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HUNTER COLORIMETER VALUES OF MUSTARD SEEDS AT DIFFERENT MOISTURE CONTENTS

HEMASANKARI PALANI*, RAMADEVI PALANI[1], PANKAJ KUMAR[1], MANJU BALA[2], R. VISWAKARMA[3], D. MRIDULA DEVI[4] AND R. KAILAPPAN

*ICAR-IIMR, Rajendranagar, Hyderabad, Telangana, India
Andhra Pradesh, India
[1]FG&OP Division, ICAR-CIPHET, Ludhiana, Punjab, India
[2,3,4]ICAR-CIPHET, Ludhiana, Punjab, India
[5]FG&OP Division, ICAR-CIPHET, Ludhiana, Punjab.
[6]CAE, TNAU, Tamil Nadu, India

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Abstract – Mustard seeds were procured from the local market and subjected to cleaning and for conducting experiment. 100g of the mustard seeds were taken and different moisture content were tested using hot air oven method. Different moisture contents of 10%, 16%,18% and 20% were made in the oilseed with water addition using formula method. The samples were then tested for its final moisture content. The color parameters of whiteness ratio, yellowness ratio, browness ratio, hue angle, chroma, redness ratio and whiteness index were determined using hunter colorimeter. At 10%mc in mustard seeds redness ratio varies between 2.41-41.25, whiteness ratio varies between 35.66-38.93, whiteness yellow ratio varies between 21.38-308.50, yellowness ratio between 0.46-6.68, browness ratio varies between 762.01-1084.15, hue angle varies between 70.68-71.57, chroma varies between 4.77-6.01. At 16% mc, total colour difference varies between 6.01-6.68, redness ratio varies between 3.06-16.72, whiteness index varies between 30.84-40.31, whiteness yellow ratio varies between 20.96 - 106.93, yellowness ratio varies between 6.82 - 4.81 browness ratio varies between 408.01 - 849.05, hue angle varies between 3.43 - 25.64, chroma varies between 3.13 - 5.08. At 18%mc, total colour difference varies between 5.76-6.47, redness ratio varies between 4.85 - 8.61, whiteness ratio varies between 32.09 - 36.65, whiteness yellow ratio varies between to 42.78 - 69.37, yellowness ratio varies between 3.34 - 19.99, browness ratio varies between 647.97 - 856.65, hue angle varies between 6.84 - 40.70, chroma varies between 4.25 to 6.97. At 20% mc total colour difference varies between 6.17 - 6.40, redness ratio varies between 8.82 - 29.53, whiteness ratio varies between 33.03 - 36.40, whiteness yellow ratio varies between 67.49 - 195.41 yellowness ratio varies between 2.12 - 6.85, browness ratio varies between 767.34 - 1204.11, hue angle varies between 1.72 - 13.50 and chroma varies between 4.53 - 6.83. The redness ratio increases from 10% to 20%mc since moisture addition adds dark colour to the mustard seed. The values were tested for its statistical significance at 5% level of significance and found to be significant. ($p \leq 0.05$) using SPSS16 software. Further analysis was done using response surface design expert software, 12 version

INTRODUCTION

India ranks 4th position in world scenario in oilseed production next to USA, China and Brazil. Mustard seed production is third in oilseed production next to soybean and palm oil. The production is 7-8 mi.t.(FAO, 2017) Generally mustard contains 20-30% oil content. The oil extracted from sesame seed is good for making value added products from mustard such as in frying of kitchen receipies and also as a preservative in making pickles. Color is important in deciding the quality of the developed value added product. Mustard seed is an important oil crop. Colour has been shown of primary importance in the judgment of food, ultimately influencing the acceptance or rejection of food.

(*Scientist (SS) (AS&PE), [1]Scientist (ss)(AS&PE), [3]Principal Scientist, (Bio-Chem), [4]Principal Scientist(AS&PE), [5]Principal Scientist (Food.Tech.), Asst. Professor, Chemistry, [6]Retd. Professor)

Colour is one of the important quality attributes on food. Although it does not necessarily reflect nutritional, flavour or functional values it determines the acceptability of a product by consumers. Moisture content is very important in biological materials. Moisture content is an important parameter in determination of mustard seeds for its market value, price fixation and its safe storage life before processing for its oil content. Moisture also decides the oil content of the oilseed and it is an indicator of harvest time in the field by visual observation and experience of the farmers growing mustard for their livelihood. In this context the present study is significant and is useful to the farmers and processors. Mustard seeds are one of the oldest important spice crop and is used to give heat, rich and nutty flavor that improves the taste to the receipies prepared in Indian traditional kitchen. The pungency of mustard gets reduced by heating it. Mustard seeds contain volatile mustard oil, phytonutrients, minerals, vitamins, anti oxidants and strongest flavor. Mustard seeds contains calcium, magnesium, phosphorous and potassium. Mustard seeds are low in calories and high in nutritional value and contain a lot of antibacterial and antiseptic qualities. The medicinal value of the mustard seeds are antibacterial, diuretic and antifungal. Natural color of mustard is brown and are spherical in shape.

MATERIALS AND METHODS

The mustard seeds were procured from the seed laboratory of PAU, Ludhiana and stored in the refrigerator for one day for conducting experiments. 100g of the seeds were weighed in an electronic balance and taken for experiments with 3 replications. Initial moisture content was measured using hot air oven method. Final moisture were adjusted using distilled water calculated by the formula method. 4 different moisture of 10%, 16%, 18% and 20% were maintained in the mustard seeds and packed in polyethylene bags and stored in the refrigerator for 1 week for moisture equilibriation. Different moisture contents of 10%, 16%, 18% and 20% were made in the oilseed with water addition using formula method. The samples were then tested for its final moisture content. The samples of the desired moisture contents were prepared by adding the amount of distilled water as calculated from the following relation (Sacilik *et al.*, 2003). The most preferred methods to objectively measure color are the tristimulus Hunter and the CIE L*a*b* systems (Seroczynska *et al.,* 2006)

(1) $Q=W_I(M_f-M_i)/(100-M_f)$

where, Wi , is the initial mass of sample in kg; Mi, is the initial moisture content of sample in % w.b.; and Mf, is the final moisture content of sample in % w.b. Initial moisture content was determined using hot air oven method. Final moisture content were found out for the pigeon pea samples after equilibriation of the moisture after storing in the refrigerator at 0°c for 10 days. Grains were scanned at three different locations and the hunter values L*, a*, and b* were recorded.

Then the seeds were taken for determination of color values in Hunter Lab Colorimeter (model D25L-9, Hunter Associates Lab, Inc., Ultra Scan PRO, USA). L, a & b and hue angle were determined for all sets of samples. The results were tabulated and analysed using SPSS 16.0 software. The L*, a* and b* values measured lightness ranging from black (0) to (100) white, greenness (minimum) to redness (maximum) and blueness (minimum) to yellowness (maximum) respectively of samples using Hunter Lab Colorimeter (UltraScan PRO, USA). The whiteness index (WI) was calculated using the formula;

(2) Whiteness index (WI) =100-[(100-L)*2 + a^2+ b^2)^½

The color of the sample was observed by hunter lab digital colorimeter (model D 25L-9, Hunter Associates Lab, Inc.). Grains were scanned at three different locations and the hunter values L*, a*, and b* were recorded. A low number (0–50) of L* value indicates dark and a high number (51–100) indicates light. A positive number of a* value indicates red and a negative number indicates green. Similarly, a positive number of b* value indicates yellow and a negative number indicates blue. Hue angle were determined from the formula

(3) $°Hue=\tan^{-1}(b/a)$

It determines the darkness or lightness of the shade.

Objective numerical values express the colour of product by the formula: L* (lightness or darkness) ranges from black (0) to white (100); a* color direction in red (a*>0) or green (a*<0); b* color direction in yellow (b*>0) or blue (b*<0).

(4) $\Delta E = \sqrt{(L - L^*)^2 + (a-a^*)^2 + (b-b^*)^2}$

Colorimeter L" values represent 'lightness', with score of 100 as white and 0 as black. Colorimeter a" values reflect red-green colors with '+' values indicating 'redness', and '–' values as 'greenness'. Colorimeter b" values measure yellow to blue colors, with '+' values indicating 'yellowness' and '–' values indicating 'blueness'.

(5) $C^* = \sqrt{\Delta}\ (a^*)^2 + (b^*)^2$

Chroma (saturation or vividness)=as chromaticity increases, a color becomes more strong; as it decreases, a color becomes more dull. Hue (tint of color)= an angular measurement, 0 = red and 90 = yellow. The color values of mustard seeds were determined using Hunter Lab Colorimeter (Hunter Associates Laboratory, Reston, VA). L* indicates lightness to darkness (0 to 100), a* indicates redness to greenness (+ to -), and b* indicates yellowness to blueness (+ to -) and these values were noted. Total color difference (ΔE), chroma (ΔC), hue angle, and whiteness index (WI) were determined using the following equations (Navyashree *et al.*, 2021). Fig.2 shows the Raw sesame oilseed (*Brassica juncea*, Indian mustard) used for conducting experiments.

Fig. 1. Colorimeter apparatus

Fig. 1 represents the colorimeter apparatus used for measuring different colors in food. The working of colorimetric is mainly based on the Beer-Lambert's Law. This law states that the light absorption when passes through a medium are directly proportional to the concentration of the medium. When a colorimeter is used, there is a ray of light with a certain wavelength is directly towards a solution. The usual wavelength range is from 400 to 700nm.

Experimental Design

Response surface methodology (RSM), is based on factorial design, is a mathematical and statistical technique for designing experiments, fitting models, and determining the optimal operating conditions for a target response. RSM models are used to optimize the relationship among the color parameters at different levels on the chroma are outlined. The software used was Design Expert 12.0 version of Stat-Ease, Inc, 2021E, Hennepin Avenue, Minneapolis, USA. The second order CCRD of these five independent factors suggested 50 trials that were performed taking chroma scores as response (Table 2). The response was again fed to the soft - ware to optimize the proportion of the factors studied. The minimum and maximum levels of the variables and the design matrix is depicted in Table 5. The basic model equation to fit the data is given by the equation:

$$Y = \beta_0 + \Sigma\, \beta_i X_i + \Sigma\, \beta_{ii} X_{ii}^2 + \Sigma\, \beta_{ij} X_i X_j \text{ (Equation 1)}$$

Where Y is the predicted response, β_0 is the intercept, n is the number of variables studied, β_i, β_{ii} and β_{ij} are the linear (effect of that single factor), quadrative (square terms) and interactive model coefficients, Xi and Xj represents the levels of the independent parameters. Positive or negative coefficients indicate synergistic or antagonistic effect of that factor on the observed response. The predicted values of the chroma responses corresponding to the optimum levels of the factors were compared with the actual responses using a one-sample t-test. 3D surface graphs were used to observe the response variable at its optimal level. 3-dimensional (3D) response surface plot was used to illustrate the relationship between responses and independent variables.

RESULTS AND DISCUSSION

Mustard seed were procured from the local market

Fig. 2. Raw sesame oilseed (*Brassica juncea*, Indian mustard)

and subjected to cleaning for conducting experiment. 100g of the mustard seeds were taken and different moisture content were tested using hot air oven method (AOAC, 1980). The selected color parameters of L, a, b, z (%), tcd, a/b, WY ratio, redness ratio, browness ratio, whiteness ratio, yellowness ratio, hue angle, chroma, browness index and whiteness index were determined using hunter colorimeter. At 10% mc in mustard seeds redness ratio varies between 2.41-41.25, whiteness ratio varies between 35.66-38.93, whiteness yellow ratio varies between 21.38-308.50, yellowness ratio between 0.46-6.68, browness ratio varies between 762.01-1084.15, hue angle varies between 70.68-71.57, chroma varies between 4.77-6.01. At 16% mc, total colour difference varies between 6.01-6.68, redness ratio varies between 3.06-16.72, whiteness index varies between 30.84-40.31, whiteness yellow ratio varies between 20.96 - 106.93, yellowness ratio varies between 6.82 - 4.81 browness ratio varies between 408.01 - 849.05, hue angle varies between 3.43 - 25.64 and chroma varies between 3.13 - 5.08. At 18 % mc, total colour difference varies between 5.76-6.47, redness ratio varies between 4.85 - 8.61, whiteness ratio varies between 32.09 - 36.65, whiteness yellow ratio varies between 42.78 to 69.37, yellowness ratio varies between 3.34 - 19.99, browness ratio varies between 647. 97 - 856.65, hue angle varies between 6.84 - 40.70 and chroma varies. between 4.25 to 6.97. The hue angle is greater in 10% mc butt not greae than 90° and is less in 20% mc, that indicates the lighter the color the more is the hue angle in mustard seeds selected for the study. But browness ratio is very much higher in 20%mc but less in 10% mc because of the presence of moisture content. Whiteness ratio is more in 10%mc and less in 20%mc because of less moisture content.

Table 1 shows the colour parameters of mustard seeds at different moisture content. This is similar to the findings made as mean color space values a* (+a* red direction; –a* green direction) ranged from –4.9 for 'Tennessee Sweet Potato' (*C. moschata*) and 'Fordhook Acorn' (*C. pepo*) to 14.8 for 'Butter -bush' (*C. moschata*). The lowest mean color space value, b* (+b* yellow direction; –b* blue direction) 9.8 found within PI 314806 (*C. pepo*) with the highest, 71.4, found within 'Waltham Butternut' (*C. moschata*). Cultigens with hue angles 90 or greater had yellow flesh, mean a* values ranging from 0.2 to –4.9, and mean b* values ranging from 9.8 to 47.8. (Rachel Itle and Eileen Kabelka,2009) At 20% mc total colour difference varies between 6.17 - 6.40, redness ratio varies between 8.82 - 29.53, whiteness ratio varies between 33.03 - 36.40, whiteness yellow ratio varies between 67.49 - 195.41 yellowness ratio varies between 2.12 - 6.85, browness ratio varies between 767.34 - 1204.11, hue angle varies between 1.72 - 13.50 and chroma varies between 4.53 - 6.83. This coincided with the findings of raw brown rice had L values ranged with 63.30±1.7 and for popped brown rice the values were between 67.78±2.5, a values varied between 9.19±0.3 for raw brown rice and 7.13 ±0.5 for popped brown rice, b values varied between 28.05±1.2 for raw brown rice and 23.27±1.2 for popped brown rice. (Shabir Ahmad Mir *et al.*, 2016) This also coincided with the kodo and kutki millet biscuits, L ranged between 47.25-55.09,a-6.85-9.80,b-26.01-28.59, YI-52.34-60.49,WI-(-155.15) – (-193.51) in kodo and L ranged between 44.36-61.64, a-10.63-14.01, b-27.40-34.12, YI-59.31-62.53, WI-(-175.60 -(-193.61) (Shiv Kumar *et al.*, 2010). The redness ratio increases from 10% to 20%mc. since moisture addition adds dark colour to the mustard seed The colour values of foxtail millet flour in terms of L*, a* and b* values were found to be 61.38 ± 2.21, 3.91 ± 0.05 and 16.2 ± 0.65, respectively (Goudra pramod

Table 1. Colour parameters of mustard seeds at different moisture content

mc (%wb)	L	a	b	z(%)	TCD	a/b	Wyrat	WI	YI	BI	huean	chroma
1 10%mc	37.12	5.04	0.93	9.56	6.56	15.40	113.93	36.90	3.51	891.71	10.24	5.17
2 16%mc	35.68	4.12	0.24	8.89	6.32	5.08	39.89	35.53	0.65	680.90	14.94	4.29
3 18%mc	36.40	4.58	0.58	9.23	6.44	10.24	76.91	36.22	2.08	786.31	12.59	4.73
4 20%mc	34.45	5.23	0.43	8.30	6.26	8.97	58.46	34.23	1.79	914.24	6.66	5.29
average	35.91	4.74	0.54	8.99	6.40	9.92	72.30	35.72	2.00	818.29	11.10	4.87
min	34.45	4.12	0.24	8.30	6.26	5.08	39.89	34.23	0.65	680.90	6.66	4.29
max	37.12	5.23	0.93	9.56	6.56	15.40	113.93	36.90	3.51	914.24	14.94	5.29
sd	1.14	0.50	0.29	0.54	0.13	4.26	31.60	1.14	1.18	107.23	3.53	0.46
sem	0.57	0.25	0.15	0.27	0.07	2.13	15.80	0.57	0.59	53.62	1.77	0.23
cv	3.17	10.47	53.94	5.98	2.08	42.94	43.71	3.19	58.72	13.10	31.81	9.35
p-val	0.00	0.00	0.03	0.00	0.00	0.02	0.02	0.00	0.04	0.00	0.01	0.00

gouda *et al.*, 2019). The mustard seed color of a value is more in grain form than in foxtal millet flour form since in disrupted form redness is less than in grain form. Thilagavathi *et al.* (2015), observed that the colour value L*, a* and b * were in the range of 103.94 ± 4.40 to 126.62 ± 1.70,-3.26 ± 0.04 to -6.67 ± 0.07 and 11.13 ± 0.48 to 37.97 ± 1.54, respectively for different minor millets. The variations observed in proximate composition of foxtail millet might be due to the chemical structure formed among different foxtail millet varieties.

Central Composite Rotational Design (CCRD) is one of the design that can estimate a second degree polynomial model, that can be used to optimize (maximize, minimize, or attain a specific target for) the response variable(s) and has successfully been applied for the development and optimization of cereal products (Thakur and Saxena, 2000, Singh *et al.,* 2004).

Optimization Using RSM

The color values were optimized using CCRD of RSM. Table 2 represent the suggested experimental design and mean values of color attributes and the regression equations for the response, chroma. Equations fit the obtained results well and was statistically significant at different p values. The adequacy of quadratic models was confirmed by the Analysis of Variance (ANOVA) using Fisher's test value (F-value) and lack-of-fit test. Fitting and Validating RSM models for optimizing independent variables. Table 2 shows the statistical summary for each model that was output by Design Expert V.12. A quadratic model was suggested, even though it has lower R2 and adjusted-R2 (Adj-R2) values than a cubic model. This is because the cubic model is aliased, that means that the effects of each variable that cause different signals become indistinguishable. For a linear relationship, the R2 and Adj-R2 values are 0.74 and 0.56, respectively. It is clear that the linear relationship is not adequate for the experimental data. The quadratic model was therefore selected to fit the experimental data (Pengpeng Qiu *et al.,* 2014).

The Model F-value of 4.18 implies the model is significant. There is only a 0.03% chance that an F-value this large could occur due to noise. P-values less than 0.05 indicate model terms are significant. In this case A, B, AB are significant model terms. Values greater than 0.10 indicate the model terms

Table 2. ANOVA for Quadratic model

Response 1: chroma

Source	Sum of Squares	df	Mean Square	F-value	p-value	
Model	5.89	20	0.29	4.18	0.00	Significant
A-mc	0.51	1	0.51	7.22	0.01	
B-L	0.78	1	0.78	11.05	0.00	
C-a	0.10	1	0.10	1.45	0.24	
D-b	0.04	1	0.04	0.58	0.45	
E-z	0.10	1	0.10	1.45	0.24	
AB	4.17	1	4.17	59.09	< 0.0001	
AC	1.78E-15	1	1.78E-15	2.52E-14	1	
AD	8.88E-16	1	8.88E-16	1.26E-14	1	
AE	8.88E-16	1	8.88E-16	1.26E-14	1	
BC	8.88E-16	1	8.88E-16	1.26E-14	1	
BD	8.88E-16	1	8.88E-16	1.26E-14	1	
BE	8.88E-16	1	8.88E-16	1.26E-14	1	
CD	8.88E-16	1	8.88E-16	1.26E-14	1	
CE	8.88E-16	1	8.88E-16	1.26E-14	1	
DE	8.88E-16	1	8.88E-16	1.26E-14	1	
A^2	0.03	1	0.03	0.38	0.54	
B^2	0.04	1	0.04	0.60	0.44	
C^2	0.03	1	0.03	0.38	0.54	
D^2	0.04	1	0.04	0.60	0.44	
E^2	0.03	1	0.03	0.38	0.54	
Residual	2.05	29	0.07			
Lack of Fit	0.80	22	0.04	0.20	0.998	not significant
Pure Error	1.25	7	0.18			
Cor Total	7.94	49				

are not significant. The Lack of Fit F-value of 0.20 implies the Lack of Fit is not significant relative to the pure error. There is a 99.82% chance that a Lack of Fit F-value this large could occur due to noise. Non-significant lack of fit is good. The standard deviation value is 0.27, mean is 4.87, CV is 5.46%, R2=0.74, Adjusted R2 is 0.56, Predicted R2 is 0.33, Adequate precision is 7.24. Table 2 shows the anova Table, quadratic model shows the level of significance as significant.

The Predicted R^2 of 0.32 is not as close to the Adjusted R^2 of 0.56 as one might normally expect; i.e. the difference is more than 0.2. This may indicate a large block effect or a possible problem with model and data. Adeq Precision measures the signal to noise ratio. A ratio greater than 4 is desirable. Ratio of 7.23 indicates an adequate signal. This model can be used to navigate the design space.

Final Equation in Terms of Actual Factors

$Chroma=241.99-10.85mc-10.63L+3.54a-1.33b+5.38z+0.31mc*L-1.42E-14mc*a-2.74E-14mc*b-9.62E-15mc*z+7.07E-14L*a-8.82E-14L*b+1.93E-13L*z-2.21E-13a*b+6.91E-14a*z-1.21E-13\ b*z-0.005\ mc^2+0.088L^2-0.401a^2+1.314b^2-0.311z^2$

The equation in terms of actual factors can be used to make predictions about the response for given levels of each factor. Here, the levels should be specified in the original units for each factor. This equation should not be used to determine the relative impact of each factor because the coefficients are scaled to accommodate the units of each factor and the intercept is not at the center of the design space. Table 3 and 4 represents the optimized parameters and high and low values of color parameters.

The Model F-value of 4.18 implies the model is significant. There is only a 0.03% chance that an F-value this large could occur due to noise. P-values less than 0.05 indicate model terms are significant. In this case A, B, AB are significant model terms. Values greater than 0.10 indicate the model terms are not significant. The Lack of Fit F-value of 0.20 implies the Lack of Fit is not significant relative to the pure error. There is a 99.82% chance that a Lack of Fit F-value this large could occur due to noise. Non-significant lack of fit is good. Table 5 shows the anova for quadratic model with response as chroma factor. The standard deviation value is 0.27,mean is 4.87, CV is 5.46%, R2=0.74, Adjusted R2 is 0.56, Predicted R2 is 0.33, Adequate precision is 7.24.

The Predicted R^2 of 0.32 is not as close to the Adjusted R^2 of 0.56 as one might normally expect; i.e. the difference is more than 0.2. This may indicate a large block effect or a possible problem with your model and/or data.

Final Equation in Terms of Actual Factors

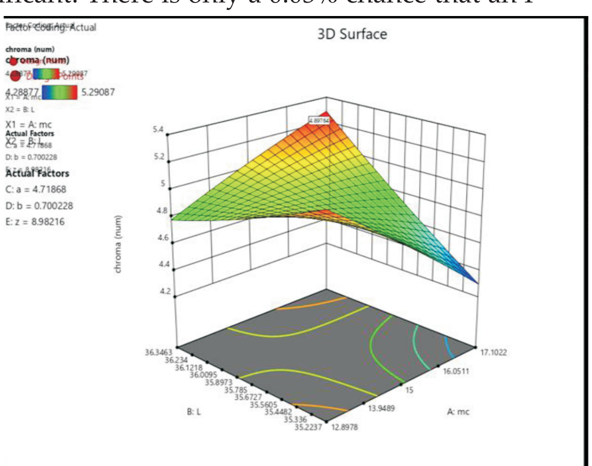
$Chroma=449.09-17.36mc-127.87tcd+4.84WI-0.27YI+0.01BI+2.72mc*tcd+9.89E-15mc*WI+8.3E-15+1.14E-16-6.97E-13tcd*WI+2.82E-13tcd*YI+4.09E-15tcd*BI+4.05E-14WI*YI+5.93\ E-16+4.77E-16YI*BI-$

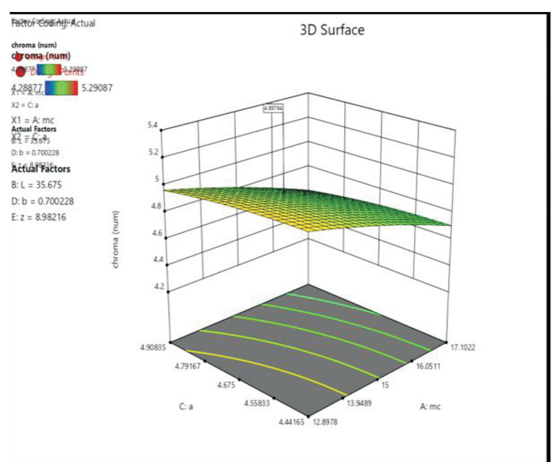
Table 3. Optimized parameters

mc	L	a	b	z
14.68	35.68	4.72	0.70	8.98

Table 4. Low level and High level of color parameters

Factor	Name	Level	Low Level	High Level
A	mc	14.68	12.9	17.1
B	L	35.67	35.22	36.35
C	a	4.72	4.44	4.91
D	b	0.70	0.44	0.73
E	z	8.98	8.67	9.19





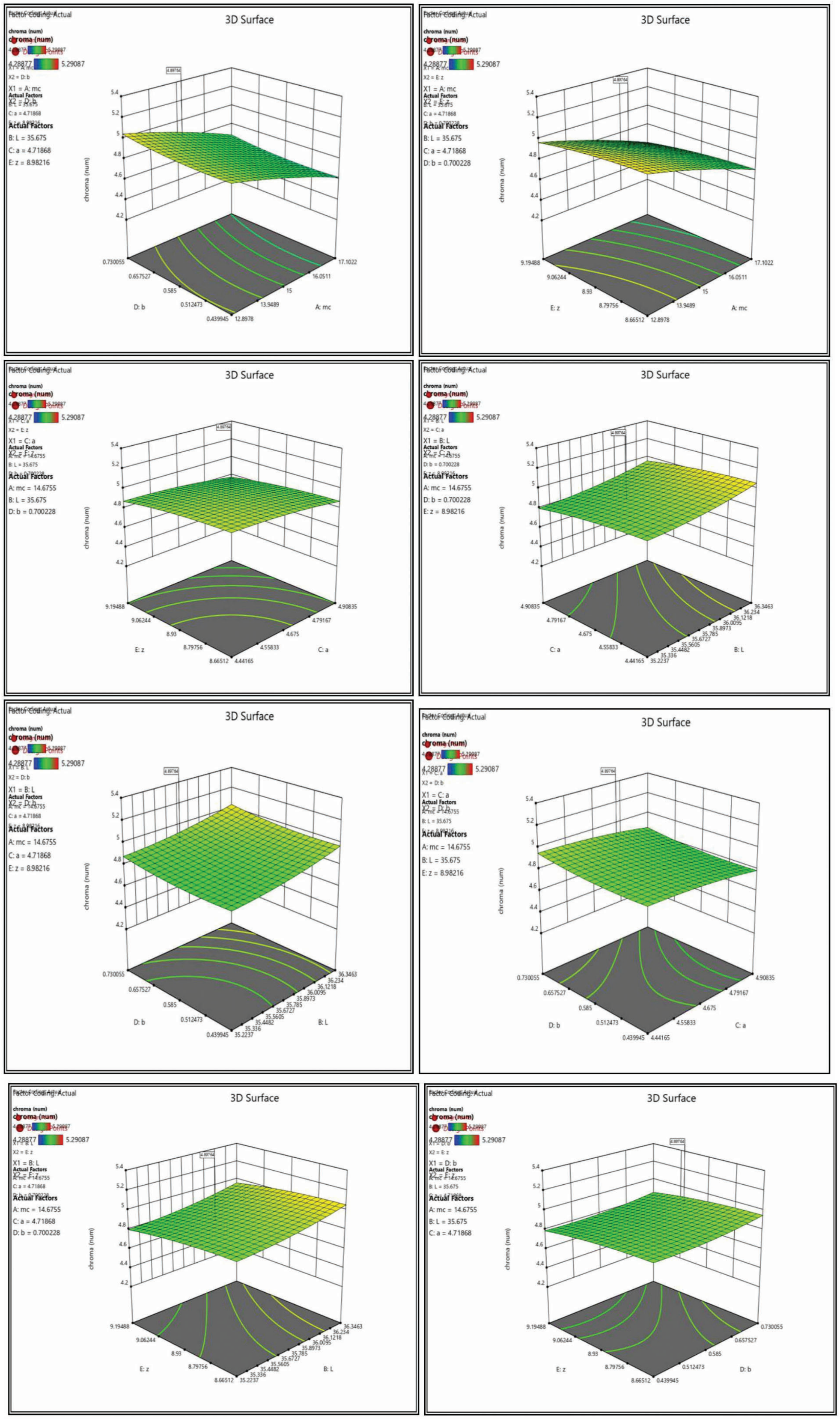


Fig.3. 3d graphs of selected color parameters of mustard seed at different moisture contents

Table 5. ANOVA for Quadratic model

Response 1: chroma

Source	Sum of Squares	df	Mean Square	F-value	p-value	
Model	5.89	20.00	0.29	4.18	0.00	significant
A-mc	0.51	1.00	0.50	7.22	0.012	
B-tcd	0.78	1.00	0.78	11.05	0.002	
C-WI	0.10	1.00	0.10	1.45	0.23	
D-YI	0.04	1.00	0.04	0.58	0.45	
E-BI	0.10	1.00	0.10	1.45	0.23	
AB	4.17	1	4.17	59.09	< 0.0001	
AC	1.78E-15	1	1.78E-15	2.52E-14	1	
AD	8.88E-16	1	8.88E-16	1.26E-14	1	
AE	8.88E-16	1	8.88E-16	1.26E-14	1	
BC	8.88E-16	1	8.88E-16	1.26E-14	1	
BD	8.88E-16	1	8.88E-16	1.26E-14	1	
BE	8.88E-16	1	8.88E-16	1.26E-14	1	
CD	8.88E-16	1	8.88E-16	1.26E-14	1	
CE	8.88E-16	1	8.88E-16	1.26E-14	1	
DE	8.88E-16	1	8.88E-16	1.26E-14	1	
A^2	0.02	1.00	0.02	0.37	0.54	
B^2	0.04	1.00	0.04	0.60	0.44	
C^2	0.02	1.00	0.02	0.37	0.54	
D^2	0.04	1.00	0.04	0.60	0.44	
E^2	0.02	1.00	0.02	0.37	0.54	
Residual	2.05	29	0.07			
Lack of Fit	0.79	22	0.03	0.20	0.99	not significant
Pure Error	1.25	7	0.17			
Cor Total	7.94	49				

Factor coding is Coded. Sum of squares is Type III - Partial

$0.0049mc^2+6.95tcd^2-0.0693WI^2+0.07YI^2-9.08E-06BI^2$

The equation in terms of actual factors can be used to make predictions about the response for given levels of each factor. Here, the levels should be specified in the original units for each factor. This equation should not be used to determine the relative impact of each factor because the coefficients are scaled to accommodate the units of each factor and the intercept is not at the center of the design space. Table 6 shows the optimized parameters and Table 7 shows the low and high level for the selected variables of mc, tcd, WI,YI and BI. Fig.5 shows the 3d graph of the effect of selected color parameters of mustard seed at different moisture contents to chroma. Fig.6 shows the predicted and actual parameters of mustard seed at different moisture content.

Fig.3 shows the selected color parameters of mustard seed at different moisture contents. Whiteness Index is less in 20%mc and most in 10%MC that shows that the dark color is more at 20%mc. Yellowness Index is more at 10% mc and less at 20%mc and browness index is most at 20%mc and less in 10%mc than that of 20%mc. Fig.7 shows the Color parameters of whiteness index, yellowness index, browness index, Whiteness yellow index, hue angle, chroma, L, a, b, z, L/b and TCD at different moisture contents. Fig. 8 shows the color parameters of mustard seed at different moisture contents. Hue angle is most at 10%mc when compared to 20%mc. Chroma the strongness of the color is more at 20%wb. The total color difference is more at 10%mc and less at 20% mc. This may be due to the fact that

Table 6. Optimized parameters

mc	tcd	WI	YI	BI
15.18	6.44	35.19	1.95	759.66

Table 7. Low level and High level of color parameters

Factor	Name	Level	Low Level	High Level
A	mc	15.18	12.90	17.10
B	tcd	6.44	6.35	6.47
C	WI	35.19	35.00	36.13
D	YI	1.95	1.48	2.68
E	BI	759.66	748.52	846.62

initial the grains intensity of color is less. Fig.4 shows the Predicted and Actual parameters of mustard seed at different moisture contents. To obtain an adequate model, an accuracy check is necessary. The model accuracy was checked by comparing the predicted and experimental values. Fig. 4 shows the linear relationship between the predicted and experimental values. The straight line means that no response transformation was required and that there was no apparent problem with normality. The good agreement between the experimental and predicted results verifies the validity of the model. These results indicate that RSM is a very effective and powerful tool for optimizing individual factors.

The pearson coefficient coefficient of L with a is (r=(-0.17)),L with b(r=0.72),L with tcd (r=0.96),a with L(r=(-0.17)), a with b(r=0.56),a with z(r=0.18), a with tcd(r=0.11), b with L (r= 0.72), b with a(r=0.56),b with z(r=0.72), b with z(r=0.89), z with a(r=(-0.18),z with b (r= 0.72), z with tcd (r=0.96), tcd with L(r=0.96),tcd with a(r=0.11),tcd with b(r=0.89), tcd with z(r= 0.96), chroma with L(r=(-0.12)), chroma with z(r=(-0.13), chroma with tcd(r=0.17), WYratio with WI (r= 0.72), As L decreases the chroma, degree of saturation increases, tcd increases chroma increases, it is that at higher moisture condition this occurs. Table 8 shows the correlation coefficient of selected color parameters of mustard seed at different moisture contents. WYratio with YI (r=0.99), WYratio with BI(r=0.59) and WYratio with hue angle(r=(-0.27)), WI with WYratio (r=0.72), WI with YI(r=0.59), WI with BI(r=(-0.13)), WI with hue angle (r=0.46), YI with WI (r=0.59), YI with BI(r=0.72),YI with hue angle(r=(-0.44)), BI with WY ratio (r=0.59), BI with WI (r=(-0.13)), BI with YI(r=0.72) and BI with hue angle(r=(-

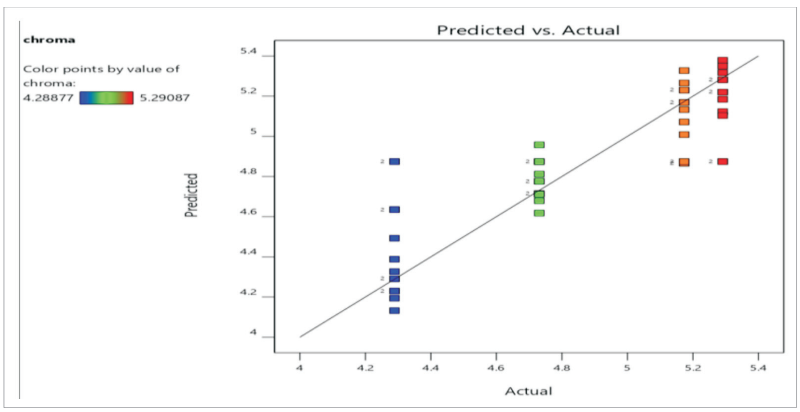


Fig. 4. Predicted and Actual parameters of mustard seed at different moisture contents

Table 8. Correlation coefficient of selected color parameters of mustard seed at different moisture contents

		L	a	b	z	tcd
L	Pearson Correlation	1	-0.17	0.72	1.00	0.96
	Sig. (2-tailed)	0.83	0.28	0.00	0.04	
	N	4	4	4	4	4
a	Pearson Correlation	-0.17	1.00	0.56	-0.18	0.11
	Sig. (2-tailed)	0.83	0.44	0.82	0.89	
	N	4	4	4	4	4
b	Pearson Correlation	0.72	0.56	1.00	0.72	0.89
	Sig. (2-tailed)	0.28	0.44	0.28	0.11	
	N	4	4	4	4	4
z	Pearson Correlation	1.00	-0.18	0.72	1.00	0.96
	Sig. (2-tailed)	0.00	0.82	0.28	0.04	
	N	4	4	4	4	4
tcd	Pearson Correlation	0.96	0.11	0.89	0.96	1
	Sig. (2-tailed)	0.04	0.89	0.11	0.04	
	N	4	4	4	4	4
Chroma	Pearson Correlation	-0.12	1.00	0.60	-0.13	0.17
	Sig. (2-tailed)	0.88	0.00	0.40	0.87	0.83
	N	4	4	4	4	4

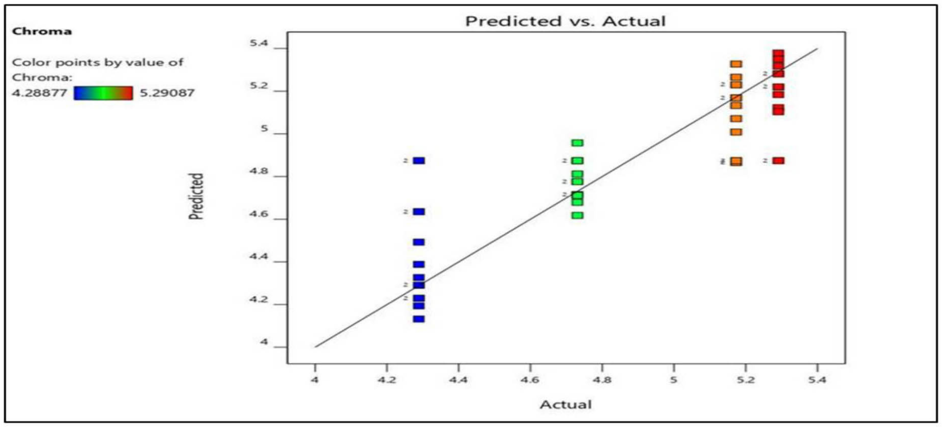


Fig. 6. Predicted and Actual parameters of mustard seed at different moisture content

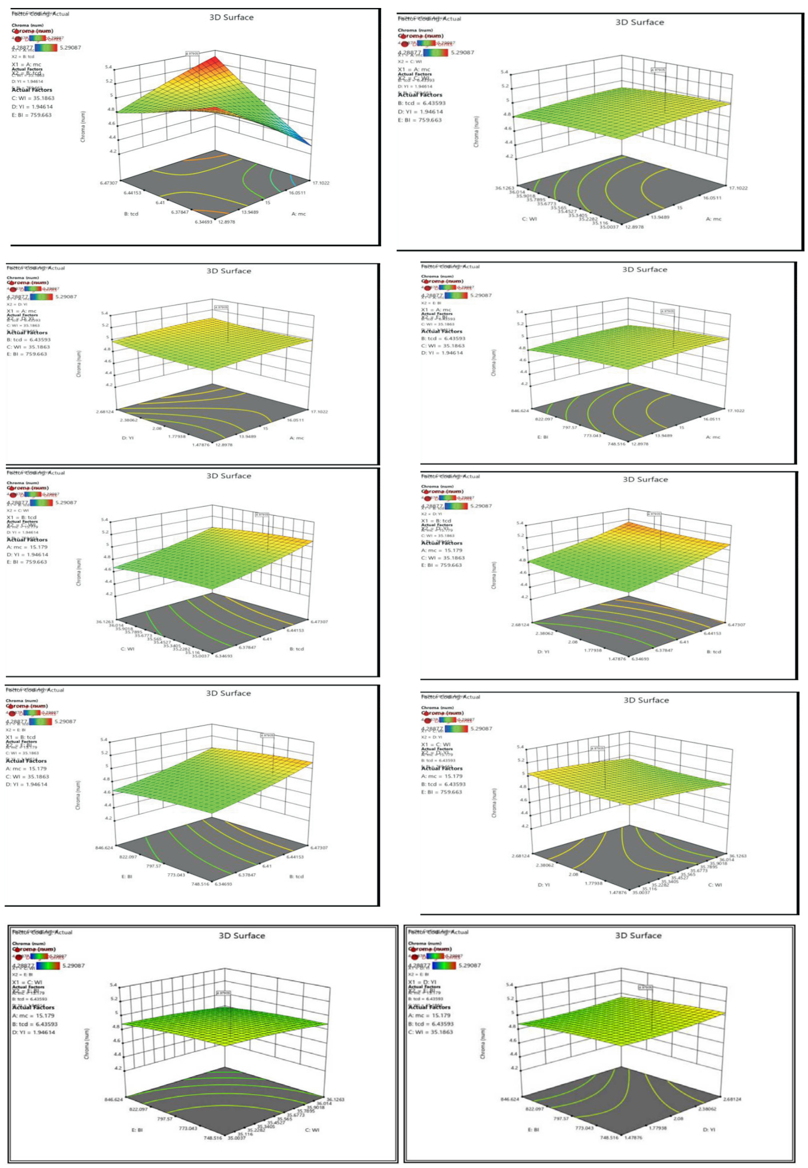
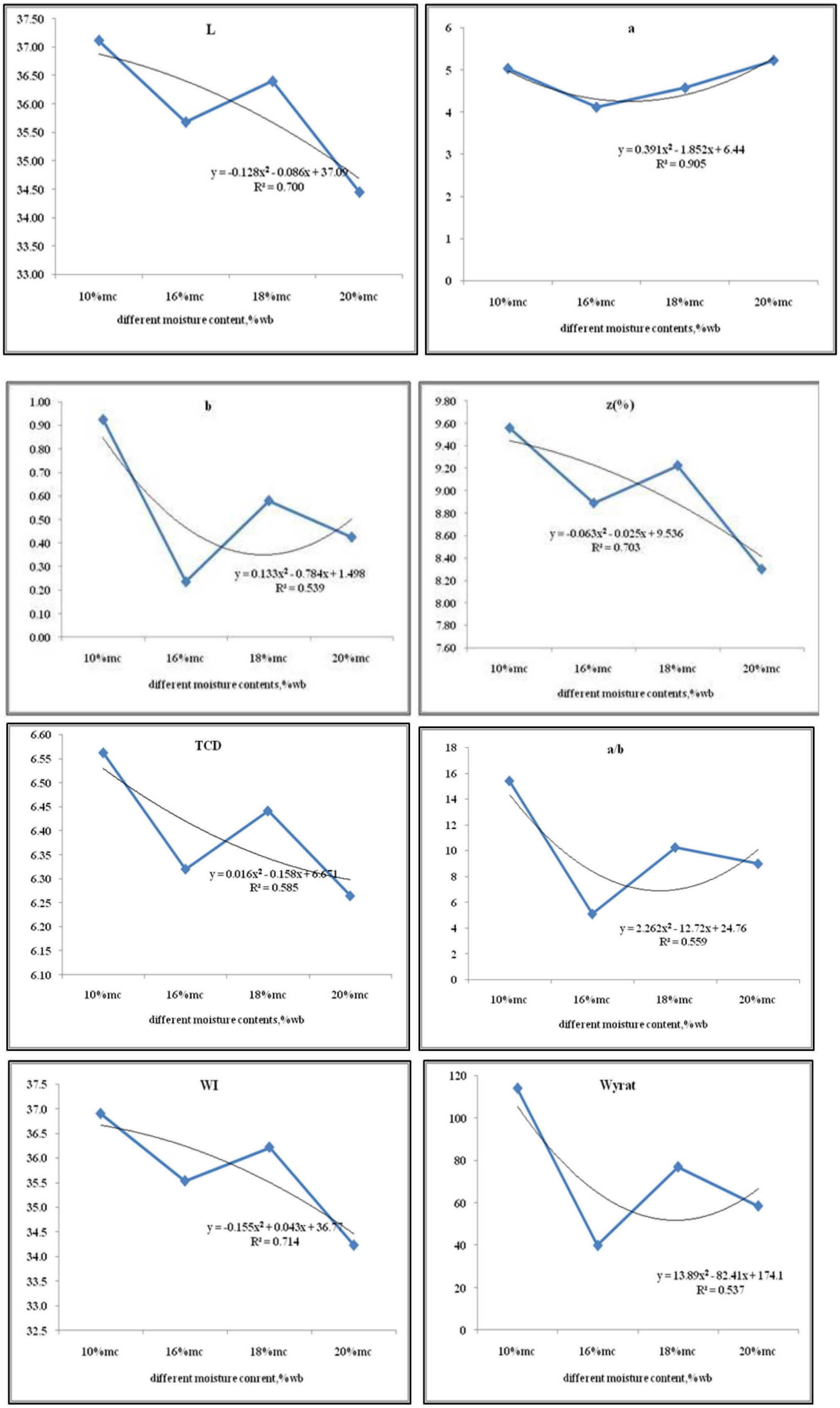


Fig. 5. 3d graphs of selected color parameters of mustard seed at different moisture


L
y = -0.128x² - 0.086x + 37.09
R² = 0.700
different moisture content,%wb
a
y = 0.391x² - 1.852x + 6.44
R² = 0.905
different moisture contents,%wb
b
y = 0.133x² - 0.784x + 1.498
R² = 0.539
different moisture contents,%wb
z(%)
y = -0.063x² - 0.025x + 9.536
R² = 0.703
different moisture contents,%wb
TCD
y = 0.016x² - 0.158x + 6.671
R² = 0.585
different moisture contents,%wb
a/b
y = 2.262x² - 12.72x + 24.76
R² = 0.559
different moisture content,%wb
WI
y = -0.155x² + 0.043x + 36.77
R² = 0.714
different moisture conrent,%wb
Wyrat
y = 13.89x² - 82.41x + 174.1
R² = 0.537
different moisture content,%wb
10%mc
16%mc
18%mc
20%mc

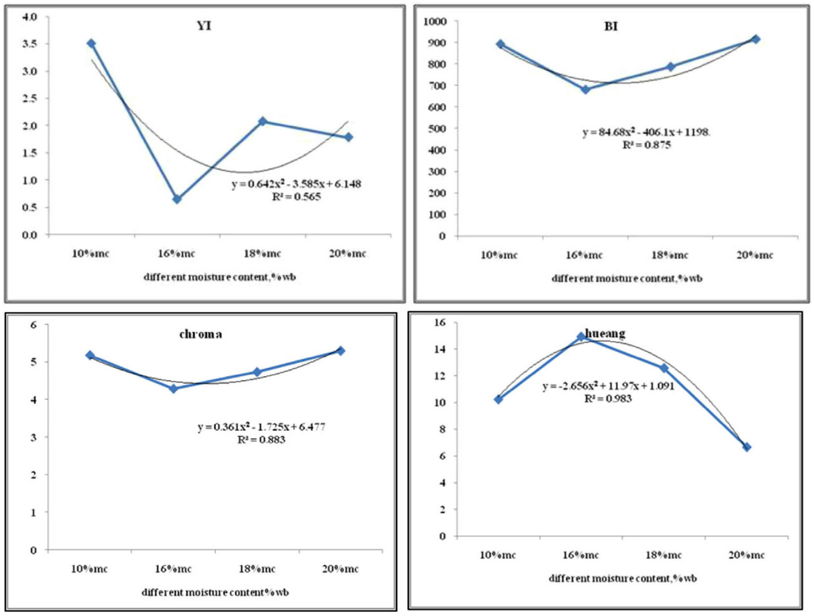


Fig. 7. Color parameters of whiteness index, yellowness index, browness index, Whiteness yellow index, hue angle, chroma, L, a, b, z, L/b and TCD at different moisture contents

0.94)), hue angle with WYratio (r=(-0.27)), hue angle with WI(r=0.46), hue angle with BI(r=(-0.94)) and chroma with WYratio (r=0.57), chroma with WI(r=(-0.15)), chroma with YI (r=0.71) and chroma with hue angle (r=(-0.94)). At higher moisture contents chroma increases with increase in yellowness index and whiteness yellow index and decreases with increase in whiteness ratio and hue angle. Table 9 shows the correlation coefficient of selected color parameters of mustard seed at different moisture contents.

CONCLUSION

The optimization function in the Design Expert software was used to obtain the optimal conditions. The optimized parameters of moisture of mustard in the selected moisture contents of 10%, 16%, 18% and

Table 9. Correlation coefficient of selected color parameters of mustard seed at different moisture contents

		WYR	WI	YI	BI	hueang
WYRatio	Pearson Correlation	1	0.72	0.99	0.59	-0.27
	Sig. (2-tailed)	0.28	0.01	0.41	0.73	
	N	4	4	4	4	4
WI	Pearson Correlation	0.72	1.00	0.59	-0.13	0.46
	Sig. (2-tailed)	0.28	0.41	0.87	0.54	
	N	4	4	4	4	4
YI	Pearson Correlation	0.99	0.59	1.00	0.72	-0.44
	Sig. (2-tailed)	0.01	0.41	0.28	0.56	
	N	4	4	4	4	4
BI	Pearson Correlation	0.59	-0.13	0.72	1.00	-0.94
	Sig. (2-tailed)	0.41	0.87	0.28	0.06	
	N	4	4	4	4	4
Hue angle	Pearson Correlation	-0.27	0.46	-0.44	-0.94	1
	Sig. (2-tailed)	0.73	0.54	0.56	0.06	
	N	4	4	4	4	4
chroma	Pearson Correlation	0.57	-0.15	0.71	1.00	-0.94
	Sig. (2-tailed)	0.43	0.85	0.29	0.00	0.06
	N	4	4	4	4	4

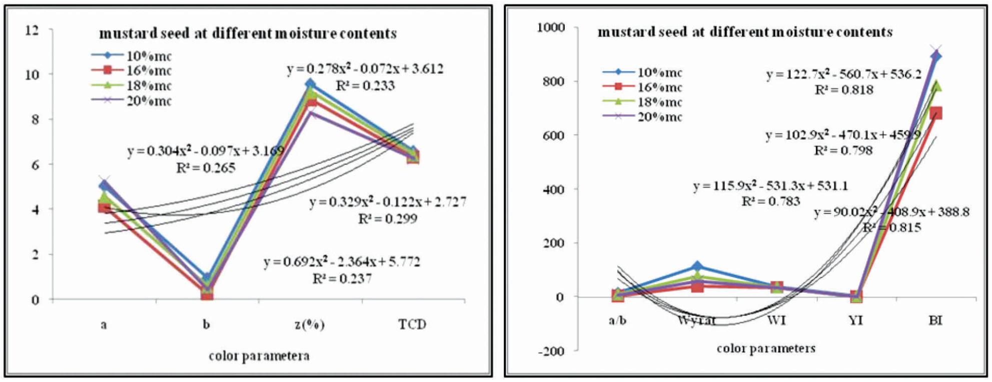


Fig. 8. Color parameters of mustard seed at different moisture contents

20%wb is 13.43%wb, redness is 12.80, whiteness is 35.29, yellowness is 9.10 and hue angle is 49.67 for maximized chroma value. Estimation of mustard seed based on the system describing color must be beneficial for marketing and consumer preferenced for making value added products. This study is also useful for determination of maturity, grading and quality of products. The low values of paramter L* indicates darkness, the negative value of b* indicates purple color of the skin, positive value of parameter a value showed the saturation of red.

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Conflict of Interest: None

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