Optimization of Extraction of Natural Dye from Turmeric

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Abstract— Nowadays, natural dyes plays an important role in the textile industry because the needs of replacement synthetic dyes which have a lots of conflict with the environmental issues. This means that the development of natural dyes will give benefits to all sides because users friendly for dyeing industry. The study seeks to explore and capture some natural plants from which dyes can be extracted. The scope is to optimize the extraction of each colour natural dyes from the natural sources. Determination of optimum parameters for extraction of natural dye are temperature, solid liquid ratio and time with one factor at one time (OFAT) followed with an optimization by response surface method (RSM) by utilizing Design Expert V8.0.6. In this research, turmeric will be used as the source of natural dye. The pigment that is contained in turmeric called curcumin. The absorption of curcumin increases with increase of extraction temperature and reaches a maximum value at 60 °C. The extraction time for curcumin reached equilibrium at minutes 25 while the solid liquid ratio on extraction of turmeric found to be 1:10 then it reached equilibrium.

Keywords— *Natural dyes, Turmeric, Curcumin, One factor at one time (OFAT), Response surface method (RSM)*

1. INTRODUCTION

Natural dyes or natural colorants are found in nature and are used to colour textile goods such as cotton [2]. Dyes are widely used in industries such as textiles, leather, paper, and plastics to colour their final products. Among them, the textile industry is one of the extensive dye users for the dyeing process of various fibre types. The harmful effects of synthetic dye and chemicals used at the time of dyeing have forced to concern about the alternative preparation of dye using natural sources. Production of synthetic dyes is dependent on petrochemical source and some of synthetic dyes contain toxic or carcinogenic amines which are not eco-friendly. Synthetic dyes are substituted by natural colour additives and growing at round 2 % annually. Natural dyes produce very uncommon, soothing and soft shades as compared to synthetic dyes [9]. The factor have driven the shift toward the use of natural dyes were increasing price and non-renewable nature of raw oil from which fraction

the synthetic dyes are originated [3]. In the light of these considerations, natural dyes offer sustainable colorants for the future of textile industry. This is mainly attributed to strict environmental standards set by many countries to avoid the health hazards associated with synthetic dyes used in textiles. The recent ban on the use of azo dyes by the European Union has also increased the scope for the use of natural dyes [8]. The natural dyes extract that selected for this study is curcumin pigment which extracted from tumeric. Curcumin or bis(4-hydroxy-3-methohyphenyl)-6-diene-3,5-dione is derived from the rhizome of the plant *curcuma longan L*, which popularly called turmeric, a member of the Zingiberaceae family [5]. From this research, turmeric is selected because it is widely used throughout the history and it's also have good colourfast properties. In addition, it can be easily obtained from anywhere. Curcumin is the main yellow bioactive component of turmeric has been shown to have a wide spectrum of biological actions [1]. The use of non-allergic, non-toxic and eco-friendly on textiles has become a matter of significant importance due to the increased environmental awareness in order to avoid some hazardous synthetic dyes natural dyes [10].

2. EXPERIMENTAL PROCEDURE

A. Materials Description

The turmeric was obtained from a mall in Taman Tas, Kuantan Pahang. The raw material was peeled and then blended into small pieces. The blended turmeric was stored at -20^{o}C not more than 2 days (48 hours) in order to make blend material is kept fresh and to avoid the colour from fading because of oxidation process.

B. Extraction of Natural Dyes

Natural dye was prepared by using water extraction. The purpose of using water extraction is to make sure that the colour is safe from the chemical and harmful substance. Turmeric was first cleaned and the unnecessary part of the turmeric was cut. The turmeric was then blended into small pieces, about 1mm, to increase the surface area. Then, the yellow natural dye was extracted by applying ratio 1:10 corresponding to the ratio of 1 g of raw material to 10 mL of water. The mixture was then centrifuged at 4 ^{o}C, 10000rpm for 15 minutes [7]. The mixture was filtered to collect the supernatant dye. The mixture was centrifuged for the second time at 4 ^{o}C, 12000rpm for 10 minutes to ensure that there is no more sediment or precipitate present in the dye solution. Finally, filtration of the supernatant was done by using stainless filter paper. The resulting extract was used for the further experiment.

C. Optimization of Extracted Natural Dyes

The preparation of natural dyes sample was done as the same procedure by changing one of parameters which called OFAT. The extraction of natural dyes samples were undergo OFAT in order to obtained the optimum conditions of extraction natural dyes for solid liquid ratio/concentration, temperature and time. The readings of absorbance for all samples were measured using UV-VIS Spectrophotometer and recorded. Table below shows the OFAT analysis for extraction of turmeric.

After the range of optimum conditions and absorbance for all parameters were obtained from OFAT approach, the experiment then undergo Central composite design (CCD) in RSM in order to get the optimum value for ratio/concentration, temperature and time.

3. RESULTS AND DISCUSSIONS

The results on effect of three parameters of turmeric extracts were obtained from OFAT which the conditions applied stated in Table 1 where the parameters involved were temperature, time and solid liquid ratio. The extraction was done using distilled water as the solvent.

Table 1: OFAT for Extraction of Turmeric

TURMERIC
Temperature, °C : 30,40,50,60,70,80 **Solid liquid ratio, g/mL:** 1:20 **Time, min** : 10
Solid liquid ratio, g/mL: 1:5,1:10,1:20,1:30,1:40,1:50 **Time, min** : 10 **Temperature, °C** : 60
Time, min : 5,10,15,20,25,30,40 **Solid liquid ratio, g/mL:** 1:20 **Temperature, °C** : 60

A. One factor at one time (OFAT)

Optimization by changing one factor at a time (OFAT) was a common and well studied method but it has many disadvantages like time consuming and does not provide details about the interaction effect of the variables involved in the process [6]. Thus, the Central composite design (CCD) of RSM was used to overcome the disadvantages. The objective of OFAT was to study the effect reaction of extraction on the turmeric dosage, pH, time and temperature. In the first step of optimization process, this method was followed to observe the effective range of factors listed for extraction of yellow natural dye from turmeric. The influences of three operational parameters (solid liquid ratio/concentration, time and temperature) on extraction of natural dyes were evaluated by applied OFAT method. The effect of temperature on extraction of turmeric is demonstrated in Fig. 1. As can be observed, the absorption of curcumin increases with increase of extraction temperature and reaches a maximum value at 60 °C then it decreases. This increase in dye uptake can be attributed to better dye exhaustion at higher temperatures. The temperature caused an increase in the reaction rate in the monitored range from 50 to 70 °C which was reflected in the dye extracted productivity. This increase in dye uptake can be attributed to better dye exhaustion at higher temperatures. However, temperature higher than 60 °C results in decrease in colour strength and attributed decomposition of curcumin at higher temperature. Effect of time on extraction of turmeric is shown in Fig. 2 where the levels of extraction time were varied, ranging from 0 to 50 minutes was tested to determine the possible optimum value for maximum extraction of curcumin. The longer the extraction time, the higher of absorption curcumin until dye exhaustion reached equilibrium and there is decrease in absorption after further increase in time over 25 minutes. The decline in absorbance is attributed to the decomposition of curcumin at longer time at 60 °C. Fig. 3 shows the effect of solid liquid ratio on extraction of turmeric. It is clearly shown that the increases of liquid added into the 1g of solid turmeric, the increases of absorbance which more curcumin absorbed until solid liquid ratio 1:10 then it reached equilibrium.

B. Model Validation

Response surface methodology (RSM) is a collection of statistical tool used to analyze and determine the optimal conditions within the design space of the experimental study [10]. Response surface methodology (RSM) used to provide superb statistical tools for design and analysis of experiments aimed at process optimization [8]. The range of optimum conditions for all parameters were analyze in the software Design Expert V 8.0.6. Factorial designs are widely used to investigate the effects of experimental factors and the interactions between those factors, that is, how the effect of one factor varies with the level of the other factors in a response. The advantages of factorial experiments include the relatively low cost, the reduced number of experiments, and the increased possibilities to evaluate interactions among the variables. The most common first-order designs are the two-level full factorial design and the two-level full fractional design. In these methodologies, each factor is experimentally studied at two levels that are coded as: -1 for low level and +1 for high level. The full factorial design consists of a 2^k experiments (k factors, each experiment at two levels), which is very useful for either preliminary studies or for initial optimization steps, while fractional designs are almost mandatory when the problem involves a large number of factors [9].The validation experiment for predicted optimum conditions was performed in triplicate to check the accuracy of the model using Central composite design (CCD) in RSM. The effect of temperature of extraction, time of the extraction and solid liquid ratio on the extractability of dye from turmeric were determined by dispersing 10.0g of sample in 100 mL of distilled water based on different combinations, as shown in Table 2 and the optical density of curcumin was taken at 419nm. The obtained absorbance was found to be 1.963 which proved the model to be 99.1% accurate when compared with the predicted absorbance 1.954. This result explained that the predicted model had a good agreement with the experimental results.

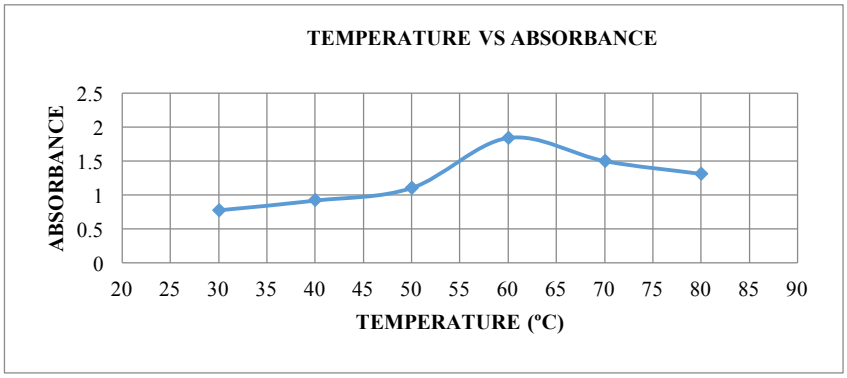

Figure 1 Effect of temperature on extraction of turmeric

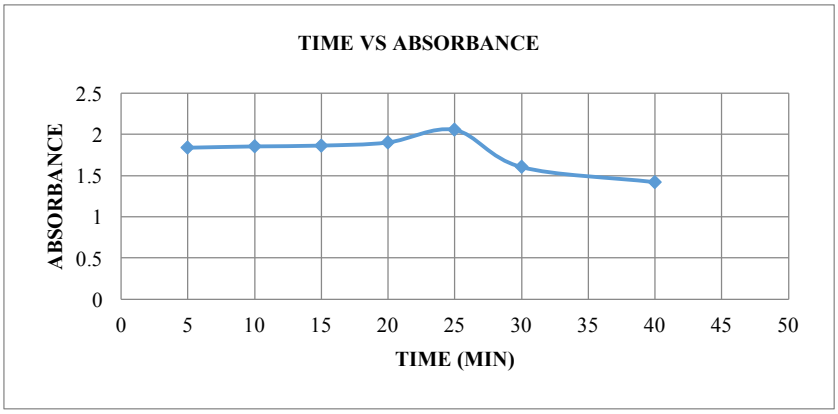

Figure 2 Effect of time on extraction of turmeric

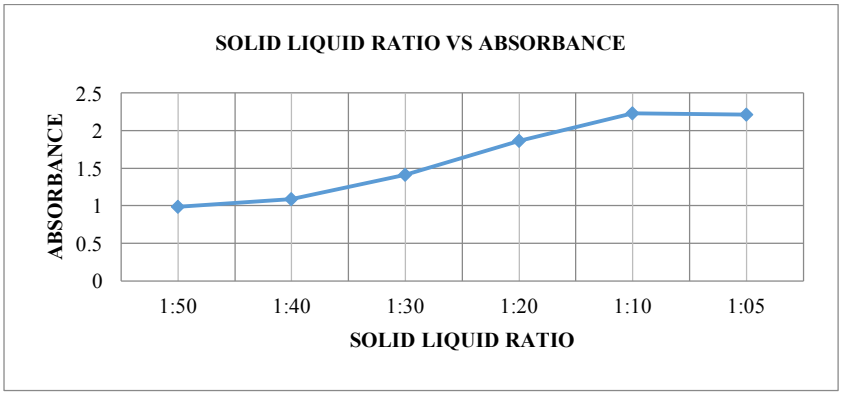

Figure 3 Effect of solid liquid ratio on extraction of turmeric

Table 2: Constraint for Extraction Conditions for Turmeric

Factor	Name	Units	Lower Limit	Upper Limit
A	Temperature	°C	55	65
B	Time	min	20	30
C	Solid Liquid Ratio	g/mL	0.08	0.13

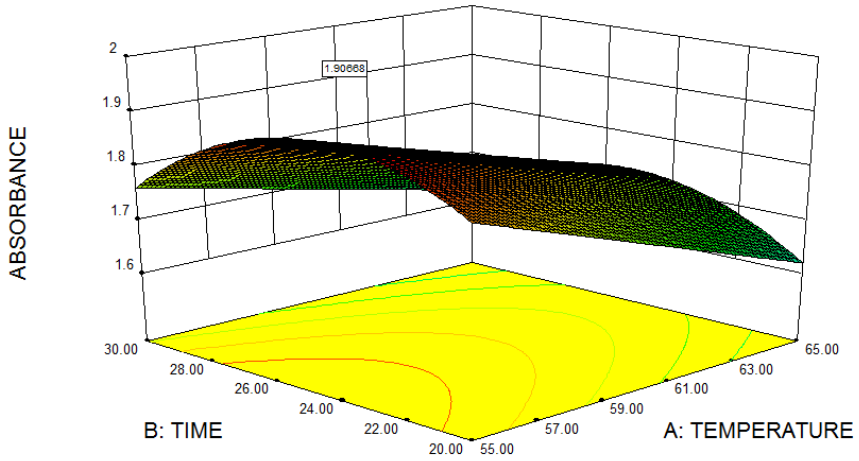

Figure 4: 3D surface plots showing the mutual effect between pair of variables, temperature (A) and time (B) on the extraction of yellow dye from turmeric by keeping the third variable constant at the middle level

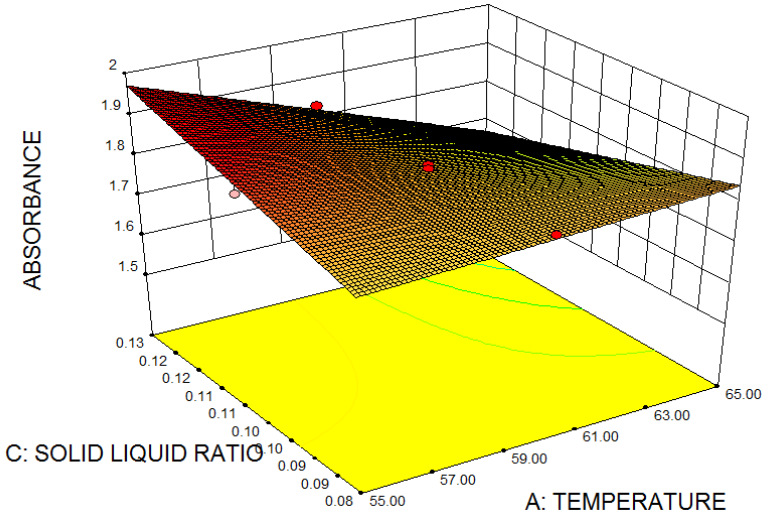

Figure 5: 3D surface plots showing the mutual effect between pair of variables, temperature (A) and solid liquid ratio (C) on the extraction of yellow dye from turmeric by keeping the third variable constant at the middle level

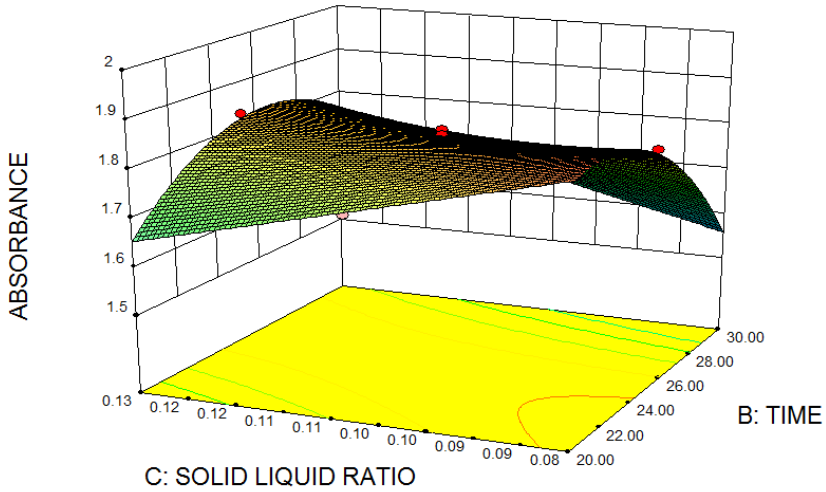

Figure 6: 3D surface plots showing the mutual effect between pair of variables, time (B) and solid liquid ratio (C) on the extraction of yellow dye from turmeric by keeping the third variable constant at the middle level

4. CONCLUSION

The study explained the utilization of turmeric for successful extraction of yellow natural pigment which is curcumin. The extraction of natural dye from turmeric was optimized. Solid liquid ratio and time of extraction play an important role to increase the efficiency of curcumin extraction at higher levels. Moreover, the experimental results revealed that the extraction of curcumin highly favoured low temperatures rather than elevated levels. The optimum conditions for extraction natural dye from turmeric were found to be extraction time: 25 minutes, temperature at 60 °C and solid liquid ratio: 1:10. Validation of the predicted model was fitted 99.1%with the experimental results conducted at the optimum condition which observed in OFAT.

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