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Natural dye from bixa seeds as a potential alternative to synthetic dyes for use in textile industry

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ABSTRACT

Dye is a substance that has affinity to the substrate to which it is being applied such as textile fibers, foodstuffs and powder. From archeological evidence, it is seen that in India dyeing has been carried out for over 5000 y, which were obtained from animal, vegetable or mineral origin. The greatest source of this dye was mainly from plant kingdom; mainly roots, bark, leave and wood. Dye from Bixa (Annatto) seed is one type of natural dye which can be used as dyeing agent for coloring textile fibers like cotton, wool, silk and for making colorful "Gulal" as well as in food industry. Bixin, the pigment extracted from the red-colored seeds, can be used as coloring agent for this purpose. It is non-carcinogenic in nature and so does not affect human body or environment. An attempt is being made in laboratory scale to extract the natural pigment from the Bixa seeds and its application in different fields such as textiles, colourful powder and food industry.

Keywords: Herbal dye; Bixa; Bixin; Synthetic dye; Gulal; Textile fibre

1. Introduction

Chemical dyes and coloured powders are made from chemical reagents of azo dye and synthetic organic dye. These chemical reagents are harmful towards the human body and have toxic effects on skin. The discovery methods of synthesizing alizanin and indigo spelt the death knell of the indigenous industry. Due to the ease of application, bright shades obtained and the hard shell of the colonial rulers, hand weavers started to opt for synthetic dyes without a clear understanding of the using of these. Some synthetic dyes are carcinogenic in nature and havoc in life systems [1–4].

As a result there is a demand for dyes which can be produced from natural sources. Being natural in origin these herbal dyes do not pose health hazards [5–8] and are safe for human use. Herbal dyes however produced from different natural sources are economical and solve the above problems. These herbal dyes are not toxic, no allergic to human health, easily available and more economical. Some natural sources for dye produce truly exquisite shades and economical to purchase than chemical dyes. Upto now most of the natural dyed textiles are imported from Third World Countries and India is still a major producer of it. Flowers of Marigold, Chinarose, Aparajita, Bougainvillia, Cineraria, Alkanet, Bixa etc. have been extensively used or dyeing fabric [6–8].

It is a small tree found throughout the hotter parts of India. Bixa is cultivated for its seeds in Orissa, Andhra Pradesh, Maharashtra, Karnataka, Tamil Nadu, Kerala and West Bengal as orange-red colour is found from its which can be used as dyeing materials for colour fibres and making colourful powder [9]. It occurs in two forms: White

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flowers and green capsules other with pink flowers and red capsules. The seeds which are dry, hard, bright red and have a characteristic smell are considered good for dyeing. The unmordanted cotton gives dull shades but using proper mordant, the colour and brightness of the colouring cloth is increased. The colourful dye extracted from Bixa is non-carcinogenic. Annatto seed extracts have been documented to raise blood glucose levels in some species of animals and to lower it in others. Annatto leaves were reported in yet another study to possess aldose reductase inhibition actions, a process implicated in the advancement of diabetic neuropathy. Study confirmed the effectiveness of a leaf-and-bark extract at neutralizing hemorrhages in mice injected with snake venom, a practice used in Colombia for many years [9]. Annatto demonstrated antigonorrheal activity in a study [9], and in other research, flower and leaf extracts demonstrated in vitro antibacterial activity against several bacteria, including *E. coli* and *Staphylococcus*. This supports its use in traditional medicine systems for gonorrhea and infections From literature, it is observed that due to its non-toxic nature, dye is extensively used in dairy-industry for colouring butter, ghee, cheese, margarine, ice cream, chocolate, meats, cereals, confectionary, spices etc. In Latin America, the seeds are fried in fat and the colour part is used to tent rice, gravies and stew. It is used as an ingredient in hair oils, shoe-polishes, soap, cosmetics and pharmaceuticals ointments. It can also be used in adsorption-indicator in agrentometric titrations.

The chief ingredient of Bixa is bixin (Fig. 1) which comprises 70–80% of the total pigments present in the seed. In addition, a water soluble yellow dye, orelilin, methyl bixin, β-carotene, cryptoxanthin, lutein and zexanthin are also reported. Bixin gives water-soluble products on saponification, and it is called as norbixin [10–13]. Bixin is the main pigment of oil-soluble annatto and norbixin is the principal colouring matter of water-soluble products. This is not belong to mordant dye classes, but it belongs to direct/acid dye class. So it can be used without use of mordant. But the colour depth and brightness is increased in presence of mordant.

The colour index of Bixa is C.I. natural orange 4 (C.I. 75120).

The main objectives of the work are:

1. Extraction of natural dye from Bixa seed by an efficient process.
2. Using natural dye in spite of chemical dye so that environmental pollution due to chemical dye can be restricted.
3. To study the color characteristics using different types of mordant.

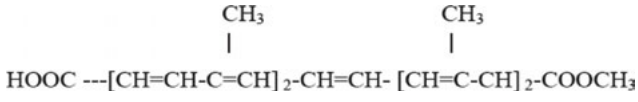

Fig. 1. Structure of bixin.

2. Experimental procedure

2.1. Water extraction method [14,15]

Dye from Bixa seeds were extracted by the aqueous extraction procedure. In this method the seeds were heated with water and the pigmented liquid was collected. The extraction process was carried out at different temperatures and for different extraction times to get the optimization point of the process. Colouring materials from the Annatto seeds were deep orange in colour and extracted for dyeing the textile fibre. Different amount of seed (0.1, 0.2, 0.5, 1, 2 g) were taken in Erlenmeyer flask (250 ml) and 100 ml water was added in each and the flasks were incubated at different temperatures (30°C, 60°C, 70°C, 80°C, 90°C, 100°C). Extract samples were taken at different time intervals (10, 30, 45, 60, 90, 120 min), filtered and dried. After the complete extraction of dye, the seeds were taken out from the liquor and again used to extract dye. The optical density of the sample was analyzed by the UV–VIS spectrophotometer (HITACHI MODEL NO: 2800) and the total weight of the extract dye per gram of the dye was determined (Fig. 2).

2.2. Influence of temperature on extraction of dye

To achieve the optimized temperature for the extraction, 1 g of Bixa was taken in 100 ml of water and extraction was for 1 h. The extraction temperature was ranging from 303 to 373 K and higher temperature than 373 K.

2.3. Influence of time on extraction of dye

To achieve the optimized time for the extraction, 1 g of Bixa was taken in 100 ml of water and temperature was controlled as 363 K. The extraction time was ranging from 10 to 120 min.

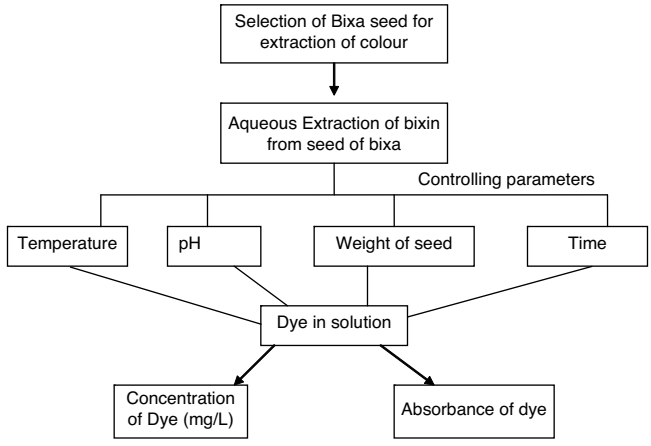

Fig. 2. Schematic diagram of extraction of dye from Bixa seed.

2.4. Influence of amount of Bixa on extraction of dye

To achieve the optimized amount of Bixa for the extraction, different amount of Bixa were taken in 100 ml of water and temperature was controlled as 363 K. The extraction time was ranging from 10 to 60 min.

2.5. Influence of different reagents on extraction of dye

Extraction procedure for dye was carried out through batch method. 0.1 N hydrochloric acid and 0.1 N sodium hydroxide were used for adjusting the initial pH of solution and extraction had been done at this pH. The pH measurements were made by using pH meter during all the experiments at initial stage and after adsorption.

2.6. Metal analysis

Metal Contents present in Bixa dye were analysed using atomic absorption spectrophotometer (Model: Perkin Elmer AANALYST 200).

3. Results and discussions

From Fig. 3 it is observed that as the temperature increases from 303 to 373 K, extraction of dye increases from 2490 to 5330 mg l^{-1}. At higher temperature (higher than 373 K) the extraction will be higher, but the problem is that as Bixa seeds is a natural products, charring will occur and the production will be lost. So, the optimum temperature is taken as 373 K.

From the experimental results it is observed that as the time increases from 15 to 150 min, the extraction increases from 2760 to 7250 mg l^{-1}. From Fig. 4 it is observed that the absorbance of dye increases as time increases due to increase in concentration of dye.

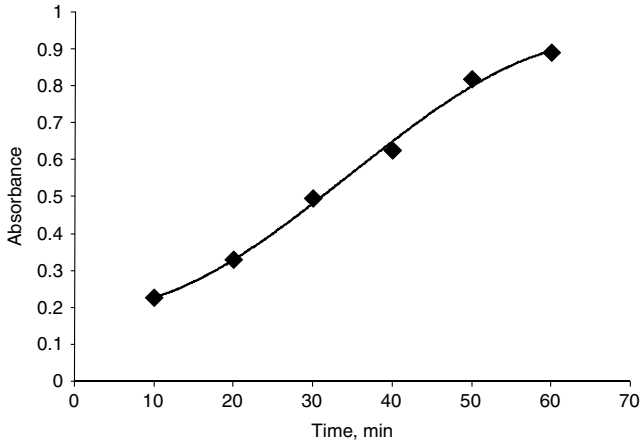

Fig. 4. Effect of Time on the extraction of dye from Bixa seeds, weight of bixa: 1 gm, Temperature 363 K.

As time increases, dye concentration and colour intensity of dye in solution increases.

It is observed from Fig. 5 that extraction is higher in basic medium than other medium, indicating that the extraction of dye is influenced by the medium pH. In basic medium the amount of dye extracted is 9400 mg l^{-1} and in case of acidic medium, the concentration is 6100 mg l^{-1}.

From Fig. 6 it is observed that as the amount of Bixa increases absorbance increases. The absorbance of 0.5 g Bixa is lower than 1 g of Bixa indicating that as the amount of Bixa increases, the concentration of solution increases and as a result absorbance increases. The highest absorbance is observed when 3 g of Bixa is used.

From Table 1 it is observed that the heavy metals are in negligible amounts in the aqueous solution of dye. Among all the metals, zinc is found in highest percentage. The sources for these are probably fertilizers used

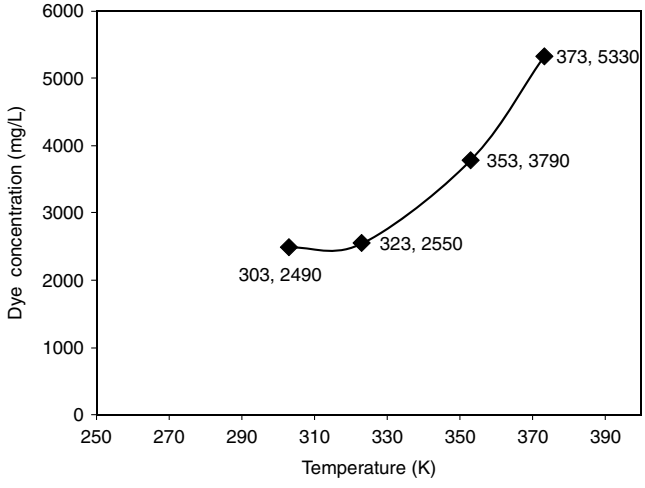

Fig. 3. Effect of temperature on extraction of dye from Bixa seeds when weight of Bixa seed is 1 g, time 60 min.

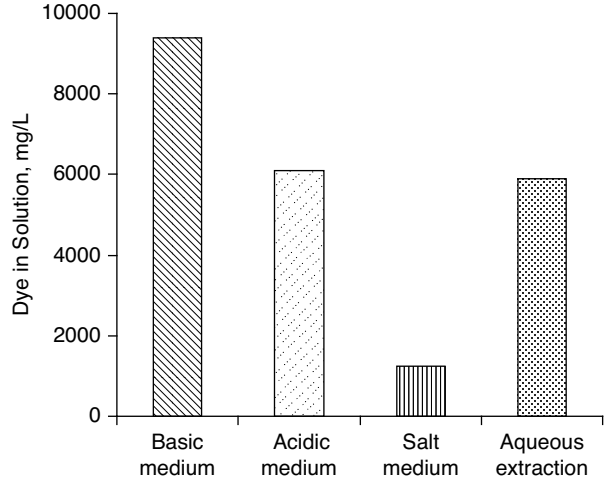

Fig. 5. Effect of pH on extraction of dye at 373 K and 1 gm of bixa seed.

Table 1
Metal concentration present in dye sample

Serial number	Extraction time (min)	Temperature (°C)	Metal concentrations (ppm or mg l^{-1})			
			Lead (Pb)	Cadmium (Cd)	Copper (Cu)	Zinc (Zn)
1	30	30	0.11	0.019	0.155	0.233
2	30	50	0.1	0	0.093	0.193
3	30	80	0.136	0	0	0.436
4	30	100	0.006	0	0.159	0.221

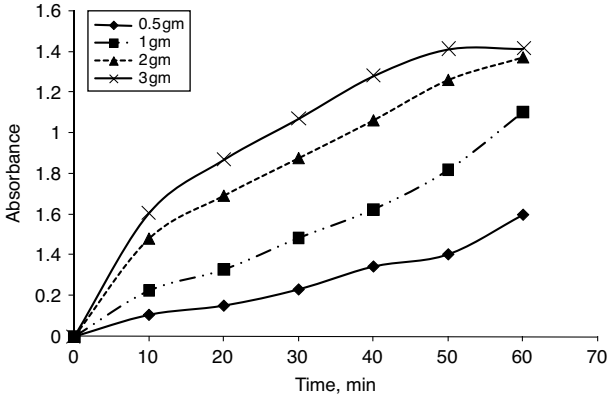

Fig. 6. Absorbance of dye using different amount of Bixa at 424 nm wavelength.

in the fields where these plants are grown and the metal is passing through the root of those plants to the flower and fruit.

4. Conclusions

The present work shows that Bixa can be used as a dye for colouring textiles. These are grown in the Indian subcontinent and so are easily available. Different shades of colour can be obtained using different mordant. Also, the colour fastness, wash fastness properties can be improved by different treatment procedures. It is observed that at higher pH and temperature from 40°C–90°C, and extraction time of 2 h, the optimized dye can be extracted from the seed. The process is economically viable as the raw materials are abundantly available and inexpensive. It is observed from the experimental results that as the amount of Bixa increases, dye concentration increases in the solution and as the temperature increases, the extraction increases. It is also observed that the extraction is dependent of the solution pH also. So, it can be concluded that the extraction of dye from the Bixa seed is dependent on the amount, pH and temperature and extraction time.

The process can be carried out both in large scale industrial setup and also through cottage industries. Production of these natural dyes as a cottage industry is a novel idea for the empowerment of village women. Herbal Gulals produced by using dye will find wide acceptance too as "Holi", the festival of colours, is a popular cultural and religious practice in India. This approach is quite promising for future entrepreneurs.

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