C for 60 min at 80 °C for 60 min. [the pH of cactus pear is 3.69].

Solvent conc. % (v/v)	Water/ethanol	Water/acetone	Water/DMF
0	0.522	0.522	0.522
5	0.555	0.589	0.577
10	0.613	0.689	0.589
15	0.678	0.745	0.778
25	0.784	0.987	1.124
50	1.241	1.878	2.841
75	1.201	2.111	2.275

Table 1c. Effect of solvent type and concentration on the plant absorbance of *Ficus benjamina* leaves at 80 °C for 60 min at 80 °C for 60 min. [the pH of *Ficus benjamina* is 3.84].

Solvent conc. % (v/v)	Water/ethanol	Water/acetone	Water/DMF
0	1.637	1.637	1.637
5	1.892	2.241	1.542
10	2.842	2.952	1.755
15	2.984	3.987	1.987
25	3.754	3.745	2.012
50	3.511	3.214	2.151
75	3.214	3.221	2.142

For water–acetone co-solvent, the salvation of extract is non-HBD type which mainly occurs through charge–dipole type of interaction, the methyl groups of acetones are responsible for the solvation of *Ficus benjamina* leaves.

On the other hand, the decrease of the amount of non-HBD acetone concentration lead to an increase with the amount of HBD solvent (water) and shall break the interactions with the plant molecule, thereby decreasing the value of absorbance [12]. By increasing the concentration of each of ethanol, DMF and acetone in water rather than (5%, 50% and 15%) v/v lead to break the interactions with the plants' molecules; as a result, decrease the extract absorbance value [19]. On decreasing the concentrations brings an increase of the other compounds concomitant extraction which lowers the plant pigment concentrations which accompanied by a lesser absorbance [20].

As shown in Table 2; the concentrations of the dried grinded powders of the three plants were studied at 80 °C for 60 min. It was observed that, by increasing the amount or concentration of plants lead to an increase in absorbance values where the maximum value was achieved with 12% w/v with the three examined plants. This can be explained by the diffusion of high amount of plant solvated in the solvent. As shown in Table 3; The effect of

Table 2. Effect of plant concentration on the plant absorbance at 80 °C for 60 min.

Waste Conc. (w/v)	Beetroot	Cactus pear	F.benjamina
3	1.452	0.987	1.254
6	1.874	1.923	2.415
9	2.444	2.841	3.987
12	3.714	3.289	4.124
15	3.709	3.054	4.121

Beetroot in 10% water/ethanol, cactus pear in 50% water/DMF, F.benjamina in 15% water/acetone.

Table 3. Effect of pH values on the plant absorbance at 80 °C for 60 min.

pH	Beetroot (in 10% water/ethanol)	Cactus pear	F.benjamina
3	2.588	2.897	3.957
5	2.874	2.787	4.250
7	1.474	2.841	3.884
9	0.212	1.589	0.123
11	0.134	1.254	0.058

Beetroot in 10% water/ethanol, cactus pear in 50% water/DMF, F.benjamina in 15% water/acetone.

Table 4. Effect of temperature on the plant absorbance at pH 5 for 60 min.

Temp. °C	Beetroot	Cactus pear	F.benjamina
40	0.897	0.542	1.243
60	1.542	1.242	2.457
80	2.452	2.872	3.994
100	2.442	2.845	3.985

Beetroot in 10% water/ethanol, cactus pear in 50% water/DMF, F.benjamina in 15% water/acetone.

Table 5. Effect of time on plant absorbance at pH 5 at 80 °C.

Time (min)	Beetroot	Cactus pear	F.benjamina
15	0.982	0.542	0.789
30	1.254	0.758	1.452
45	1.875	1.052	2.452
60	2.442	2.841	3.983
90	3.583	2.973	4.321
120	3.544	2.853	4.310

Beetroot in 10% water/ethanol, cactus pear in 50% water/DMF, F.benjamina in 15% water/acetone.

pH values on extraction absorbance was studied at 80 °C for 60 min. It was denoted that the maximum absorbance was achieved in the acidic medium due to the increased solubility and diffusion coefficients of the plants' extracts. The decrease of absorbance in the neutral and alkaline mediums might due to the hydrolysis or polymerization of the possible degradation of pigment compounds [21].

From Tables 4 and 5, it was observed that the standard parameter of extraction time was achieved after 90 min 80 °C. By the increase in temperature and time, the absorbance values increased due to the de-aggregation of plant molecules in the extract bath. While with prolong extraction than 90 min, at temperature higher than 80 °C, the absorbance value decreased not only due to the hydrolytic decomposition of the extract molecules but also the loss of solvent by evaporation [22,23].

The effect of dyeing cotton, silk and wool with the resulted optimum extraction of the three plants was carried out as shown in Fig. 3.



Fig. 3. The optimum extraction of the three plants on dyeing wool, cotton and silk fabrics.

It was observed that cotton, wool and silk are significantly attracted by the three colored extracts though they are totally different in chemical composition as cotton is cellulosic fiber while wool and silk are highly protein ones. This indicates the availability of studying the optimum condition of dyeing and the effect of different mordants and mordanting methods in part 2 to dye with a mixture of different percentages of the three extracts to promote delightful artistic textile patterns assisted by graphic design.

4. Conclusion

Interdisciplinary teaching promotes real-world learning, not isolated educational experiences. As such, the knowledge base for the treatment of complex problems should be expanded, so that it will match the entirety of the aspects of the issues at hand. This paper presents a multidisciplinary approach to teach different processes to extract pigments from waste materials that are valorized this way, within the circular economy approach and has highlighted how collaborative Arts-courses can enrich the students' experience. This circular economy provides a framework to both challenge and guide the students as they rethink and redesign their future. From this research

trail; it is concluded is a great potentiality of the utmost utilization of the waste natural products in art education for yielding natural color extracts in textile printing courses in order to produce art works that serve the environment and economy. The use of organic solvents enhances the extraction of pigments to avoid any loss in the color quality at quite latent heat of vaporization to allow their extraction at low temperatures with minimum energy consumption. Good results with variable colors were obtained and in dyeing cotton, wool and silk with delightful colors. This will give the chance in part 2 to study the effect of dyeing and mordanting condition to promote a variety of hues with high quality aesthetic dyed patterns through an economical point of view for a trial to apply multidisciplinary integration in art education strategy between graphic design and eco-friendly textile Printing.

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