

**STUDIES ON STABILIZATION OF BETALAIN FROM (CELOSIA ARGENTEA
VAR.CRISTATA)****H.Vimal**

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ABSTRACT

Celosia argenteavar.cristata is an ornamental plant, the colored vegetative tissues of plants in the family Amaranthaceae contain various inflorescences colour varieties. Inflorescence colour varied from yellow to various shades of red and violet. It was being stated true that red inflorescences of common cockscomb contain a nitrogen containing pigment. It was found that betalain were found in red inflorescences. Therefore *celosia argenteavar.cristata* was used as a potential alternative to the betalains from beet root. In the present study, attempts were carried out to extract betalain from *celosia argenteavar.cristata* and attempts were also made to study the stability of the extracted betalains under factors such as changes in pH, temperature and presence of antioxidants. The activation energy and rate constants for the degradation kinetics were determined. The studies were also carried out to stabilize the extracted betalain by dehydrating them using malto dextrin and gum acacia as filler and coating agent respectively.

Key words: *Celosia argentea var.cristata*, betalain, malto dextrin, dehydration.

INTRUDUCTION

Color is often the first notable characteristic of a food and it influences the expectations of consumers buying the product food colorants play an important role in quality perception. It also influences food handlers who makes quality-related decisions, for example, during visual inspections. More specifically, color predetermines our expectations and perceptions of flavor and taste. Color is often used as an indicator of food quality due to short evaluation times and cost savings. People consider the colors of raw materials, half fabricates, and final products in order to make decisions to accept or reject food products. Additionally, color may also serve as a key to cataloging a food as safe. Undesirable colors of meats, fruits, and vegetables warn us about potential dangers or at least of the presence of undesirable flavors. Thus color is used as a way to identify a food and judge its quality. Food colorants could be either like natural like carotenoids, chlorophyll, anthocyanins, betalain etc or artificial like tartrazine, sunset yellow, ponceau 4R and brilliant blue FCF. Typical

food colorants consumed daily in considerable quantities in human diets are anthocyanins, carotenoids, and chlorophylls. Natural colorants are widely spread throughout nature in fruits, vegetables, seeds, and roots. They are commonly found in raw materials and unprocessed food products.

1.1 Scope of the natural colorants

Colour is one of the most important attributes of foods, being considered as a quality indicator and determining frequently their acceptance. Many naturally coloured foods, such as fruit products, are submitted to colour losses during processing, requiring the use of colorants to restore their colour. Natural colorants have many disadvantages when compared to synthetic ones, including higher cost in use and lower stability. However, people have increasingly avoided synthetic colorants, preferring natural colors, which are considered to be harmless or even healthy. These requirements compelled numerous regulations changes worldwide. For instance, the USA permitted list of synthetic colorants was reduced from 700 to only seven until the beginning of the XXI century. (Azeredo.,2008)

1.2. Classification of natural colorants

Pigments have been classified in accordance with different systems. These systems are clearly defined, but all are closely related; the same type of colorants could be classified in different groups(eg; carotenoids could be ordered in every group). Today, classification of colorants by their origin and legislation are the most important systems. This is in agreement with consumer preferences. In addition, the introduction of natural colorants as additives is not as easy task by the actual FDA, EU, and WHO legislation

1.3. Importance of natural colorants

Colorants have been used to give an attractive presentation to human-made products. Synthetic dyes now replaced with natural colorants. Synthetic colorants were used extensively in foods, medicines, and cosmetics, but through the years their importance diminished. Currently, only seven synthetic pigments can be used in food pigmentation under FDA (Food and Drug Administration) regulations.

2. MATERILS AND METHODS

2.1. Material

Red-colored inflorescence of *Celosia argentea* var. *crinata* purchased from a local market and used fresh inflorescence and stored in plastic bags at -10°C. for natural color extraction.

3. METHODS

3.1.Extraction

To complete extraction of betalains, methanol or ethanol solutions are preferred. It is also recommended that the extraction be carried out at low temperature and in darkness. The extract obtained by this procedure contains a large quantity of sugars; thus, tinctoreal power is low. Consequently, a fermentation process reduces the sugar content and improves the coloring agent. Sometimes, it is desirable to inactivate degradative enzymes by heating (70°C, 2 min.), although this may destroy some of the pigments. By their structural nature, betalains are basic compounds and greater purification can be achieved by a slight acidification with hydrochloric acid or with acidified ethanol (0.4 to 1% HCL); subsequently, the addition of 95% aqueous ethanol yields betaxanthins

3.2. Separation and purification

Common methodologies used in betalains analysis are shown table. Analytical separations include

electrophoresis and TLC. By using electrophoresis, betalain isomers and aglycones have been separated, which makes it a powerful methodology for analysis. Electrophoretic mobility for betaxanthins has been related to indicaxanthin and for betacyanins with betanin. Electrophoresis is in close agreement with the HPLC determination Reports on TLC are scarce because of the high polarity of betalains of the high polarity of betalains; however, introduction of acids improves the separation.

Betalains are directly observed after chromatographic separation. In the preparative purification, the use of ion exchange, followed by column chromatography using polyamide, polyclarc-AT, or polyvinyl pyrrolidone ,sephadex G-15, and G-25, is recommended. The chromatographic and electrophoretic properties of the isolated compounds can be compared with those of the literature to achieve a tentative identification.

Today, the method of choice for chromatographic separation of betalains is HPLC; reverse-phase supports with particle sizes between 3 to 10 μ m are preferred. It must be pointed out that discrepancies between spectrophotometric and HPLC methods have been observed; differences up to 15% have been reported after extended heat treatment of betalains. Such differences have been attributed to degradation products or interfering substances formed during processing. Interestingly, it has been shown that betalain quantization by capillary zone. (Degaldo-Vargas *et al.*,2000).

3.3. Spectrophotometric Identification

Betalains are water soluble, nitrogen-containing pigments, which are synthesized from the amino acid tyrosine into-two structural groups; the red-violet betacyanins and the yellow-orange betaxanthins. Chromophore common to all betalain pigments (stracket *al.*, 2003)the nature of the betalamic acid addition residues determines the pigment classification as betacyanin or betaxanthin. The structural differences reflect in varying appearance of the betalain subgroups. Betacyanins contain a cyclo-3, 4-dihydroxyphenylalanine (cyclo-Dopa) residue.

3.4. Processing and Stability

The chemical stability and colorant properties of three betaxanthins recently identified from *celosia argenteavarities* were evaluated. Lyophilized betaxanthin powders from yellow inflorescence of *celosia* exhibited bright yellow color and high color purity with strong hygroscopicity. The aqueous solutions containing these betaxanthins were bright yellow in pH range 2.2-7.0, and they were most stable at pH 5.5. The betaxanthins in a model system (buffer) were susceptible to heat, and found to be as unstable as red betacyanins(betanin and amaranthine) at high temperatures (>40° C), but more stable at 40°C with the exclusion of light and air. The three betaxanthins had slightly higher pigment retention than amaranthine/ isoamaranthine in crude extracts at 22° C, as verified by HPLC analysis. Lyophilized betaxanthins had much better storage stability (mean 95.0% pigment retention) than corresponding aqueous solutions (14.8%) at 22°C after 20 weeks. Refrigeration (4°C) significantly increased pigment retention of aqueous betaxanthins to 75.5%.

3.5. Techniques for preservation of betalain as natural colorant

The work carried out for improvement and extension of a previously developed process for the production of cactus pear juice. The total yield was increased by 10% through processing whole instead of peeled fruits and by further optimization of pulp enzymation. As an alternative to HTST pasteurization, cross-flow microfiltration was applied for non-thermal cactus pear juice preservation.

Juice concentrates and fruit powders were produced by rotary evaporation and freeze drying at laboratory scale and compared to products obtained at pilot plant- scale applying a three stage column evaporator and spray drying, respectively. To monitor process-related quality changes, the resulting products were characterized in terms of color and selected quality parameters. For both juice concentrates and fruit powders, initial color characteristic were retained. In addition to betaninisomerisation, C11- epimerization of proline-betaxanthin was demonstrated to be a valuable indicator of the respective heat treatment applied

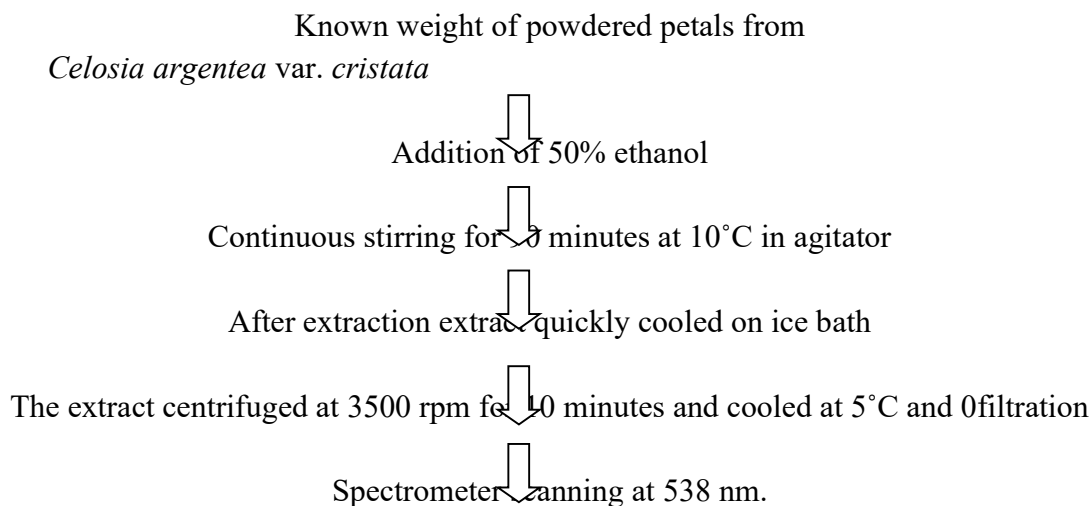
3.6. Spray-dried production of Amaranthusbetacyanin pigments

Amaranthusbetacyanin extracts were spray-dried using a range of maltodextrins [10-25 dextrose equivalent (DE)] as carrier and coating agents at 5 inlet/outlet air temperatures and 4 feed solid contents (Cai&Croke., 2000). Higher inlet/outlet air temperatures caused greater betacyanin loss during spray drying, and affected slightly the pigment stability during storage. Temperatures of inlet/outlet (165-180° C/ 92-96°C) and 20-40% feed solid content were shown to be optimal for production of Amaranthusbetacyanin extracts with less pigment degradation. Adding maltodextrins significantly reduces the hygroscopicity of the betacyanin extracts and enhance storage stability. Maltodextrins of 25 and 10 DE gave the highest pigment retention (97.3 and 88.7%) at 5 and 32% relative humidity (RH), respectively. The 25DE/10DE mixed powders provided a longer predicted half-life (63.6 weeks) in a 32% RH container filled with oxygen at 25 °C, compared to the 25 DE (49.2 weeks) and the 10 DE (43.6 weeks) powders separately. The best spray-dried pigment powder made was superior to commercial red beet powder made was superior to commercial red beet powder in physical properties. The results demonstrate the feasibility of production of spray-dried Amaranthusbetacyanin extracts as a food-grade colorant.

4. METHODOLOGY

4.1. Extraction

The method followed was based on the report of Delgado-Vargas *et al.*,2000 with modifications.



4.2. HPLC Characterization

The method followed was based on the report of (Florian *et al.*,2007) with modifications. Betalain analysis performed on a prominence HPLC (SHIMAZU, Japan) equipped with LC solution software.

For characterization, acetonitrile/water (80/20 v/v) was used as mobile phase and C18 reverse phase column (Arthodiacyl ethyl silica gel) was used as a stationary phase. The samples were filtered through 0.25 micron membrane filter. 20 µl of the sample was injected, operating at a flow rate of 1 ml/min and a temperature of 30°C, Run time 60 min. The peaks were observed at the range of 538 nm using diode array detector.

4.3. Stability Studies

4.3.1. Effect of pH on stability

The sample was extracted with different pH buffers varying from 3 to 7. They were incubated at a temperature of (30± 2°C). The stability of betalain was studied by periodically removing aliquots of the sample and observing the absorbance at 538 nm.

4.3.2. Effect of temperature on stability

The sample was extracted with different pH buffers varying from 3 to 7 and the temperatures was varied from 5°C, 15°C, 25°C, 30°C, 60°C, 70°C, 90°C. The stability of betalain was studied by periodically removing aliquots of the sample and observing the absorbance at 538 nm.

4.3.3. Storage stability of crude betalain extracts

To 10 ml of crude extract was added 50 ppm and 100 ppm of ascorbic acid and kept in lower temperature 5°C and RT (Wooet *al.*, 2011, Yi-Zhonge *et al.*, 2005). The stability of betalains was studied by periodically removing aliquots of the sample and observing the absorbance. Calculated % color retention by using following formula, Color Retention (%) = C value at X days x 10² / C value at zero storage time

4.3.4. Calculation of activation energy (Ea)

Temperature dependence of betalain degradation and color loss was determined by the Arrhenius equation:

$$k = k_0 \cdot e^{-E_a/RT}$$

where, E_a is the activation energy (Kcal mol⁻¹), k is the constant, k₀ is the pre-exponential factor, R is the universal gas constant (1.987 kcal mol⁻¹), and T is the absolute temperature (K). Taking logarithm of both side of Arrhenius equation,

$$\ln k = \ln k_0 - E_a/RT$$

Then arranged this equation to fit the equation of straight line,

$$y = m x + c$$

$$\ln k = E_a/RT [1/T] + \ln k_0$$

According to this equation plot graph of -ln kVs 1/T and find the activation energy.

4.3.5. Calculation of half- life values (t_{1/2})

The half-life values of betalain degradation and color loss were also calculated using the equation given below:

$$t_{1/2} = \ln 2/k$$

where, K is the rate constant (min⁻¹).

4.3.6. Conversion of natural colorant in powder form by using spray dryer

Natural extract of plant of amaranthaceae lab scale spray drying at varying inlet temp. 140 ,150,160 C, outlet temp.70,80,90 C respectively for 25-35 min. Then dissolved in water and take spectrometer

scanning at 538 nm and calculated % color retention by using following formula,

$$\text{Color Retention (\%)} = \frac{\text{C value at X days}}{\text{C value at zero storage time}} \times 10^2$$

Where C is the concentration of betalain.

4.3.7. Composite Scoring Test

This method is useful in grading products and composition of quality attributes by indicating which characteristic is at fault in poor products. It gives more information than the straight numerical method.

| Quality | Possible Score | Sample Scores | | | |
|--------------------|----------------|---------------|---|---|---|
| | | A | B | C | D |
| Color | 20 | | | | |
| Consistency | 20 | | | | |
| Flavour | 40 | | | | |
| Absence of defects | 20 | | | | |
| Total score | 100 | | | | |

5. RESULT AND DISCUSSION

5.1. HPLC Characterization

HPLC profile of the extracted and purified betalains is given in figure 4. An observed from the chromatogram. The chromatogram showed a major peak with a retention time of 1.818 for celosia argentea var. cristata at 538nm.

5.1.1 HPLC chromatograms

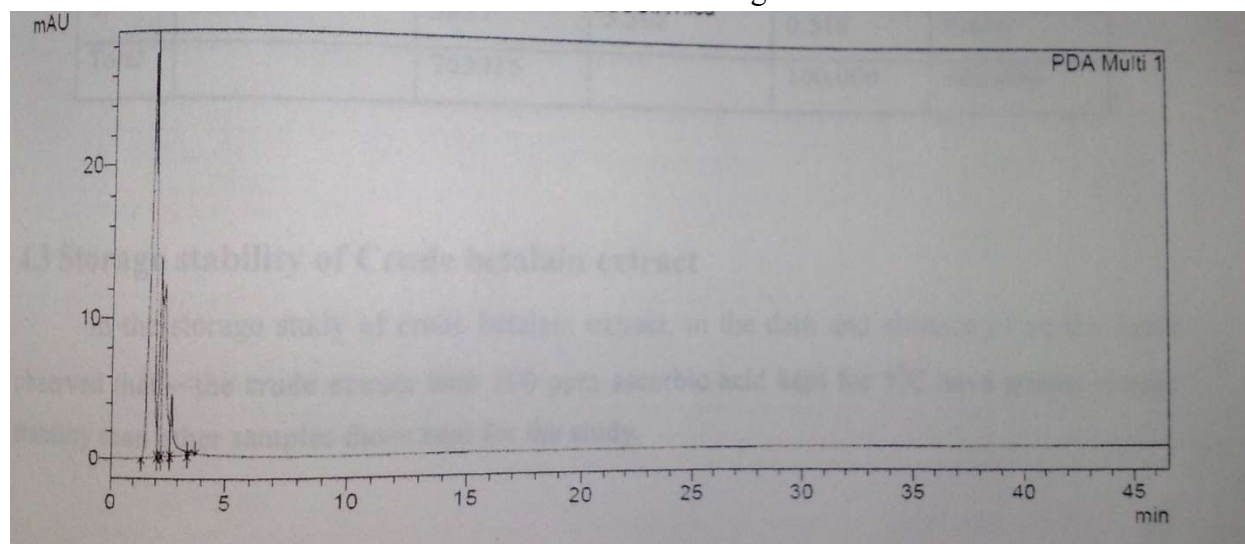


Figure.1– HPLC Chromatograms of celosia argentea var. cristata

5.1.2 Peak Table

PDA at 538 nmTable 2: peak table of *celosia argenteavar. cristata*

| PEAK | RETENTION TIME | AREA | PEAK START | AREA% | HEIGHT % |
|-------|----------------|--------|------------|---------|----------|
| 1. | 1.818 | 451531 | 1.365 | 59.108 | 46.982 |
| 2. | 2.088 | 102227 | 2.009 | 13.657 | 23.918 |
| 3. | 2.539 | 150385 | 2.125 | 20.752 | 20.898 |
| 4. | 2.896 | 45755 | 2.365 | 5.965 | 7.755 |
| 5. | 3.559 | 3579 | 3.399 | 0.518 | 0.446 |
| TOTAL | | 753477 | | 100.000 | 100.000 |

5.1.3. Storage stability of crude betalain extract

In the storage study of crude betalain extract, in the dark and absence of air the result observed that the crude extract with 100 ppm ascorbic acid kept for 5°C have greater storage stability than other samples those kept for the study.

Table.3.Storage stability of crude betalain extracts in the dark and absence of air.

| Sample | Botanical Source | Storage time (days) | Color Retention(%) | | | | | |
|---------------|--------------------------------|---------------------|--------------------|-------|-------|------------|-------|-------|
| | | | 5°C | | | Room Temp. | | |
| | | | A | B | C | A | B | C |
| Crude Extract | Celosia Argentea var. cristata | 3 | 64.07 | 62.88 | 81.91 | 65.82 | 83.13 | 86.02 |
| | | 6 | 27.05 | 44.32 | 54.25 | 29.11 | 49.39 | 45.16 |
| | | 9 | 8.23 | 12.37 | 36.17 | - | 26.50 | 29.36 |
| | | 12 | - | 2.06 | 18.08 | - | - | - |
| | | 15 | - | - | 8.51 | - | - | - |

Color Retention(%)= C value at X× days 10²/C value at zero storage time. (Cai and croke., 1999)
A= crude extract,
B= Crude extract+ 50 ppm Ascorbic acid,
C= Crude extract + 100 ppm Ascorbic acid.

5.1.4 Color Retention (%) in Lab-scale spray dryer natural colorant

Table.4. Color Retention in (%) in lab scale spray dryer natural colorant

| Sample | Form of the sample | Color Retention(%) |
|--|--------------------|--------------------|
| Celosia argentea var. cristata+50gm maltodextrin | Powder | 89.53 |
| Celosia argentea var.cristata+10gm maltodextrin+1gm gum acacia | Powder | 83.14 |

Natural extract of plant of amaranthaceae lab scale spray drying at inlet temp. 140 C, outlet temp.80 C for 25-35 min.then dissolved in water and take spectrometer scanning at 538 nm. The results found that betalain in powdered form have high color retention than concentrate form.



5.1.5. Composite Scoring Test

The evaluation of the product done by six expert persons and as evaluation result product

Table.5. Composite Scoring Test Score Card

| Quality | Possible score | Sample Scores | |
|---|----------------|---------------|-------|
| | | A | B |
| Color | 20 | 14.52 | 11.26 |
| Consistency | 20 | 15.66 | 12.11 |
| Flavor | 40 | 29.83 | 25.11 |
| Absence of defects | 20 | 13.22 | 11.33 |
| Total scores | 100 | 73.23 | 59.81 |
| A= Celosia argentea var. cristata+ Maltodextrin(powder) | | | |
| B= Celosia argentea var. cristata+ Maltodextrin+ gum acacia(powder) | | | |

5.1.7. Color degradation kinetics

Color degradation increasing with the increase in the temperature and less degradation occurred at lower temperature 5°C, 15°C, 25°C and Room temperature. Color higher at the pH 3, 6 and 7. Less color degradation occurred in the pH range 4-5 at the lower temperature. Towards better understanding of the degradation kinetics the activation energy and rate of constant determined for pH 2-6 with temperature range 10°C, 30°C, 50°C, 70°C. Obtained optimum pH 5 for *Celosia argentea* var. *cristata* processing.

Table.6 first order kinetics study for color degradation of *Celosia argentea* var. *cristata*.

| pH | Temp. (°C) | Time (min) | Concentration (mg/kg) | In (C/Co) | k = -ln(C/Co)/t (min ⁻¹) | t _{1/2} (min) | k value by graph | ln k | Ea (kcal mol ⁻¹ /kg°K) |
|----|------------|------------|-----------------------|-----------------------|--|------------------------|----------------------|------|-----------------------------------|
| 3 | 10°C | 0 | 175.07 | | k ₀ = | | 4.2×10 ⁻⁴ | 1.38 | 1.78 |
| | | 10 | 173.42 | 4.11×10 ₋₃ | k ₁₀ =4.11×10 ₋₄ | 732.43 | | | |
| | | 20 | 171.54 | 8.84×10 ₋₃ | k ₂₀ =4.42×10 ₋₄ | 716.73 | | | |
| | | 30 | 168.02 | 1.78×10 ₋₂ | k ₃₀ =5.93×10 ₋₄ | 507.63 | | | |
| | | 40 | 167.12 | 2.01×10 ₋₂ | k ₄₀ =5.02×10 ₋₄ | 599.66 | | | |
| | | 50 | 166.23 | 2.25×10 ₋₂ | k ₅₀ =4.50×10 ₋₄ | 668.95 | | | |
| | | 60 | 165.43 | 2.45×10 ₋₂ | k ₆₀ =4.08×10 ₋₄ | 752.57 | | | |
| | 30°C | 0 | 170.53 | | k ₀ = | | 3.2×10 ⁻⁴ | 1.51 | |
| | | 10 | 169.12 | 3.60×10 ₋₃ | k ₁₀ =3.60×10 ₋₄ | 836.19 | | | |
| | | 20 | 168.37 | 5.53×10 ₋₃ | k ₂₀ =2.76×10 ₋₄ | 1114.92 | | | |
| | | 30 | 166.49 | 1.04×10 ₋₂ | k ₃₀ =3.46×10 ₋₄ | 885.38 | | | |
| | | 40 | 164.36 | 1.60×10 ₋₂ | k ₄₀ =4.00×10 ₋₄ | 752.57 | | | |
| | | 50 | 163.79 | 1.75×10 ₋₂ | k ₅₀ =3.50×10 ₋₄ | 860.08 | | | |
| | | 60 | 162.11 | 2.19×10 ₋₂ | k ₆₀ =3.65×10 ₋₄ | 824.73 | | | |
| | 50°C | 0 | 135.01 | | k ₀ = | | 5.4×10 ⁻⁴ | 1.16 | |

| | | | | | | | | | |
|--|------|----|--------|-----------------------|--------------------------------|--------|----------------------|------|--|
| | | 10 | 133.79 | 3.94×10^{-3} | $k_{10} = 3.94 \times 10^{-4}$ | 771.87 | | | |
| | | 20 | 131.81 | 1.04×10^{-2} | $k_{20} = 5.20 \times 10^{-4}$ | 578.90 | | | |
| | | 30 | 129.11 | 1.94×10^{-2} | $k_{30} = 6.46 \times 10^{-4}$ | 465.99 | | | |
| | | 40 | 127.43 | 2.50×10^{-2} | $k_{40} = 6.25 \times 10^{-4}$ | 481.64 | | | |
| | | 50 | 126.25 | 2.91×10^{-2} | $k_{50} = 5.82 \times 10^{-4}$ | 517.23 | | | |
| | | 60 | 125.31 | 3.23×10^{-2} | $k_{60} = 5.38 \times 10^{-4}$ | 559.53 | | | |
| | 70°C | 0 | 98.82 | | $k_0 =$ | | 7.9×10^{-4} | 1.07 | |
| | | 10 | 96.12 | 1.20×10^{-2} | $k_{10} = 1.20 \times 10^{-3}$ | 2508.5 | | | |
| | | 20 | 94.21 | 2.07×10^{-2} | $k_{20} = 1.03 \times 10^{-3}$ | 292.26 | | | |
| | | 30 | 92.47 | 2.88×10^{-2} | $k_{30} = 9.60 \times 10^{-4}$ | 313.57 | | | |
| | | 40 | 91.11 | 3.52×10^{-2} | $k_{40} = 8.80 \times 10^{-4}$ | 342.07 | | | |
| | | 50 | 90.71 | 3.71×10^{-2} | $k_{50} = 7.42 \times 10^{-4}$ | 406.79 | | | |
| | | 60 | 88.56 | 4.76×10^{-2} | $k_{60} = 7.93 \times 10^{-4}$ | 379.60 | | | |

| pH | Temp (°C) | Time (min.) | Concentration (mg/kg) | In (C/Co) | $k = -\ln(C/Co)/t$ (min ⁻¹) | t _{1/2} (min) | k value by graph | ln k | Ea (kcal mol ⁻¹ /kg°K) |
|----|-----------|-------------|-----------------------|-----------------------|---|------------------------|----------------------|------|-----------------------------------|
| 4 | 10°C | 0 | 230.71 | | $k_0 =$ | | 2.5×10^{-4} | 1.62 | 1.51 |
| | | 10 | 229.81 | 1.69×10^{-3} | $k_{10} = 1.69 \times 10^{-4}$ | 1781.24 | | | |
| | | 20 | 227.67 | 5.76×10^{-3} | $k_{20} = 2.88 \times 10^{-4}$ | 1075.10 | | | |
| | | 30 | 225.23 | 1.04×10^{-2} | $k_{30} = 3.46 \times 10^{-4}$ | 885.38 | | | |
| | | 40 | 224.20 | 1.24×10^{-2} | $k_{40} = 3.10 \times 10^{-4}$ | 971.06 | | | |
| | | 50 | 223.17 | 1.44×10^{-2} | $k_{50} = 2.88 \times 10^{-4}$ | 1075.1 | | | |

| | | | | | | | |
|------|----|--------|-----------------------|--------------------------------|--------|----------------------|-----|
| | | | $\times 10^{-2}$ | $\times 10^{-4}$ | 0 | | |
| | 60 | 221.91 | 1.68×10^{-2} | $k_{60} = 2.80 \times 10^{-4}$ | 1075.1 | | |
| | | | | | 0 | | |
| 30°C | 0 | 194.23 | | $k_0 =$ | | 4.0×10^{-4} | 1.4 |
| | 10 | 192.31 | 4.31×10^{-3} | $k_{10} = 4.31 \times 10^{-4}$ | 700.06 | | 1 |
| | 20 | 190.77 | 7.80×10^{-3} | $k_{20} = 3.90 \times 10^{-4}$ | 771.87 | | |
| | 30 | 188.81 | 1.22×10^{-2} | $k_{30} = 4.66 \times 10^{-4}$ | 654.41 | | |
| | 40 | 186.68 | 1.07×10^{-2} | $k_{40} = 2.67 \times 10^{-4}$ | 1157.8 | | |
| | 50 | 187.72 | 1.48×10^{-2} | $k_{50} = 2.96 \times 10^{-4}$ | 1016.9 | | |
| | 60 | 186.13 | 1.84×10^{-2} | $k_{60} = 3.06 \times 10^{-4}$ | 1003.4 | | |
| | | | | | 3 | | |
| 50°C | 0 | 157.63 | | $k_0 =$ | | 4.7×10^{-4} | 1.3 |
| | 10 | 155.44 | 6.07×10^{-3} | $k_{10} = 6.70 \times 10^{-4}$ | 501.71 | | 2 |
| | 20 | 153.23 | 1.22×10^{-2} | $k_{20} = 6.10 \times 10^{-4}$ | 493.49 | | |
| | 30 | 151.37 | 1.75×10^{-2} | $k_{30} = 5.83 \times 10^{-4}$ | 519.07 | | |
| | 40 | 150.71 | 1.94×10^{-2} | $k_{40} = 4.85 \times 10^{-4}$ | 627.14 | | |
| | 50 | 149.13 | 2.40×10^{-2} | $k_{50} = 4.80 \times 10^{-4}$ | 627.14 | | |
| | 60 | 147.01 | 3.02×10^{-2} | $k_{60} = 5.33 \times 10^{-4}$ | 567.98 | | |
| | | | | | | | |
| 70°C | 0 | 119.52 | | $k_0 =$ | | 6.1×10^{-4} | 0.9 |
| | 10 | 117.47 | 7.51×10^{-3} | $k_{10} = 7.51 \times 10^{-4}$ | 401.37 | | 1 |
| | 20 | 115.74 | 1.39×10^{-2} | $k_{20} = 6.95 \times 10^{-4}$ | 436.27 | | |
| | 30 | 113.84 | 2.11×10^{-2} | $k_{30} = 7.03 \times 10^{-4}$ | 430.04 | | |
| | 40 | 112.17 | 2.75×10^{-2} | $k_{40} = 6.87 \times 10^{-4}$ | 442.69 | | |
| | 50 | 111.77 | 2.91×10^{-2} | $k_{50} = 5.82 \times 10^{-4}$ | 519.01 | | |
| | | | | | | | |

| | | | | | | | | | |
|--|--|----|--------|-----------------------|--------------------------------|--------|--|--|--|
| | | 60 | 109.10 | 3.96×10^{-2} | $k_{60} = 6.60 \times 10^{-4}$ | 456.10 | | | |
|--|--|----|--------|-----------------------|--------------------------------|--------|--|--|--|

| pH | Temp (°C) | Time (min.) | Concentration (mg/kg) | In (C/Co) | $k = -\ln(C/Co)/t$ (min ⁻¹) | t _{1/2} (min) | k value by graph | In k | Ea (kcal mol ⁻¹ /kg°K) |
|----|-----------|-------------|-----------------------|-----------------------|---|------------------------|----------------------|------|-----------------------------------|
| 5 | 10°C | 0 | 239.70 | | $k_0 =$ | | 2.9×10^{-4} | 1.6 | 1.43 |
| | | 10 | 238.49 | 2.19×10^{-3} | $k_{10} = 2.19 \times 10^{-4}$ | 1433.47 | | | |
| | | 20 | 236.14 | 6.49×10^{-3} | $k_{20} = 3.24 \times 10^{-4}$ | 940.71 | | | |
| | | 30 | 234.71 | 9.13×10^{-3} | $k_{30} = 3.04 \times 10^{-4}$ | 1003.43 | | | |
| | | 40 | 232.84 | 1.26×10^{-2} | $k_{40} = 3.15 \times 10^{-4}$ | 971.06 | | | |
| | | 50 | 230.29 | 1.73×10^{-2} | $k_{50} = 3.46 \times 10^{-4}$ | 885.38 | | | |
| | | 60 | 229.33 | 1.92×10^{-2} | $k_{60} = 3.20 \times 10^{-4}$ | 940.71 | | | |
| | 30°C | 0 | 200.01 | | $k_0 =$ | | 3.5×10^{-4} | 1.42 | |
| | | 10 | 198.13 | 4.10×10^{-3} | $k_{10} = 4.10 \times 10^{-4}$ | 734.21 | | | |
| | | 20 | 196.71 | 7.22×10^{-3} | $k_{20} = 3.6 \times 10^{-4}$ | 836.19 | | | |
| | | 30 | 194.45 | 1.22×10^{-3} | $k_{30} = 4.06 \times 10^{-5}$ | 7527.74 | | | |
| | | 40 | 192.77 | 1.60×10^{-2} | $k_{40} = 4.00 \times 10^{-4}$ | 7527.70 | | | |
| | | 50 | 191.61 | 1.86×10^{-2} | $k_{50} = 3.72 \times 10^{-4}$ | 813.59 | | | |
| | | 60 | 190.07 | 2.22×10^{-2} | $k_{60} = 3.66 \times 10^{-4}$ | 836.19 | | | |
| | 50°C | 0 | 169.77 | | $k_0 =$ | | 4.4×10^{-4} | 1.28 | |
| | | 10 | 168.14 | 4.18×10^{-3} | $k_{10} = 4.18 \times 10^{-4}$ | 734.21 | | | |

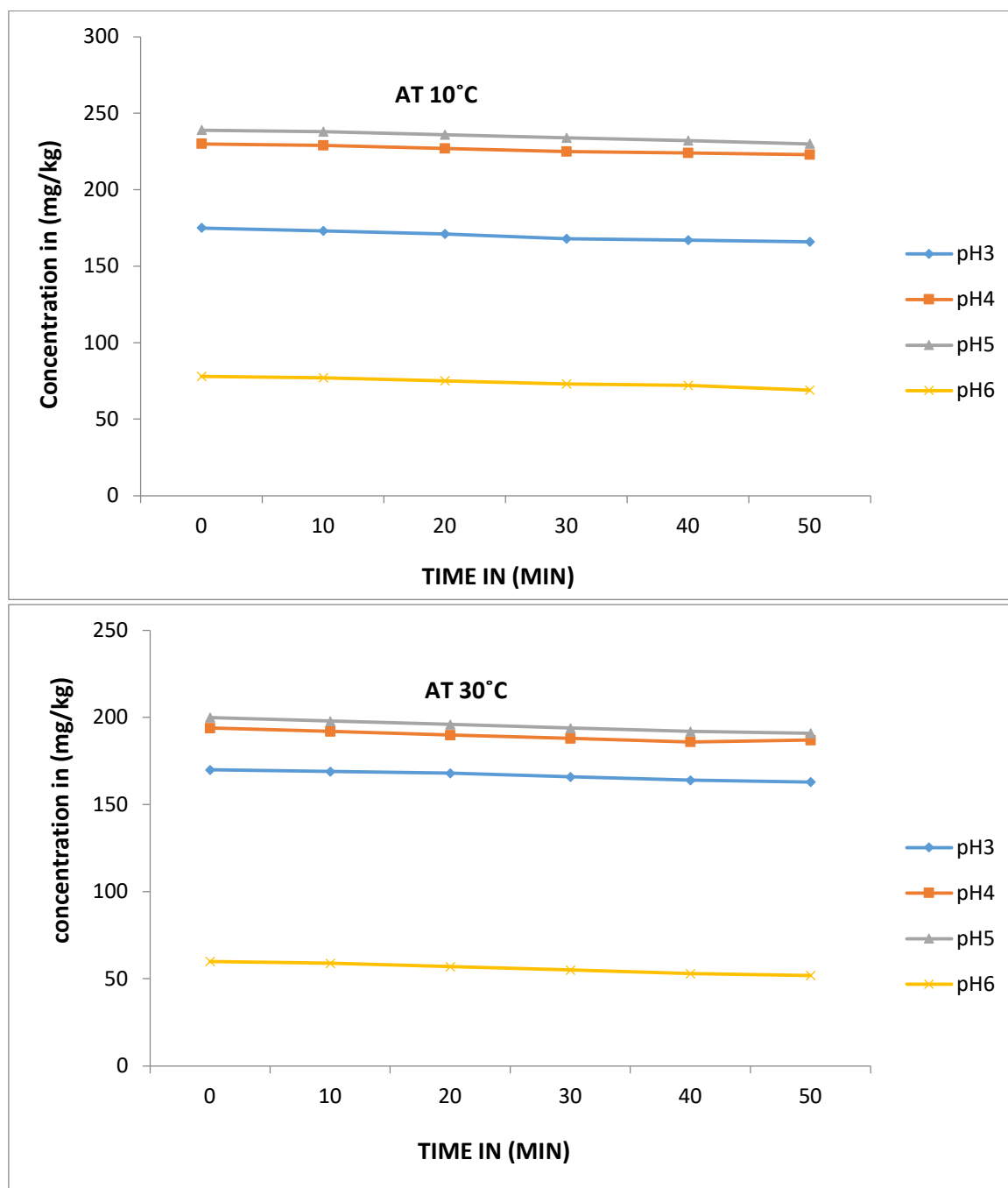
| | | | | | | | | | |
|--|------|----|--------|-----------------------|--------------------------------|--------|----------------------|------|--|
| | | 20 | 166.61 | 8.15×10^{-3} | $k_{20} = 4.07 \times 10^{-4}$ | 752.57 | | | |
| | | 30 | 164.54 | 1.35×10^{-2} | $k_{30} = 4.50 \times 10^{-4}$ | 668.95 | | | |
| | | 40 | 162.55 | 1.88×10^{-2} | $k_{40} = 4.70 \times 10^{-4}$ | 640.48 | | | |
| | | 50 | 160.17 | 2.52×10^{-2} | $k_{50} = 5.00 \times 10^{-4}$ | 602.05 | | | |
| | | 60 | 158.72 | 2.92×10^{-2} | $k_{60} = 4.86 \times 10^{-4}$ | 627.14 | | | |
| | 70°C | 0 | 130.71 | | $k_0 =$ | | 5.7×10^{-4} | 1.23 | |
| | | 10 | 129.44 | 4.24×10^{-3} | $k_{10} = 4.24 \times 10^{-4}$ | 716.73 | | | |
| | | 20 | 127.50 | 1.07×10^{-2} | $k_{20} = 5.35 \times 10^{-4}$ | 567.98 | | | |
| | | 30 | 125.88 | 1.63×10^{-2} | $k_{30} = 5.43 \times 10^{-4}$ | 557.46 | | | |
| | | 40 | 123.71 | 2.39×10^{-2} | $k_{40} = 5.97 \times 10^{-4}$ | 510.22 | | | |
| | | 50 | 121.49 | 3.17×10^{-2} | $k_{50} = 6.34 \times 10^{-4}$ | 477.82 | | | |
| | | 60 | 119.79 | 3.78×10^{-2} | $k_{60} = 6.30 \times 10^{-4}$ | 477.82 | | | |

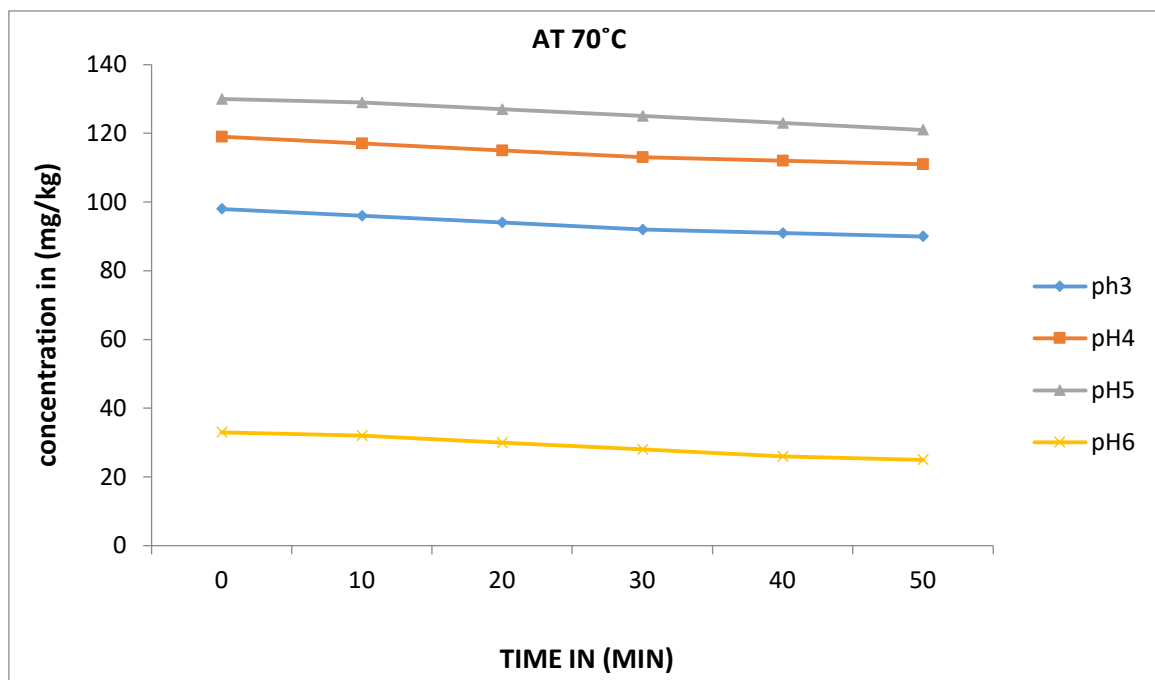
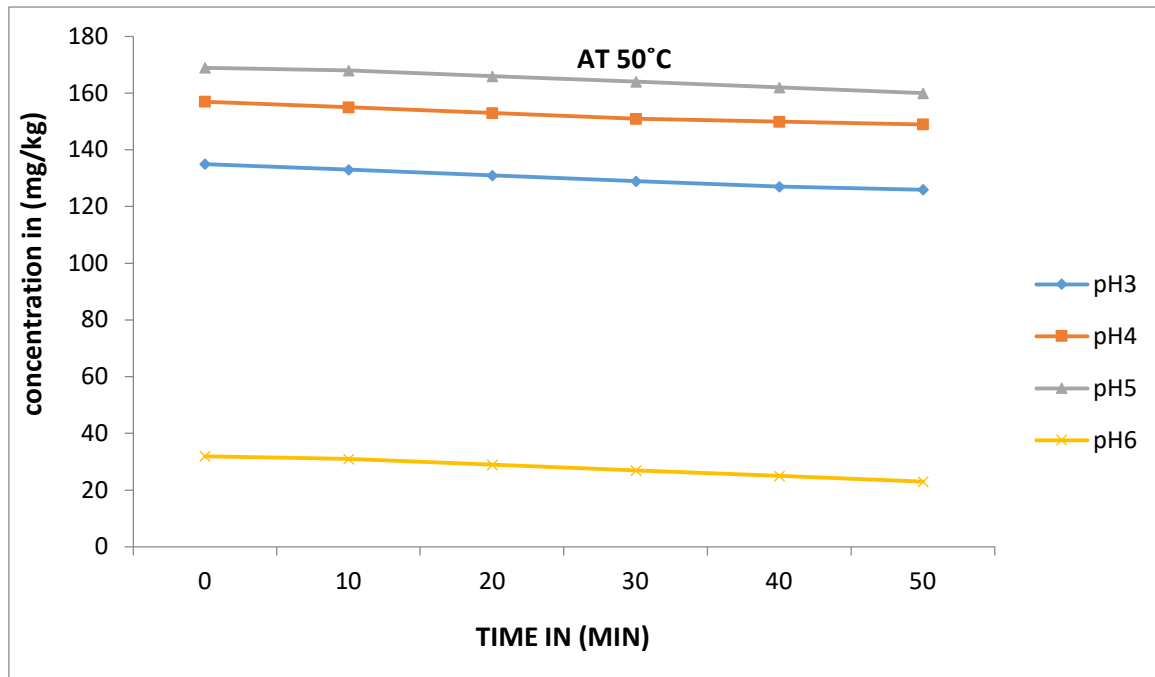
| pH | Temp (°C) | Time (min.) | Concentration (mg/kg) | In (C/Co) | $k = -\ln(C/Co)/t$ (min ⁻¹) | t _{1/2} (min) | k value by graph | In k | Ea (kcal mol ⁻¹ /kg°K) |
|----|-----------|-------------|-----------------------|-----------------------|---|------------------------|----------------------|------|-----------------------------------|
| 6 | 10°C | 0 | 78.07 | | $k_0 =$ | | 9.4×10^{-4} | 0.99 | 2.62 |
| | | 10 | 77.88 | 1.002 | $k_{10} = 0.1002$ | 3.004 | | | |
| | | 20 | 75.02 | 1.73×10^{-2} | $k_{20} = 8.65 \times 10^{-4}$ | 350.03 | | | |
| | | 30 | 73.23 | 2.77×10^{-2} | $k_{30} = 9.23 \times 10^{-4}$ | 327.20 | | | |
| | | 40 | 72.41 | 3.26×10^{-2} | $k_{40} = 8.15 \times 10^{-4}$ | 371.64 | | | |
| | | 50 | 69.77 | 4.88×10^{-2} | $k_{50} = 9.76 \times 10^{-4}$ | 310.3 | | | |

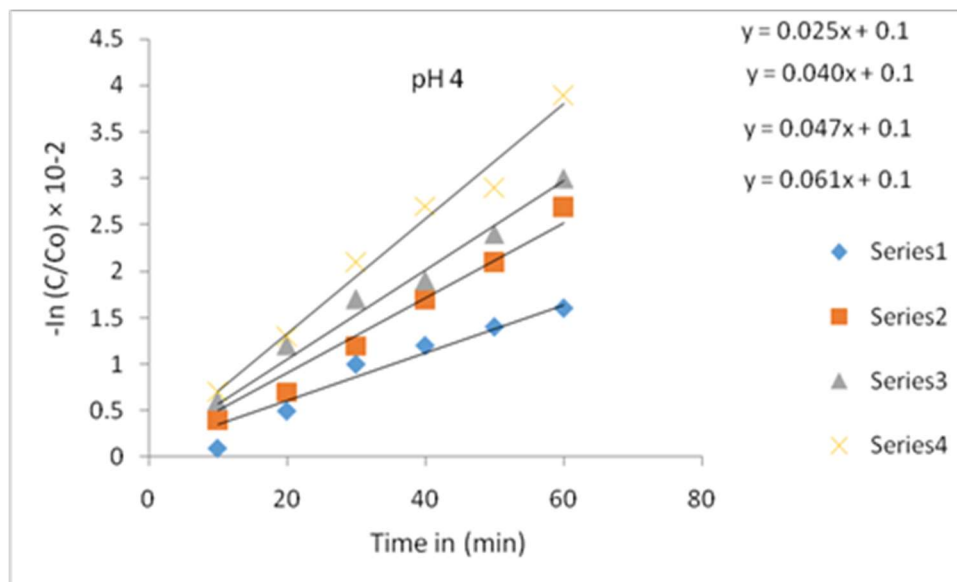
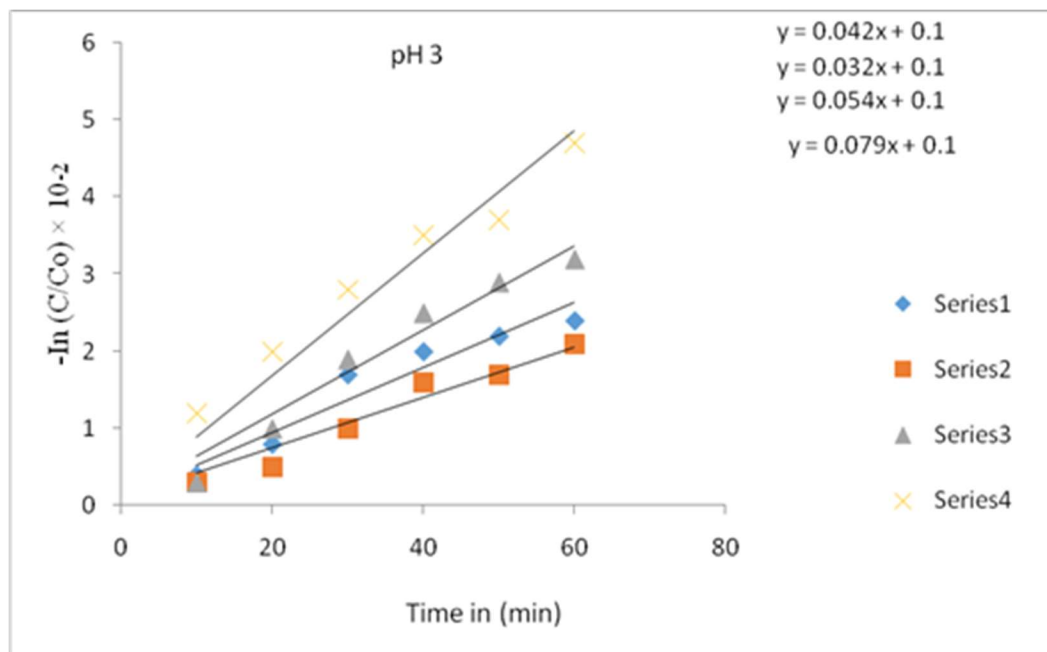
| | | | | | | | |
|------|----|-------|------------------------|---------------------------------|--------|----------------------|------|
| | | | 2 | 4 | 4 | | |
| | 60 | 67.17 | 6.53×10^{-2} | $k_{60} = 1.088 \times 10^{-3}$ | 278.73 | | |
| 30°C | 0 | 60.97 | | $k_0 =$ | | 1.2×10^{-3} | 0.96 |
| | 10 | 59.33 | 1.18×10^{-2} | $k_{10} = 1.18 \times 10^{-3}$ | 255.11 | | |
| | 20 | 57.44 | 2.59×10^{-2} | $k_{20} = 1.29 \times 10^{-3}$ | 233.35 | | |
| | 30 | 55.91 | 3.70×10^{-2} | $k_{30} = 1.23 \times 10^{-3}$ | 244.73 | | |
| | 40 | 53.17 | 5.94×10^{-2} | $k_{40} = 1.48 \times 10^{-3}$ | 203.39 | | |
| | 50 | 52.41 | 6.57×10^{-2} | $k_{50} = 1.31 \times 10^{-3}$ | 229.79 | | |
| | 60 | 51.57 | 7.27×10^{-2} | $k_{60} = 1.21 \times 10^{-3}$ | 248.78 | | |
| 50°C | 0 | 32.87 | | $k_0 =$ | | 2.6×10^{-3} | 0.39 |
| | 10 | 31.44 | 1.93×10^{-3} | $k_{10} = 1.93 \times 10^{-3}$ | 155.97 | | |
| | 20 | 29.54 | 4.63×10^{-2} | $k_{20} = 2.31 \times 10^{-3}$ | 130.31 | | |
| | 30 | 27.61 | 7.57×10^{-2} | $k_{30} = 2.52 \times 10^{-3}$ | 119.45 | | |
| | 40 | 25.94 | 0.102×10^{-1} | $k_{40} = 2.55 \times 10^{-3}$ | 118.05 | | |
| | 50 | 23.77 | 0.140×10^{-1} | $k_{50} = 2.80 \times 10^{-3}$ | 107.51 | | |
| | 60 | 21.81 | 0.178 | $k_{60} = 2.96 \times 10^{-3}$ | 101.69 | | |
| 70°C | 0 | 33.01 | | $k_0 =$ | | 2.1×10^{-2} | 0.31 |
| | 10 | 32.71 | 3.96×10^{-3} | $k_{10} = 3.96 \times 10^{-4}$ | 760.17 | | |
| | 20 | 30.47 | 3.47×10^{-2} | $k_{20} = 1.73 \times 10^{-3}$ | 174.00 | | |
| | 30 | 28.50 | 6.38×10^{-2} | $k_{30} = 2.12 \times 10^{-3}$ | 141.99 | | |
| | 40 | 26.17 | 0.1001 | $k_{40} = 2.50 \times 10^{-3}$ | 120.41 | | |
| | 50 | 25.41 | 0.1130 | $k_{50} = 2.26 \times 10^{-3}$ | 133.19 | | |

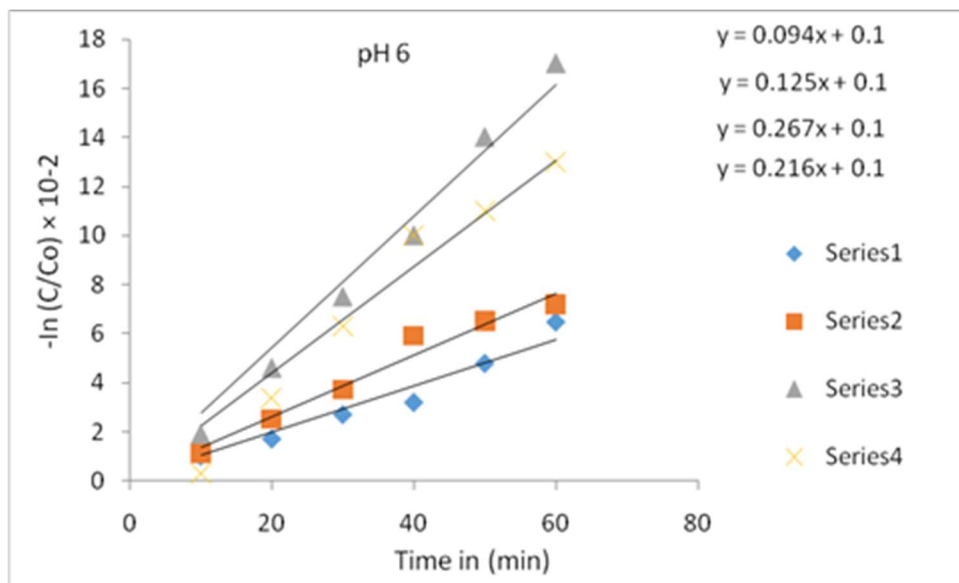
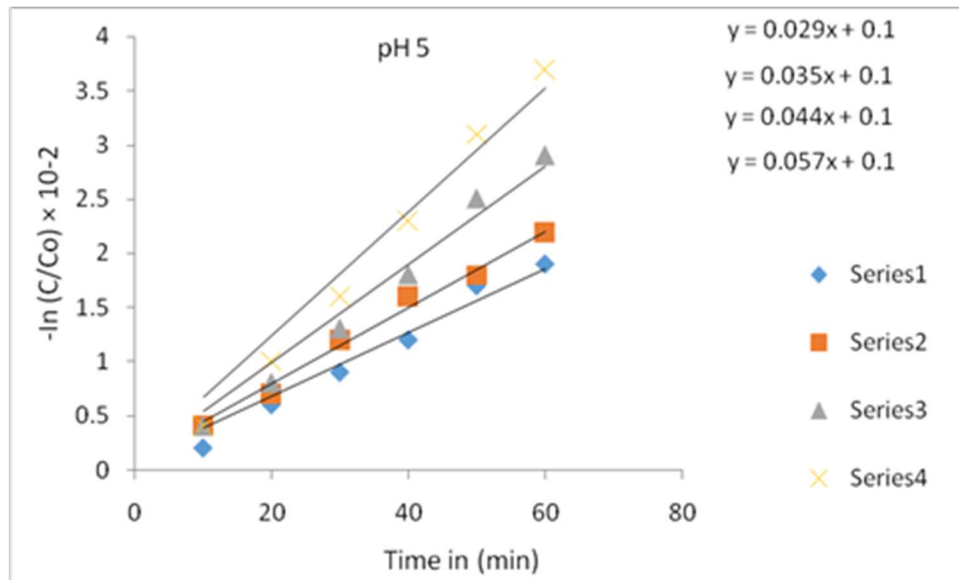
| | | | | | | | | |
|--|--|----|-------|--------|------------------------------|--------|--|--|
| | | 60 | 24.19 | 0.1350 | $k_{60}=2.25 \times 10^{-3}$ | 133.79 | | |
|--|--|----|-------|--------|------------------------------|--------|--|--|

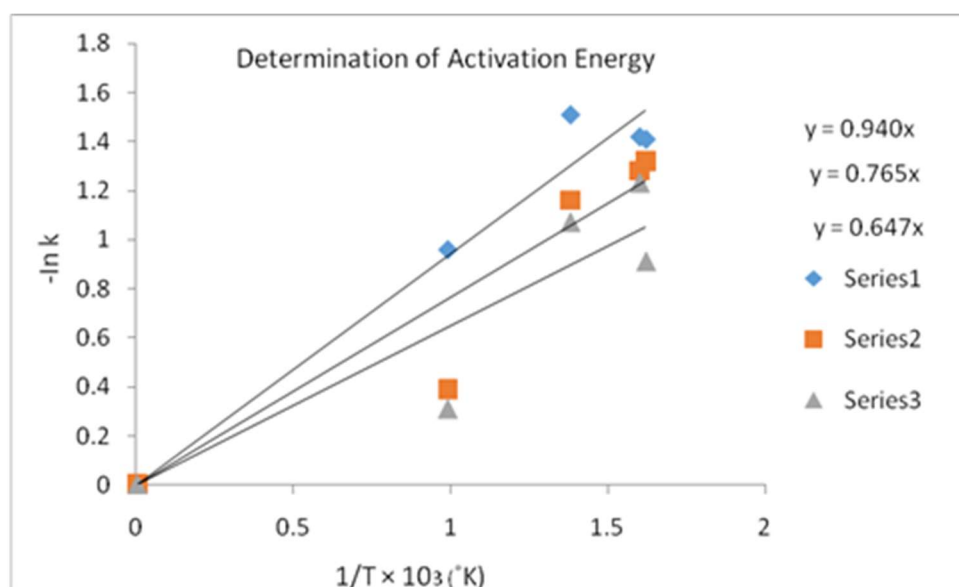
Figure color degradation kinetics of *celosia argenteavar. cristata*











6. CONCLUSION

In the present study, attempts were made to extract betalains from flowers of *Celosia argentea* var. *cristata* of *Amaranthaceae* family, and study their stability to pH and temperature. The result showed that extracts of *Celosia argentea* var. *cristata* has a higher betalain content. The pH study was in the range of 3 to 7 and temperature study of 45°C, 60°C, 70°C, and 90°C. study was also carried out to understand the storage stability of crude extract by using 50 ppm and 100 ppm ascorbic acid as antioxidant. The Result shows that the degradation of betalain follows first order kinetics with maximum degradation observed at pH 3 and pH 6 with an increase in temperature. Towards better understanding of the degradation kinetics were more stable between pH 3 to pH 5 at lower temperature. HPLC characterization of extract showed the betalain present in *Celosia argentea* var. *cristata*. Stabilization the extracted betalains by dehydrating them using maltodextrin and gum acacia as a filler and coating agent respectively and result found that *Celosia argentea* var. *cristata* powder made from maltodextrin as a coating agent have more acceptability than *Celosia argentea* var. *cristata* powder made from maltodextrin and gum acacia as a coating agent. Further studies are required to confirm the results.

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