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Extraction of Quercetin from Citrus Sinensis Using Ultrasound Assisted Hydrotropic Extraction

Prince P., Anandhakrishnan M. and Karthika M.

* Correspondence: princeprince59875@gmail.com; aanandhakrishnan31@gmail.com; karthikagk0425@gmail.com

Abstract: Quercetin, a potent flavonoid with significant antioxidant and anti-inflammatory properties, is abundantly present in Citrus sinensis (sweet orange). Conventional extraction methods often involve toxic solvents and prolonged extraction times, limiting efficiency and sustainability. This study explores ultrasound-assisted hydrotropic extraction (UAHE) as a green and efficient alternative for quercetin recovery from C. sinensis peel. Hydrotropes (e.g., sodium Benzoate) were employed to enhance solubility, while ultrasound irradiation facilitated cell disruption and mass transfer. Parameters such as hydrotrope concentration, sonication time, temperature, and solid-liquid ratio were optimized using response surface methodology (RSM) to maximize yield. The optimized UAHE process demonstrated a quercetin yield of [91]% under mild conditions, significantly outperforming conventional solvent extraction. UV analysis confirmed the purity of the extracted quercetin. UAHE reduced extraction time and solvent consumption while improving yield, aligning with green chemistry principles. This method offers a scalable, eco-friendly approach for bioactive compound extraction from agro-industrial waste, with potential applications in nutraceuticals and pharmaceuticals.

Keywords: quercetin; citrus sinensis; ultrasound-assisted extraction; hydrotropy; green extraction; response surface methodology

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Introduction

Bioactive compounds from natural sources have gained significant attention in recent years due to their diverse pharmacological properties and potential therapeutic applications. Among these compounds, quercetin, a plant flavonoid with remarkable antioxidant and anti-inflammatory properties, has emerged as a compound of particular interest Sharma et al., 2019. However, the practical application of quercetin is often limited by its poor aqueous solubility, which affects its bioavailability and therapeutic efficacy.

Citrus sinensis (orange) peel, a widely available agricultural by-product, contains substantial amounts of quercetin (approximately 300 mg/100g), making it an attractive source for extraction Aranda-Ledesma et al., 2024. Traditional extraction methods often involve organic solvents, which raise environmental concerns and may leave harmful residues in the final product. Therefore, developing green extraction technologies that are both efficient and environmentally sustainable has become imperative.

Hydrotropic extraction has emerged as a promising approach for enhancing the aqueous solubility of poorly soluble compounds. Hydrotropes, such as sodium benzoate, can significantly increase the solubility of hydrophobic compounds through molecular self-assembly and complex formation Narayanan et al., 2022. This technique offers advantages including high selectivity, easy recovery of solutes, and environmental compatibility.

Recent advances in extraction technologies have demonstrated that ultrasound-assisted extraction (UAE) can significantly enhance the recovery of bioactive compounds from plant matrices. The mechanism of UAE involves acoustic cavitation, which creates microscopic bubbles in the

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extraction medium. The collapse of these bubbles generates localized areas of high temperature and pressure, leading to improved mass transfer and cell wall disruption Borah et al., 2024.

The combination of hydrotropic extraction with ultrasound assistance represents a novel approach that could potentially overcome the limitations of conventional extraction methods. While both techniques have been studied separately, their synergistic effects on quercetin extraction from orange peel have not been thoroughly investigated. The integration of these methods could offer several advantages, including:

- Enhanced extraction efficiency through improved mass transfer
- Reduced extraction time and energy consumption
- Environmentally friendly processing conditions
- Improved selectivity and product quality.

Materials and Methods

2.1. Materials:

All chemicals used were of analytical grade. Sodium benzoate (hydrotrope) and quercetin standard were sourced from SRL, India. Urea was obtained from TCI, India, and acetone from SRL, India. Double distilled water was used throughout the study.

2.1.1. Plant Material

Fresh *Citrus sinensis* peels were procured from local markets, washed with distilled water, and air-dried at 25 ± 2°C for 48 hours. The dried peels were ground to a fine powder and stored in airtight containers until use.

2.1.2. Equipment

Key equipment included a UV-Visible Spectrophotometer (Hitachi UV-200), Ultrasonic Bath (Equitron), Magnetic Stirrer (Remi 1MLH), and Laboratory Centrifuge (Remi R-24).

2.2. Analytical Methods:

2.2.1. Molar Absorptivity Determination

Standard quercetin solutions were prepared in distilled water, and absorbance was recorded at λmax using a UV-Vis spectrophotometer. Molar absorptivity was calculated using Beer-Lambert's law from the slope of the absorbance vs. concentration curve.

2.3. Extraction Procedure:

2.3.1. Hydrotropic Solution Preparation

Sodium benzoate solutions (0–3 M) were prepared in distilled water and stirred until fully dissolved.

2.3.2. Ultrasound-Assisted Hydrotropic Extraction (UAHE)

UAHE was carried out using a 3 M sodium benzoate solution (50 mL) and 5 g of orange peel powder at 25 ± 2°C. After 30 minutes of sonication, the mixture was magnetically stirred, filtered, diluted below minimum hydrotrope concentration (MHC), centrifuged (20 min), and the precipitate was redissolved in 50 mL acetone for analysis.

2.4. Optimization Studies

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2.4.1. Preliminary Studies

Initial trials identified suitable ranges for hydrotrope concentration, extraction time, and solid loading.

2.4.2. Response Surface Methodology (RSM)

Box-Behnken Design (BBD) was employed to optimize three variables:

- X_1: Hydrotrope concentration
- X_2: Extraction time
- X_3: Solid loading

2.5. Statistical Analysis

Model adequacy was evaluated via ANOVA, R^2 values, lack of fit tests, and normal probability plots using appropriate statistical software.

Results and Discussion

3.1. Molar Absorptivity of Quercetin

The standard quercetin solutions of 10, 20, 30 40, 50 µg/mL are prepared by adding a known amount of quercetin in 500 ml of double distilled water. The solutions are individually primed below the maximum aqueous solubility of quercetin. Using UV visible spectrophotometer (Elico-SL210), the standard quercetin samples are analysed and the absorbance value at λ_{max} (278.5nm) for each concentration is obtained. The absorbance value of quercetin is represented in Table 3.1 and the UV spectra is represented in figure 4.1.

Table 3.1. Absorbance value of standard quercetin solution.

Concentration (µg/ml)	Absorbance
10	0.015
20	0.034
30	0.055
40	0.073
50	0.094

With the absorbance value, the molar absorptivity value of bio active compounds in water is determined as 13001 mol^{-1} cm^{-1} as depicted in Figure 4.2. The obtained molar absorptivity is close to the value seen in literature.

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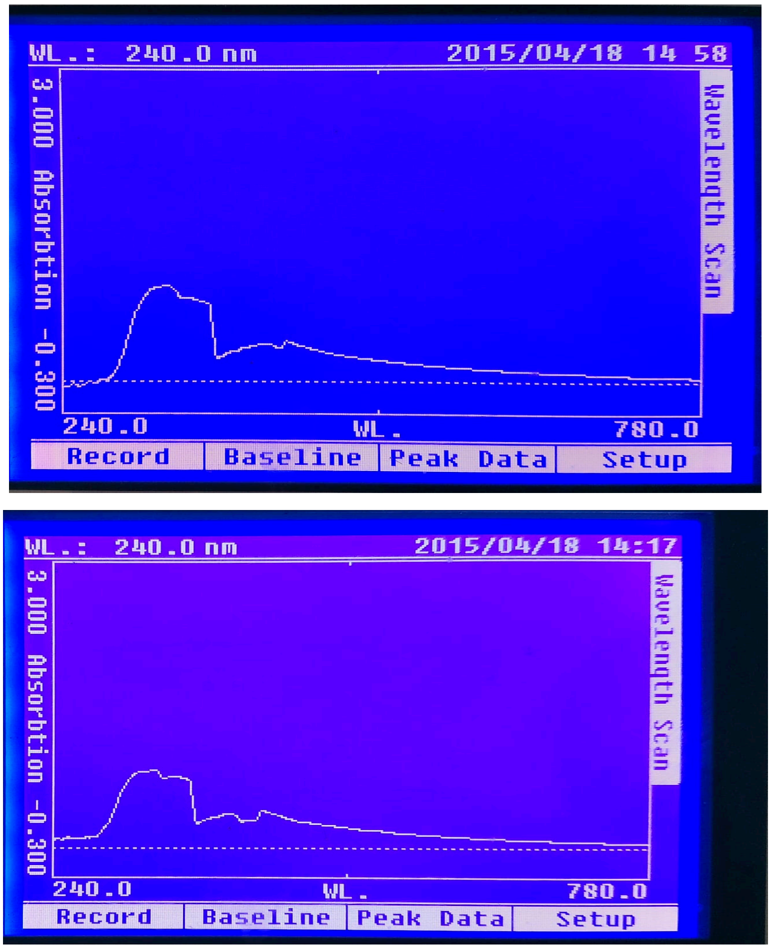

Figure 3.1. UV Spectra of Quercetin.

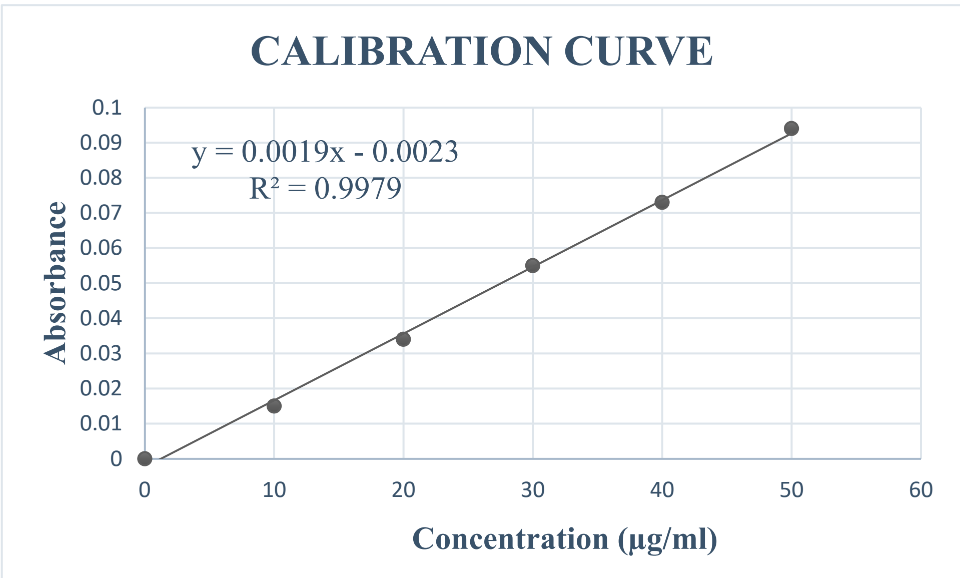

Figure 3.2. Calibration curve of standard quercetin solution.

3.2. Extraction Parameters Range Fixation

3.2.1. Effect of Hydrotrope on the Solubility of Quercetin

Hydrotrope (SB) is fed in to estimate the efficacy of the solubility on quercetin. The most important scope of this investigation is to enhance the oral efficacy of bio active compounds.

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Accordingly, the hydrotropes are also chosen in such a way that it should be orally administered. Based on this criterion the hydrotrope, SB (available as food preservative) were selected. The selected hydrotrope is freely soluble in water, nontoxic and do not produce any temperature effect when dissolved in water.

The experimental results for the impact of hydrotrope on the solubility of quercetin is captured in Figure 4.2. The impact of hydrotrope concentration and a wide range of system temperature on the aqueous solubility of quercetin are premeditated. When sodium benzoate, as a hydrotrope is added to the aqueous phase, an appreciable augmentation in solubility is observed. remarkable change During initial stage i.e., when the concentration of hydrotrope is very less, there is no in solubility. When the concentration of hydrotrope reaches above 0.2 mol/L, a significant improvement occurs. On further increase in concentration of hydrotrope, there is an upswing trend in the dissolving of quercetin. There is rising trend in solubilization till the hydrotrope concentration reaches 2.6 mol/L and beyond which there is no visible change in solubility. This may be attributed to the non-availability of sufficient water molecules. It is deciphered from Table 4.2 that the hydrotrope solution facilitates the solubility of quercetin only till 0.2 mol/L and below this concentration there is no glaring change in the solubility. This concentration level of hydrotrope is called Minimum Hydrotropic Concentration (MHC), i.e., for significant solubilization of quercetin to occur, the minimum amount of hydrotrope viz 0.2 mol/L should be available in the aqueous phase.

Table 3.2. Effect of SB on the solubility of quercetin.

Hydrotrope Concentration (mol/L)	Solubility x10^3 mol/L
0	0.0002
0.2	0.0005
0.4	0.0037
0.6	0.0055
0.8	0.0076
1	0.0094
1.2	0.011
1.4	0.013
1.6	0.015
1.8	0.018
2	0.02
2.2	0.021
2.4	0.0223
2.6	0.0228
2.8	0.0228
3	0.0228

It is also inferred from Table 3.2 that after hydrotrope concentration reaches 2.6 mol/L, there is no appreciable change in solubility of quercetin and the rate of increase in solubility of quercetin dwindles. The value at which there is no appreciable change in solubility is called maximum hydrotrope concentration (C_{max}).

The solubility curve can be divided into 3 regions (Figure 3.2) viz, the first one is the self-aggregation region or quercetin inactive region where there is no solubilization. The region above MHC where the very high rate of solubilization occurs represents the second. The region above C_{max} is the third one in which the rate of solubilization is less, i.e., above this concentration there is no noticeable increase in solubilization.

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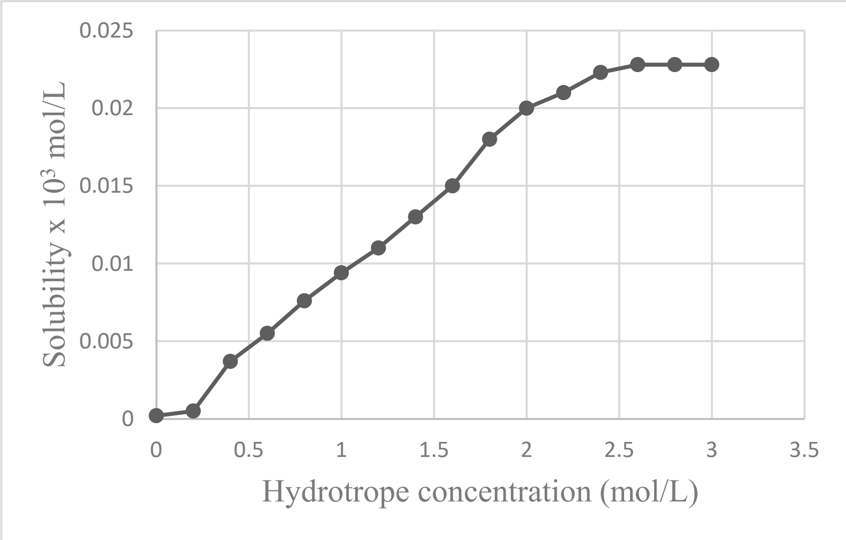

Figure 3.3. Effect of SB on solubility on quercetin.

3.2.2. Extraction Time

The extraction time was assessed from 10 minutes to 60 minutes. From Figure 3.4, there was a significant increase of yield with increase in extraction time prolonging from 10 to 30 min. After then, yield decreased, meaning that long extraction time would possibly induce degradation of compounds under ultrasound treatment.

Compared to conventional hydrotropic extraction, the time required for extraction was greatly reduced. As reported in the literature, the extraction time was extended up to 8 hours (Nagarajan et al., 2016) in case of conventional hydrotropic extraction. However, embedding ultrasound results in shrunken time of extraction because of improved diffusion of solvent as well as damage of the cell wall.

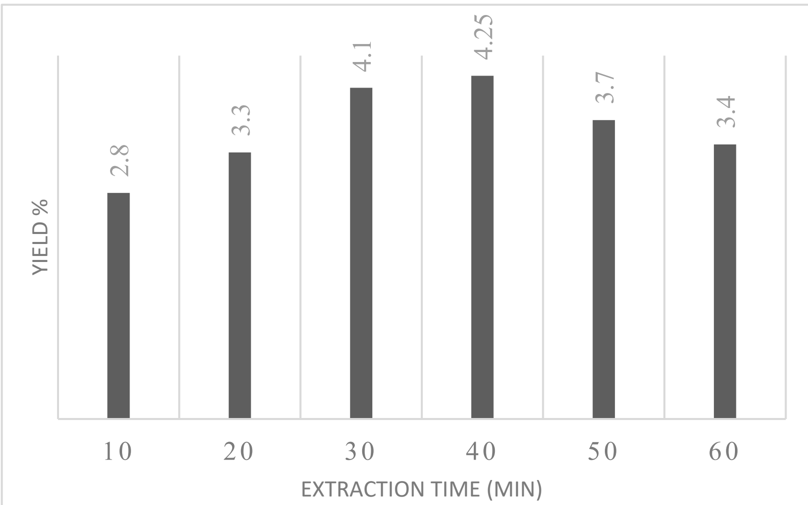

Figure 3.4. Effect of extraction time.

3.2.3. Raw Material Loading

The amount of solvent is an important factor for the solute to leach out during UAHE. The yield showed significant increase by increase in raw material loading which meant that an increase of solvent (SB hydrotrope) benefited the release of quercetin from *Orange peels*. However, higher solid

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loading decreased the yield possibly due to high liquid–solid ratio and paste-like formation. Large amount of extraction solvent also leads to increase of solvent wastage and process cost (Mtetwa et al., 2020). The raw material loading around 30% w/v were found to be optimum for further study.

3.3. Response Surface Methodology

3.3.1. Optimization with Sodium Benzoate as Hydrotrope

In the present study, RSM model has been used to study relation between yield of quercetin and extraction parameters such as hydrotrope concentration(X_1), extraction time(X_2) and solid loading(X_3). Table 1 specifies the extraction parameters and operating ranges considered.

Table 3.3. Extraction parameters for RSM (Sodium Benzoate).

Extraction Parameters	**Operating Ranges**	
	Lowest	**Highest**
Hydrotrope concentration (mol)	1	3
Extraction Time (min)	10	30
Solid Loading (w/v)	10	30

The selected parameters were optimized using Box-Behnken design in Minitab software. The BBD procedure of RSM resulted in a total of 15 randomized experiments. Based on 15 different extraction parameters, a total of 15 experiments were carried out by Ultrasound-Assisted Hydrotropic Extraction method. The obtained extract is analysed by UV-visible spectroscopy to determine the yield of quercetin.

Table 3.4. Experimental Design and yield of quercetin extracted with sodium benzoate as hydrotrope.

Run	Hydrotrope Concentration (mol)	Extraction time (min)	Solid Loading (% w/v)	Yield (µg/g)
1	3	30	20	26.6
2	3	20	30	19.9
3	1	10	20	11.9
4	3	20	10	25.6
5	2	20	20	18.7
6	2	10	30	14.6
7	2	20	20	18.8
8	2	10	10	13.77
9	1	30	20	6.7

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10	2	30	30	16.4
11	1	20	10	8.5
12	1	20	30	5.57
13	3	10	20	24.8
14	2	20	20	18.8
15	2	30	10	20.3

The mathematical model representing the yield of quercetin as a function of independent variables such as hydrotrope concentration, extraction time and solid loading within the region under investigation is expressed by following equation:

$$YIELD = -11.4 + 11.20\, X_1 - 0.074\, X_2 + 1.250\, X_3 - 1.32\, X_1^2 + 0.0005\, X_2^2 - 0.0255\, X_3^2 + 0.175\, X_1{*}X_2 - 0.069\, X_1{*}X_3 - 0.0118\, X_2{*}X_3 \quad \text{Eqn.(1)}$$

It is obvious from equation 1 that the quercetin yield highly depends on the hydrotrope concentration followed further by extraction time and then by solid loading. The prediction of quercetin yield using equation 1 has been compared with the experimental values as shown in Figure 1. It can be ascertained from the figure that the model equation predictions satisfactorily match the experimental values.

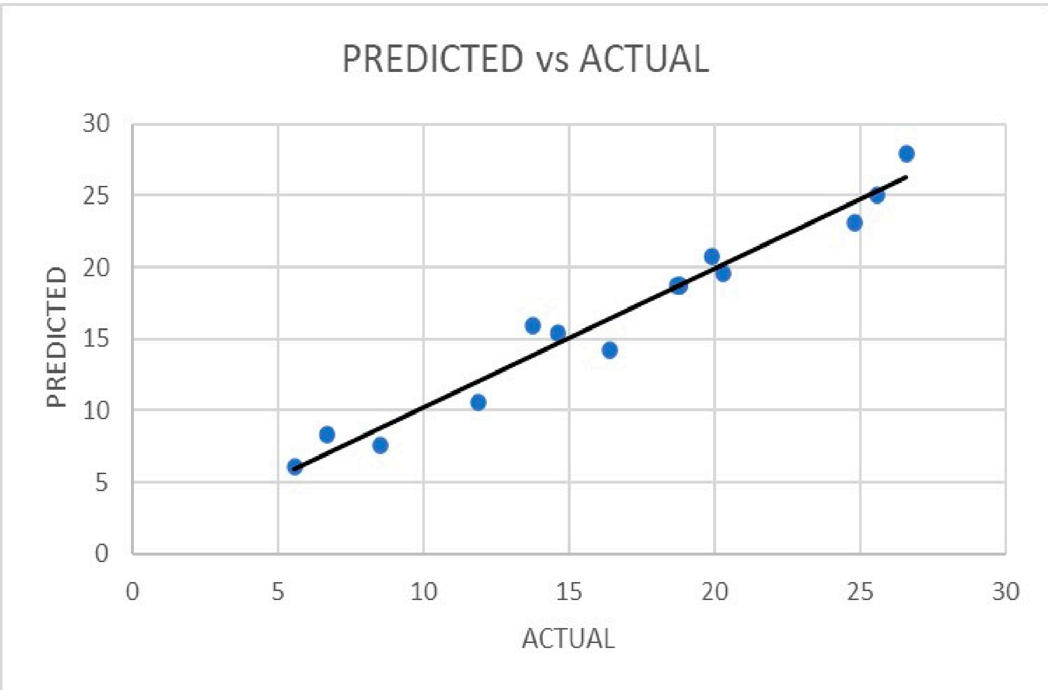

Figure 3.5. Predicted vs Actual Values.

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The Analysis of Variance (ANOVA) to determine the statistical significance of the model equation was evaluated and the results are presented in Table 3.

Table 3.5. Analysis of Variance for quadratic model (Sodium Benzoate).

Analysis of Variance (ANOVA)					
Source	DF	Adj SS	Adj MS	F-Value	P-Value
Model	9	584.774	64.975	15.25	0.004
Linear	3	535.836	178.612	41.92	0.001
A- Hydrotrope Concentration	1	515.687	515.687	121.03	0
B- Time	1	3.038	3.038	0.71	0.437
C- Solid Loading	1	17.111	17.111	4.02	0.101
Square	3	29.177	9.726	2.28	0.197
A^2	1	6.442	6.442	1.51	0.274
B^2	1	0.011	0.011	0	0.962
C^2	1	24.072	24.072	5.65	0.063
2-Way Interaction	3	19.761	6.587	1.55	0.312
AB	1	12.25	12.25	2.87	0.151
AC	1	1.918	1.918	0.45	0.532
BC	1	5.593	5.593	1.31	0.304
Error	5	21.305	4.261		
Lack-of-Fit	3	21.298	7.099	2129.79	0
Pure Error	2	0.007	0.003		
Total	14	606.079			

The ANOVA of the regression model showed that the model is statistically significant ($p = 0.001$). The linear and quadratic term in the model were highly significant ($p = 0.001$). The linear and quadratic term in the model were highly significant. In the ANOVA chart if the lack of fit is mentioned as "not significant" then the model is said to be significant. Hence the model for extraction of quercetin is considered significant. The model adequacies were checked by R^2. A higher value of R^2 (0.96) shows that the predicted model suits the experimental behaviour of the system.

3.3.1.1. Contour Plot Analysis

Contour plots showing the effects of extraction parameters on the quercetin yield are given below. The darker green regions in the respective graph indicates the optimum range of parameters to get a higher yield.

(I) Yield vs Time, Hydrotrope concentration

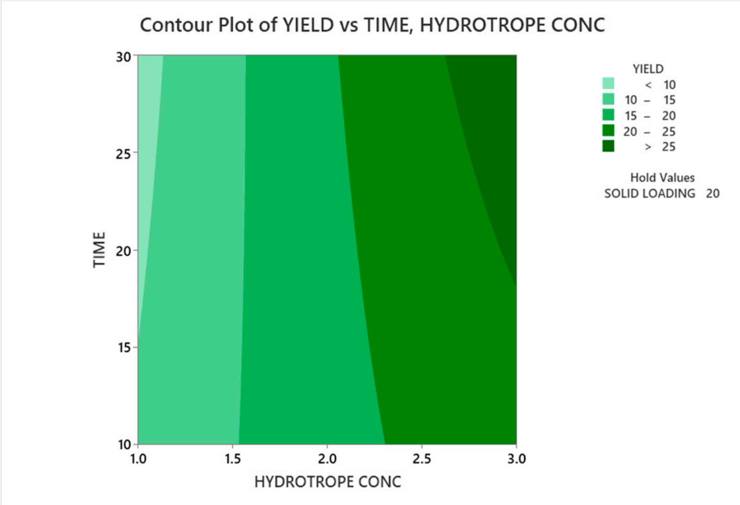

Figure 3.6. Effect of Yield vs Time, Hydrotrope concentration.

(II) Yield vs Time, Solid Loading

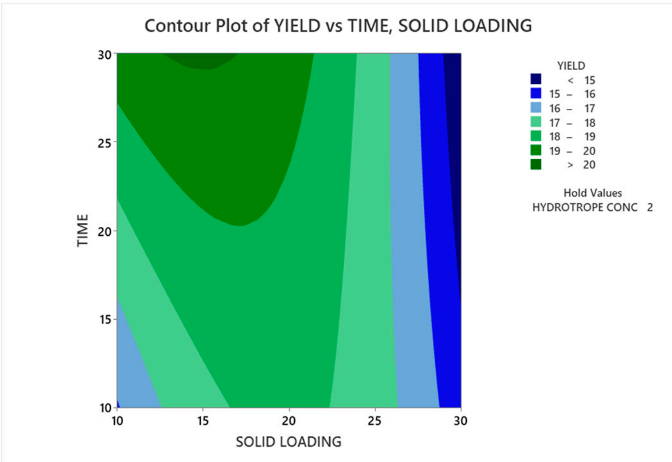

Figure 3.7. Effect of Yield vs Time, Solid Loading.

(III) Yield vs Solid Loading, Hydrotrope concentration

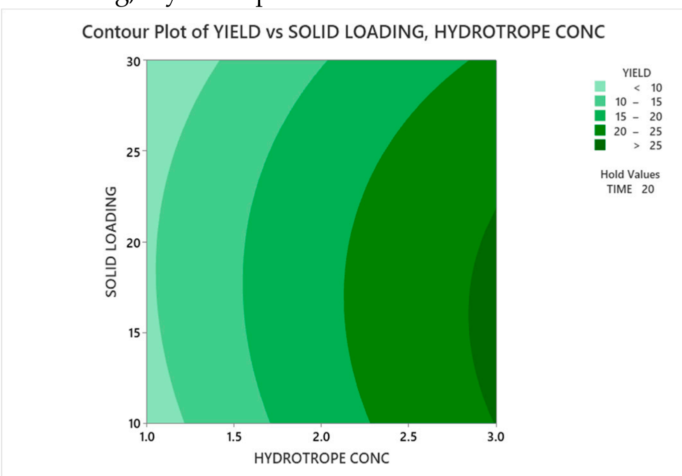

Figure 3.8. Effect of Yield vs Solid Loading, Hydrotrope Concentration.

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3.3.1.2. Response Surface Plot Analysis

The RSM plot shows the combined effects of extraction parameters on quercetin yield. Figure 2 shows the effect of hydrotrope concentration and time against quercetin yield with solid loading kept at a constant of 20% w/v. From Figure 3.9, it can be inferred that as hydrotrope concentration is increased, yield increases. Also, when time is increased, yield also increases.

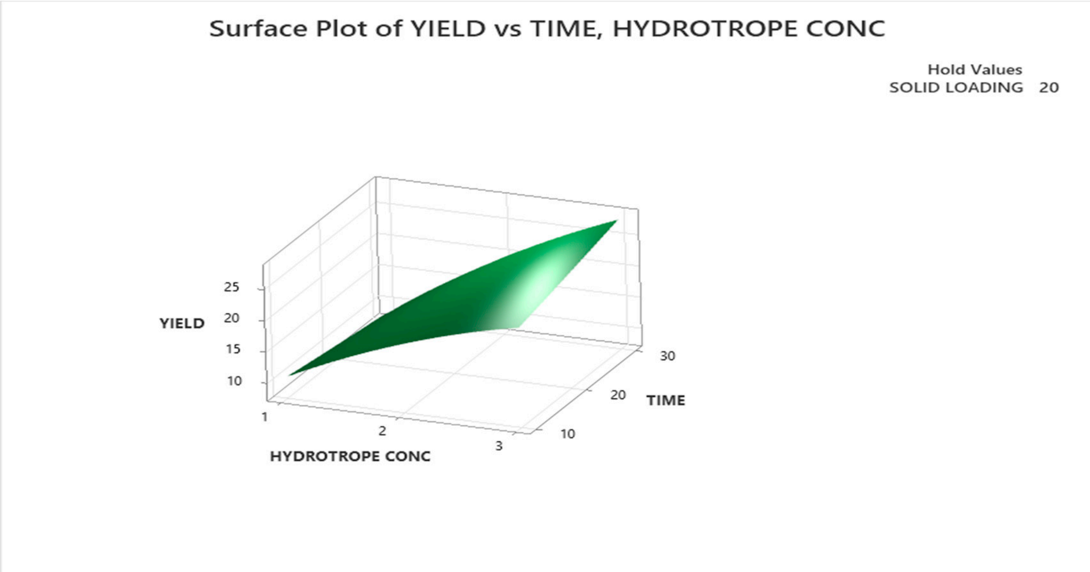

Figure 4.9. Effect of Hydrotrope concentration, time vs quercetin yield.

Figure 4.10 shows the effect of time and solid loading against quercetin yield with hydrotrope concentration at constant value of 2 mol. Figure 3 depicts that initially when solid loading is increased, yield also increases but for solid loading beyond 20% w/v, decrease in yield can been seen. This decrease in yield is possibly due to high liquid–solid ratio and paste-like formation.

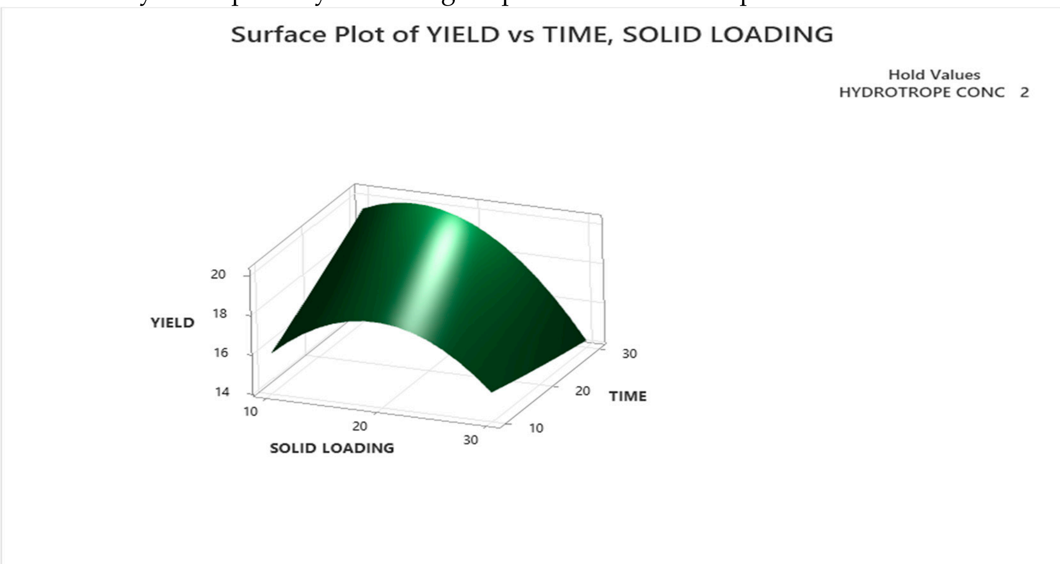

Figure 3.10. Effect of solid loading, time vs quercetin yield.

Figure 3.11 shows the effect of hydrotrope concentration, solid loading against quercetin yield with time as a constant at 20 min. Figure 4 depicts that with increase in hydrotrope concentration, yield increases and with increase in solid loading, yield increases initially but then gradually decreases.

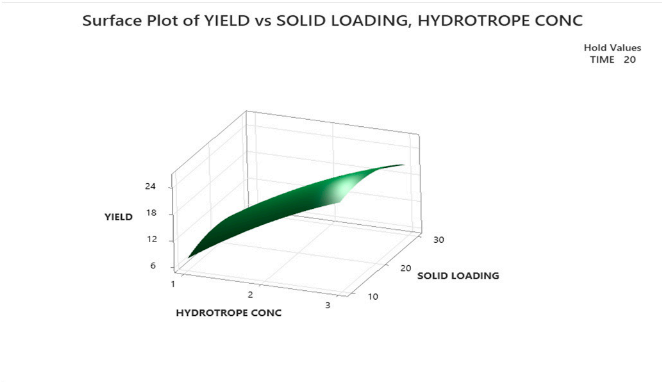

Figure 3.11. Effect of Hydrotrope concentration, solid loading vs quercetin yield.

3.3.2. Optimization with Urea as Hydrotrope

Here, RSM model has been used to study relation between yield of quercetin and extraction parameters such as hydrotrope concentration(X_1), extraction time(X_2) and solid loading(X_3) with Urea as hydrotrope. Table 1 specifies the extraction parameters and operating ranges considered.

Table 3.6. Extraction parameters for RSM (Urea).

Extraction Parameters	**Operating Ranges**	
	Lowest	**Highest**
X_1 - Hydrotrope concentration (mol)	1	3
X_2 -Extraction Time (min)	10	30
X_3 - Solid Loading (w/v)	10	30

The selected parameters were optimized using Box-Behnken design in Minitab software. The BBD procedure of RSM resulted in a total of 15 randomized experiments. Based on 15 different extraction parameters, a total of 15 experiments were carried out by Ultrasound-Assisted Hydrotropic Extraction method. The obtained extract is analysed by UV-visible spectroscopy to determine the yield of quercetin.

Table 3.7. Experimental Design and yield of quercetin extracted with Urea as hydrotrope.

Run	Hydrotrope Concentration (mol)	Extraction time (min)	Solid Loading (% w/v)	Yield (µg/g)
1	2	30	30	9.6
2	3	20	30	12.5
3	1	10	20	4.5
4	2	10	30	7.8

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5	3	20	10	18.8
6	2	20	20	11.9
7	3	10	20	18
8	2	20	20	12
9	3	30	20	19.2
10	2	20	20	12
11	1	30	20	1.2
12	2	10	10	6.9
13	1	20	10	1.07
14	1	20	30	0.43
15	2	30	10	13.4

The mathematical model representing the yield of quercetin as a function of independent variables such as hydrotrope concentration, extraction time and solid loading within the region under investigation is expressed by following equation:

$$\text{YIELD} = -23.41 + 13.18\,X_1 + 0.091\,X_2 + 1.408\,X_3 - 1.233\,X_1^2 - 0.00008\,X_2^2 - 0.02533\,X_3^2 + 0.1125\,X_1{*}X_2 - 0.1415\,X_1{*}X_3 - 0.01175\,X_2{*}X_3 \qquad \text{Eqn (1)}$$

It is obvious from equation 1 that the quercetin yield highly depends on the hydrotrope concentration followed further by extraction time and then by solid loading. The prediction of quercetin yield using equation 1 has been compared with the experimental values as shown in Figure 1. It can be ascertained from the figure that the model equation predictions satisfactorily match the experimental values.

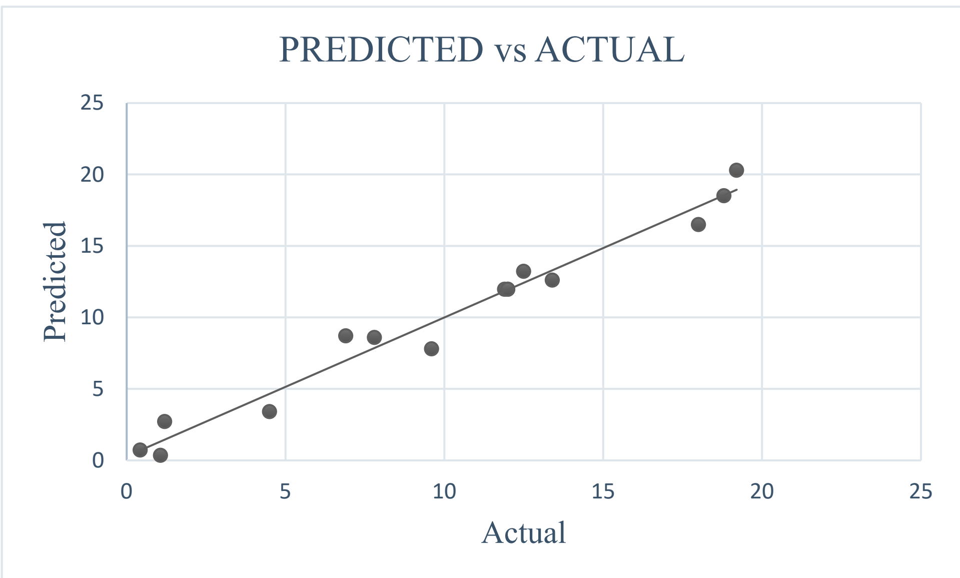

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Figure 3.12. Predicted vs Actual Values.

The Analysis of Variance (ANOVA) to determine the statistical significance of the model equation was evaluated and the results are presented in Table 3.

Table 3.8. Analysis of Variance for quadratic model (Urea).

Analysis of Variance (ANOVA)					
Source	DF	Adj SS	Adj MS	F-Value	P-Value
Model	9	533.169	59.241	18.60	0.002
Linear	3	486.619	162.206	50.92	0.000
D- Hydrotrope Concentration	1	469.711	469.711	147.45	0.000
E- Time	1	4.805	4.805	1.51	0.274
F- Solid Loading	1	12.103	12.103	3.80	0.109
Square	3	27.956	9.319	2.93	0.139
A^2	1	5.616	5.616	1.76	0.242
B^2	1	0.000	0.000	0.00	0.993
C^2	1	23.696	23.696	7.44	0.041
2-Way Interaction	3	18.594	6.198	1.95	0.241
AB	1	5.062	5.062	1.59	0.263
AC	1	8.009	8.009	2.51	0.174
BC	1	5.522	5.522	1.73	0.245
Error	5	15.920	3.106		
Lack-of-Fit	2	15.921	5.207	1592.15	0.088
Pure Error	2	0.007	0.003		
Total	14	549.097			

The ANOVA of the regression model showed that the model is statistically significant ($p = 0.002$). The linear and quadratic term in the model were highly significant ($p = 0.000$). In the ANOVA chart if the lack of fit is mentioned as "not significant" then the model is said to be significant. Hence the model for extraction of quercetin is considered significant. The model adequacies were checked by R^2. A higher value of R^2 (0.97) shows that the predicted model suits the experimental behaviour of the system.

3.3.2.1. Contour Plot Analysis

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Contour plots showing the effects of extraction parameters on the quercetin yield are given below. The darker green regions in the respective graph indicates the optimum range of parameters to get a higher yield.

Effect of Yield vs Extraction Time, Hydrotrope concentration

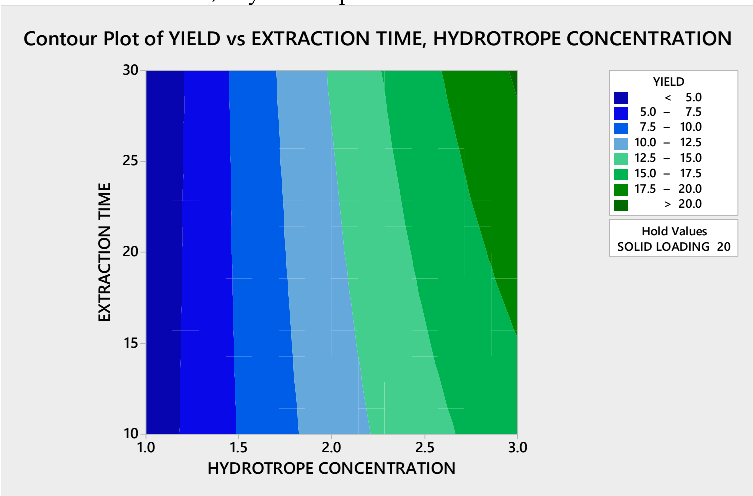

Figure 3.13. Effect of yield vs extraction time, hydrotrope concentration.

Yield vs Solid loading, Hydrotrope concentration

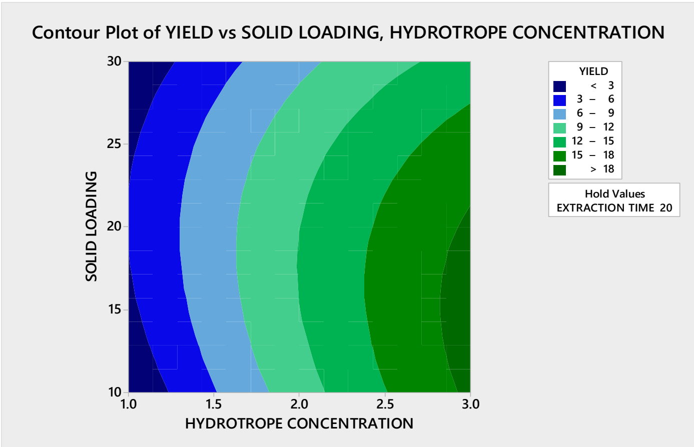

Figure 3.14. Effect of Yield vs Solid Loading, Hydrotrope concentration.

Effect of yield vs solid loading, extraction time

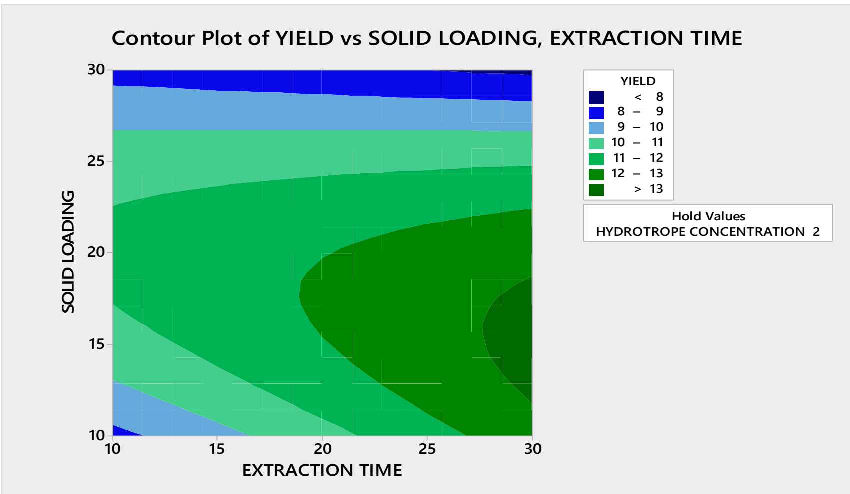

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Figure 3.15. Effect of Yield vs Solid Loading, Extraction time.

3.3.2.2. Response Surface Plot Analysis

The RSM plot shows the combined effects of extraction parameters on quercetin yield. Figure 3.16 shows the effect of hydrotrope concentration and time against quercetin yield with solid loading kept at a constant of 20% w/v. From Figure 2, it can be inferred that as hydrotrope concentration is increased, yield increases. Also, when time is increased, yield also increases.

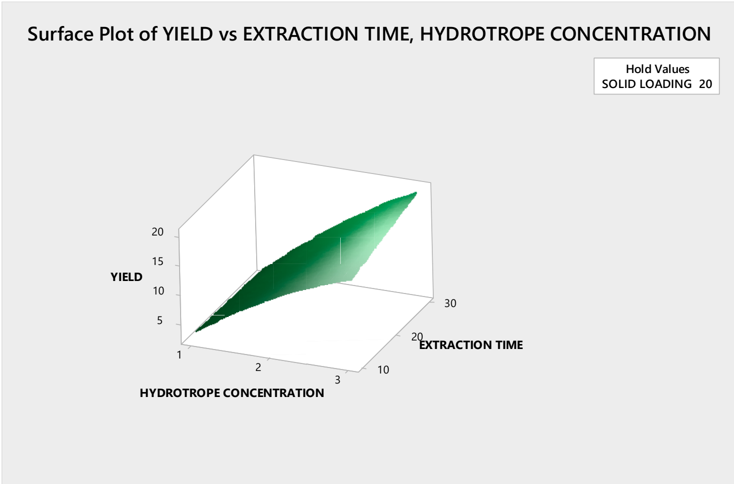

Figure 3.16. Effect of Hydrotrope concentration, time vs quercetin yield.

Figure 3.17 shows the effect of time and solid loading against quercetin yield with hydrotrope concentration at constant value of 2 mol. Figure 3 depicts that initially when solid loading is increased, yield also increases but for solid loading beyond 20% w/v, decrease in yield can been seen. This decrease in yield is possibly due to high liquid–solid ratio and paste-like formation.

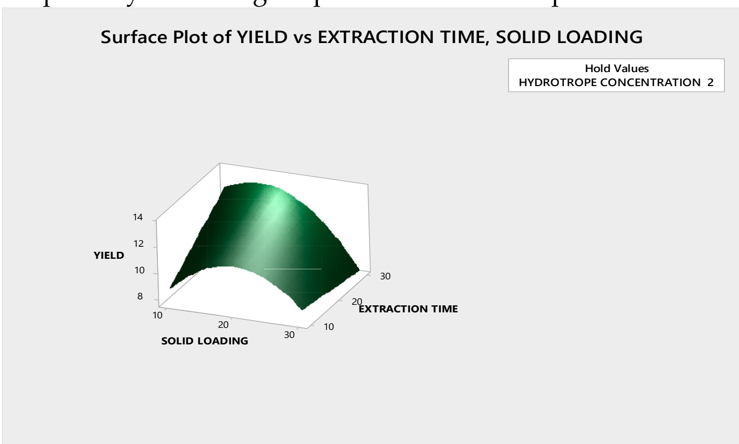

Figure 3.17. Effect of solid loading, time vs quercetin yield.

Figure 3.18 shows the effect of hydrotrope concentration, solid loading against quercetin yield with time as a constant at 20 min. Figure 4 depicts that with increase in hydrotrope concentration, yield increases and with increase in solid loading, yield increases initially but then gradually decreases.

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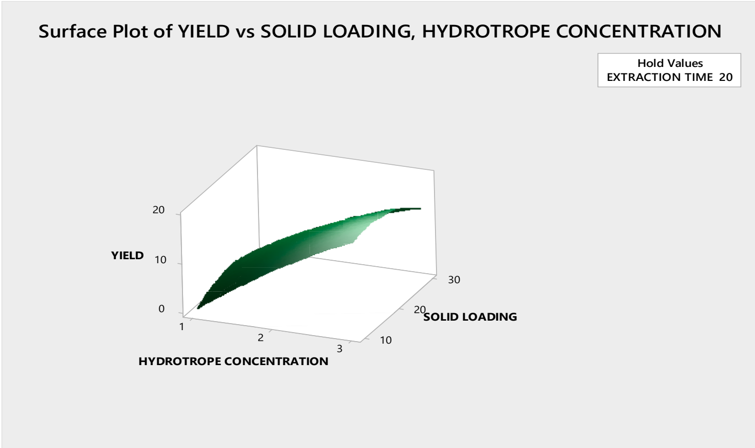

Figure 3.18. Effect of Hydrotrope concentration, solid loading vs quercetin yield.

3.4. Optimization of Ultrasound Assisted Hydrotropic Extraction

The optimized value for the extraction of quercetin with sodium benzoate and Urea as hydrotropes is shown in table 4.9 which is obtained from the RSM Box- Behnken method.

Table 3.9. Comparison of predicted and experimental yield of quercetin.

Variables	**Optimum Conditions (Urea)**		**Optimum Conditions (Sodium benzoate)**	
Hydrotropic Concentration (mol)	3		3	
Extraction Time (min)	30		30	
Solid Loading (%w/v)	20		20	
Yield of quercetin (µg/g)	**Experimental**	**Predicted**	**Experimental**	**Predicted**
	19.2	20.2875	26.2	27.235

Conclusion

4.1. Conclusion

The main objective of the present investigation was to enhance the solubility of bio active compound, quercetin using hydrotropic phenomenon. The study is mainly designed to overcome the demerits such as degradation of bioactive compound, post purification and high cost encountered in other solubilization techniques. The conclusions of this study are summarized below:

- Sodium benzoate has been chosen as the hydrotrope due to its high solubility in water.
- *Orange peels* has been chosen as the herb for the extraction of quercetin by UAHE.
- The molar absorptivity of quercetin in water is determined using UV spectroscopy.
- A Minimum Hydrotrope Concentration (MHC) in the aqueous phase is found to be essential for the initiation of the hydrotropic solubilization of bioactive compounds.
- The solubilization of bioactive compound increases with the increase in hydrotrope concentration.
- UAHE is carried out to fix the range of parameters such as extraction time, raw material loading and hydrotropic concentration. By the trial run, 30 minutes, 30% w/v, 2.6 mol/L was found to be optimum parameters for extraction of quercetin from *Orange peels*.

- Response surface methodology was carried out to study the relation between yield of quercetin and extraction parameters such as hydrotrope concentration, extraction time and solid loading.
- The highest yield was obtained at optimum conditions of 3 mol, 30 min, 20 %w/v by using sodium benzoate as hydrotrope.
- The highest yield was obtained at optimum conditions of 3 mol, 30 min, 20 %w/v by using sodium benzene sulphonate as hydrotrope.
- Sodium benzoate shows better yield than sodium benzene sulphonates.

4.2. Scope for Future Work

The obtained extract of quercetin by ultrasound-assisted hydrotropic extraction shall be subjected to clinical activity such as anti-microbial, anti-inflammatory, anti-cancer testing for pharmaceutical applications.

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