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Extraction of Carotenoids as Natural dyes from the Daucus carota Linn (carrot) using Ulturasound in Kingdoum of Saudi Arabia

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Abstract

Dyes derived from natural sources have emerged as an important alternative to synthetic dyes. Therefore, there is a need for developing better solid-liquid extraction techniques for leaching natural colorants from plant materials for applications in plant research concerned on boiling and solvent extraction. Water, methanol and acidified methanol were used as solvent to extract Carotenoids as the natural dyes from plant, as well as dyeing industries. The influence of ultrasound on natural colorant extraction from different potential dye yielding plant materials has been studied in comparison with magnetic stirring process as control. The color yielding plant materials used in the present study include Daucus carota Linn. (carrot). Analytical studies such as UV-VIS spectrophotometry and gravimetric analysis were performed on the extract. The dyes produced were dyed on silk fabric and tested for their colour fastness to washing properties. Several mordants were also used for fixing the colour on the fabrics. Moreover, the dyes obtained from the plant may also be alternative sources to synthetic dyes for the dyeing of natural silk fibre. Therefore, this methodology could be employed for extracting coloring materials from plant materials in a faster and effective manner.

Keywords: Daucus carota, carrot, carotenoids, dyes, ulturasound, spectral data.

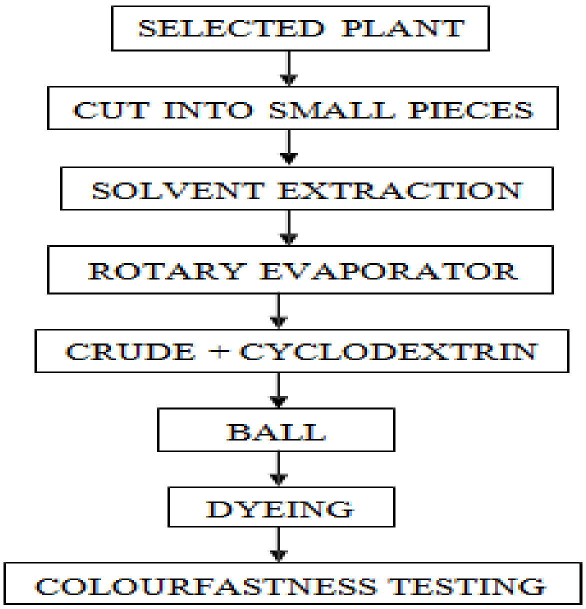
Introduction

Natural dyes can be sorted into three categories: natural dyes obtained from plants for example indigo, those obtained from animals for example cochineal, and those obtained from minerals for example ocher[1-4]. Natural dyes/colorants derived from flora and fauna are believed to be safe because of its non-toxic, non-carcinogenic and biodegradable in nature[5].

However, the use of natural dyes to colour textiles declined rapidly after the discovery of synthetic dyes in 1856[6-8]. The main reason for the replacement of natural dyes by their synthetic counterparts is that most natural dyes have poor to moderate wash and light fastness, while synthetic dyes represent the full range of wash and light fastness at moderate costs[9]. Lately however, there is a growing interest in the revival of natural dyes in textile colouration[10,11]. This is as a result of the worldwide concern over the carcinogenic effects, toxicity and allergic reactions associated with synthetic dyes[12,13]. Moreover, many countries already imposed stringent environmental standards over synthetic dyes. Germany, for instance banned the azo dyes[14]. In contrast, natural dyes are environmental friendly, exhibit better biodegradability and generally have a higher compatibility with the environment than synthetic dyes[15], with a tropical climate, is home to a very large number of plant species; many of them are used by natives in folk medicine. Malaysia is among the world's mega biodiversity - rich countries in terms of number of plant species[16-20] which also included *Melastoma malabathricum* L. and *Dicranopteris linearis* plant. Although it is unlikely all dyestuffs will be produced solely from plants, it is an interesting and exciting prospect that one day a percentage of everyday colours could be naturally derived[21]. It was used in native mediciene for ulcers, carbuncles, infected wounds[22]. Seeds of the plant when ground to powder and taken as tea for colic and to increase urine flow[23,24]. Tea of carrot blossoms has been used for treatment of dropsy. Astringent, antiseptic, anti-inflammatory, antioxidant, sudorific[25]. Nutritionally roots contain vitamin A. B, C, E, the minerals phosphorus, potassium and calcium[26].

Material and Methods

Extraction of natural dyes from *Daucus carota* Linn. (carrot) plant was carried out through boiling and solvent extraction process. The materials were cut into small pieces and soaked in water, methanol or acidified methanol. In the case of boiling method, the materials were cut into small pieces, soaked in distilled water and heated for 1hour at 100°C. However, for solvent extraction method, the materials were cut into small pieces and soaked in methanol or acidified methanol and placed in dark room for two days at room temperature. The solution was then filtered and mixed with 2% of selected mordant based on weight fabric (o.w.f.). The dye liquor was used to dye silk fabric at 80°C for 1 hour. Soap at boil was carried out to remove unattached dyes for 5 minutes. The dyed fabrics were also analysed in terms of colour fastness to washing using several standard methods.



Extraction using magnetic stirring (control experiment): 80.0 grams of sample was taken and 1.0 litere distilled water was added in a glass beaker in order to keep the plant materials along with ultrasound tip fully immerse in solvent. The beaker was covered using aluminum foil to prevent loss of solvent by evaporation. This beaker was stirred magnetically for 3 hours. In order to have the fair comparison with ultrasound system, where ultrasonic bath temperature is around 45 °C without external heating, the temperature of the extraction bath for control process was also maintained at 45 °C. This would also provide idea about improvements with ultrasound extraction other than temperature induced effects of ultrasound. Extract samples were taken at every 30 minutes and the optical density was determined with the help of UV-VIS spectrometer. At the end of 3 hours, the yield and extraction efficiency of each sample was determined by gravimetric method. The extract was tightly closed and stored at low temperature for future reference.

Results and Discussion

UV–VIS spectrum of natural dye obtained from *Daucus carota* (carrot) was obtained. Here, the dye extracted was analyzed at the wave length of 480 nm. The absorbance values for natural dye extract obtained by ultrasound and magnetic stirring control are shown in figure-1. The results indicate that there is about 12.5% improvement in the % yield of extract due to the use of ultrasound as compared to the control process.

Figures 1, 2 and 3 show the colour reflectance of dyed silk fabrics using *Daucus carota* (carrot) dyes extracted through boiling and solvent extraction process. The same source of dye was mixed with different mordant to give different colours. For instance, fabrics dyed using iron as mordant gave the darkest colour in comparison with other mordants for both dyes from *Daucus carota* (carrot).

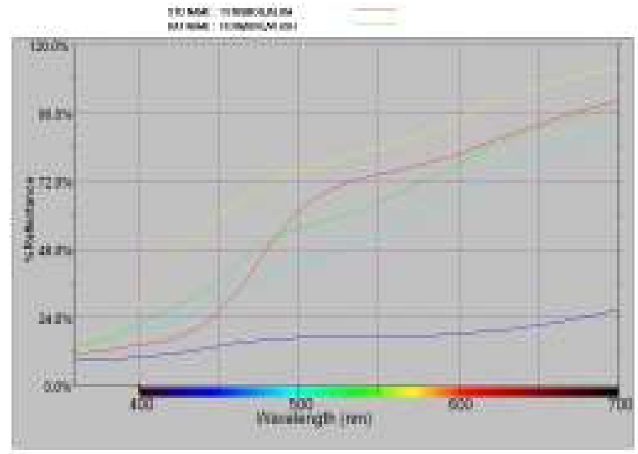


Figure-1
Colour reflectance from *Daucus carota* (carrot) with several mordant (boiling)

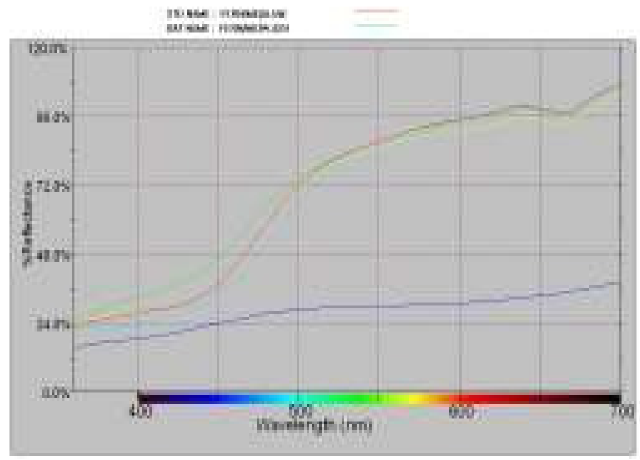


Figure-2
Colour reflectance from *Daucus carota* (carrot) extracted through solvent extraction method (methanol)

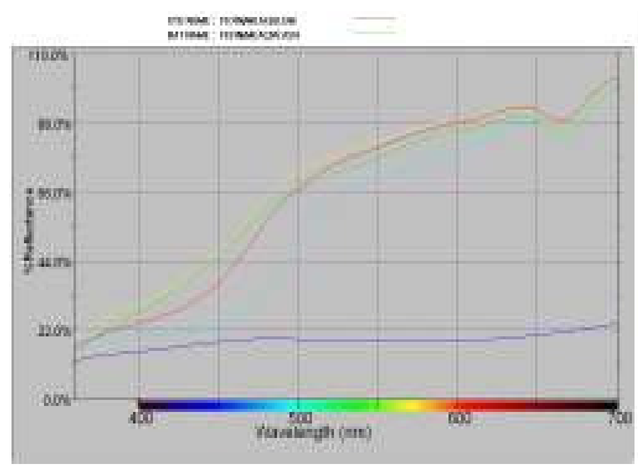


Figure-3
Colour Reflectance from *Daucus carota* (carrot) extracted through solvent extraction method (methanol/acid)

β-Carotene is a strongly-coloured red-orange pigment abundant in plants. It is an organic compound and chemically is classified as a hydrocarbon and specifically as a terpenoid (isoprenoid), reflecting its derivation from isoprene units. β-Carotene is biosynthesized from geranylgeranyl pyrophosphate[27]. It is a member of the carotenes, which are tetraterpenes, synthesized biochemically from eight isoprene units and thus having 40 carbons. Among this general class of carotenes, β-Carotene is distinguished by having beta-rings at both ends of the molecule[28,29]. Isolation of β-carotene from fruits abundant in carotenoids is commonly done using column chromatography. The separation of β-carotene from the mixture of other carotenoids is based on the polarity of a compound. β-Carotene is a non-polar compound, so it is separated with a non-polar solvent such as hexane[30]. Being highly conjugated, it is deeply colored, and as a hydrocarbon lacking functional groups, it is very lipophilic[31-32].

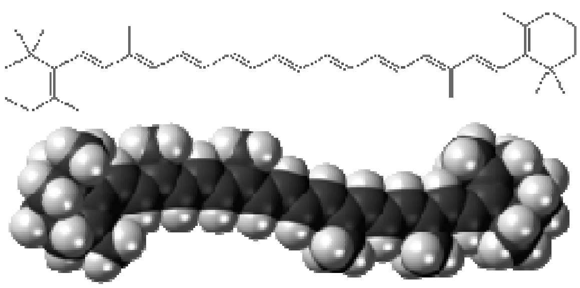


Figure-4
Betacarotene or 1,1'-(3,7,12,16-Tetramethyl-1,3,5,7,9,11,13,15,17-octadecanonaene-1,18-diyl) bis (2,6,6-trimethylcyclohexene)

Comparison of extraction yield: Extraction of natural dye from *Daucus carota* (carrot) using water as solvent. The % yield for extraction using ultrasound and magnetic stirrer compared was obtained. The results indicate that there it is a significant improvement in the % yield of coloring matter extract obtained due to the use of ultrasound. The difference in the enhancement in extraction yield with ultrasound for different plant material could be due to different degree of binding of coloring matter attached to plant cell membranes. Moreover, another important factor is chemical constituents present in plant material responsible for the color (chromophore group) and their solubility nature. Considering the example of the plant, the basic chromophore group is carotenoid having hydroxyl group, which is expected to be extracted better with aqueous solvents such as organic solvents. Whereas, in the case of Green wattle, the basic chromophore is poly phenolic (Kaempferol) which is expected to be extracted better with water.[33,34] Hence, better yields are observed for carrot as compared to Green wattle using water as solvent. These aspects are planned for our future study.

Conclusion

Natural dyes provide an environmentally safe option for coloring of food and other materials. It was found that the application of ultrasound can increase the extraction of dyes from different parts of various plant resources. Extraction was done using ultrasound as well as magnetic stirring methods and the kinetics and the extraction efficiency were compared. The reason for the improvement could be due to better leaching of natural dye material from plant cell membranes and mass transfer to solvent assisted by acoustic cavitation provided by ultrasound. The results indicate that there is about 12–100% improvement in % yield of extract obtained due to the use of ultrasound as compared to magnetic stirring at 45 °C. Various process parameters such as solvent system, temperature, ultrasound power, amount of dye material etc. are interesting for our study as future work. One would expect better extraction efficiency with solvents like n-hexane for those dye materials better soluble in organic solvents. But, our objective is to develop sustainable effective process with aqueous system without using organic solvents. Extraction efficiency may decrease if temperature is lowered than 45 °C; however, higher temperatures could affect plant material itself as they are sensitive to the same. This novel technique can be employed effectively for the extraction of coloring matter from various plant resources even dispensing with conventional heating requirements. This process provides effective utilization of natural resources as eco-friendly method in current situation of global environmental concern.

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