The Pharma Innovation Journal 2023; 12(5): 1149-1154

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2023; 12(5): 1149-1154

www.thepharmajournal.com
Received: 02-03-2023
Accepted: 04-04-2023

Chandani Popalia
College of Agricultural Engineering and Technology, Junagadh Agricultural University, Junagadh, Gujarat, India

VK Chandegara
College of Agricultural Engineering and Technology, Junagadh Agricultural University, Junagadh, Gujarat, India

PJ Rathod
College of Agricultural Engineering and Technology, Junagadh Agricultural University, Junagadh, Gujarat, India

Corresponding Author:
Chandani Popalia
College of Agricultural Engineering and Technology, Junagadh Agricultural University, Junagadh, Gujarat, India

Valorization of sweet orange peel by fluidized bed drying and cryogenic grinding: Colour characteristics evaluation

Chandani Popalia, VK Chandegara and PJ Rathod

Abstract
The family *Rutaceae* includes the sweet orange (*Citrus sinensis*). During the sweet orange juice extraction process, a 50-60% usable by-product is produced, which is a waste. When the peel is the major byproduct of the extraction of delicious orange juice. The peel is currently widely used in animal feeds and biogas production. It could be an intriguing source of health benefits and pharmaceutical ingredients. Attempts were made to explore the influence of drying temperature (40, 50, and 60 °C). The effects of drying duration (60, 120, and 180 minutes) and grinding temperature (-15 °C, 5 °C, and 25 °C) on the colour attributes (Colour L*, Colour a*, Colour b*, hue angle, chroma, and ΔE) of sweet orange peel. The results showed that parameters decreased as drying time and temperature increased, whereas colour analyses proved the opposite. In the study, the grinding temperature was an important element, with lower grinding temperatures demonstrating greater colour characteristics. The best treatment combination was 50 °C drying temperature, 180 min drying time, and -5 °C grinding condition, which resulted in better colour qualities.

Keywords: Sweet orange peel, fluidized bed drying, cryogenic grinding, color characteristics

1. Introduction

India is the largest producer of horticultural crops and the processing of horticultural produce generates a vast amount of waste that contains useful compounds having medicinal, cosmetic, and nutritional value. Natural antioxidants, antimicrobials, and antidiabetic activities of fruits and vegetable processing wastes are currently attracting a lot of attention.

Citrus fruit is popular due to its characteristic flavor, taste, aroma, and multiple health benefits. Sweet orange (*Citrus sinensis* L.) is also called Moosambi in Kannada, Mousambi/Mosambi in Hindi or Urdu, Sathkudi in Tamil, and BathayaKaayalu in Telugu. Sweet orange (*Citrus sinensis*) belongs to the family Rutaceae and sub-family Aurantoideae (Milind and Dev, 2012) [12]. Sweet oranges mature in 9-12 months with the harvesting season in India being from October to March. The fruits of sweet orange (*Citrus sinensis* L.) are subglobose to round or oval in shape. Sweet orange diameter ranges from 5.7 to 9.5 cm with greenish-yellow to orange in color and is tightly skinned. The major constituents of sweet orange are juice (40-50%), flavedo (8-10%), and albedo (15-30%). The flavedo is the outer yellow sub-epidermal layer containing carotenoid pigments and numerous oil glands filled with aromatic essential oils. The albedo is the inner white spongy layer of parenchymatous cells closely adherent to the outer wall segment and having a thickness of around 0.16 to 1.43 cm. It has a high concentration of glucosides, flavonoids, pectin, and pectic enzyme. Most sweet orange and lime segments have one to three or four seeds linked to the septum wall by placentae. Oil (30-40%) and bitter limonoids are abundant in the seeds (Hashmi *et al.*, 2012) [5]. After juice extraction, the waste from the sweet orange processing sector, such as peels, seeds, and pulps, which account for roughly 50-60% of the raw processed fruit, can be exploited as a possible source of valuable by-products. It represents more than 1.5 million tons per year of waste (El-Adawy *et al.*, 1999) [1]. Citrus peels extract containing polymethoxylated flavones (PMFs) may help prevent diabetes as well as reduce the level of serum triglycerides (TG) and cholesterol. Citrus peels contain a high level of antioxidants more than vitamin E that contributes to the protection of DNA from cancer-causing damage and include degenerative diseases atherosclerosis, ischemic heart disease, ageing, diabetesmellitus, cancer, and immune suppressant (Shyura *et al.*, 2005) [9]. Peel is the main by-product obtained from citrus fruit juice processing industries and is highly perishable (Silalahi, 2002) [10].

If not processed, the peels become waste and in turn, may become a possible source of environmental pollution. By-product recovery from fruit wastes can improve the overall economics of processing units and the problem of environmental pollution can also be reduced considerably (Silke and Ankit, 2009) [11]. It has very good nutritional value, which is evident by the presence of ascorbic acid, total phenolic compounds, limonene, naringenin, carotenoids, fiber, minerals, and many Phyto-chemicals with antimicrobial, antioxidant, antibacterial, antiviral, anti-yeast and antimutagenic properties, which states an ideal substrate for production of value-added products as drug or as a food supplement (Mohnen, 2008) [7]. Therefore, there is a need to optimize the drying and grinding conditions to produce high-quality dried sweet orange by-products as value-added product ingredients.
The objective of the present work was to evaluate color characteristics of sweet orange peel powder obtained from fluidized bed drying and cryogenic grinding methods.

2. Materials and Methods

Sweet orange peel was collected from the juice processing industry in Junagadh, Gujarat. Then, the peels were cut into small pieces (30x10 mm). After that, the peel surface moisture was removed, followed by fluidized drying at different temperatures (40 °C, 50 °C, 60 °C) and time (60min., 120min., 180min.) and grinding temperature (-15 °C, 5 °C, 25 °C).

2.1 Experimental Design

The conditions for obtaining the accurate analysis of color characteristics from the sweet orange peel were optimized by using a central composite design, response surface methodology (RSM). The design was composed of 19 experiments structured in three blocks with three levels (−1, 0, +1). Each experiment was carried out in duplicate. The independent variables were drying temperatures (40 °C, 50 °C, 60 °C), drying time (60 min., 120 min., 180 min.), and grinding temperature (-15 °C, 5 °C, 25 °C). Table 1 shows the experimental design made by design expert 11 software.

Table 1: Coded and Uncoded parameters of central composite rotatable design for fluidized bed drying and grinding process of lime and sweet orange peel

Run	Treatment	Coded variable			Uncoded variables		
					Fluidized bed drying		
		X1	X2	X3	Drying temperature (°C)	Drying time (min.)	Grinding temperature (°C)
1	3	-1	+1	-1	40	180	-15
2	10	+1	0	0	60	120	5
3	19	0	0	0	50	120	5
4	12	0	+1	0	50	180	5
5	2	+1	-1	-1	60	60	-15
6	14	0	0	+1	50	120	25
7	9	-1	0	0	40	120	5
8	15	0	0	0	50	120	5
9	6	+1	-1	+1	60	60	25
10	11	0	-1	0	50	60	5
11	18	0	0	0	50	120	5
12	16	0	0	0	50	120	5
13	17	0	0	0	50	120	5
14	5	-1	-1	+1	40	60	25
15	8	+1	+1	+1	60	180	25
16	4	+1	+1	-1	60	180	-15
17	1	-1	-1	-1	40	60	-15
18	7	-1	+1	+1	40	180	25
19	13	0	0	-1	50	120	-15

2.2 Estimation of colour analysis

A CIELAB scale L*, a*, b* scale Lovibond colorimeter (Make: Lovibond) installed at College of Food Processing Technology & Bio- energy, Anand Agricultural University, Anand was used for colour analysis of sweet orange and lime peel powder as shown in plate 3.10 Low L* (0-50) values indicates dark and a high value (50-100) indicates light. Positive a* values indicate red and a negative value indicates green. Positive b* values indicate yellow and a negative value indicates blue. The L* value for each scale therefore indicates the level of light or dark, the a* value indicates redness or greenness and the b* value indicates yellowness or blueness (Arjeh and Sahari, 2015). All three values are completely needed to judge the colour. The instrument was calibrated and L*, a*, and b* values were recorded for three replicates of each sweet orange and lime peel sample for analysis.
Total colour difference was calculated using following Eq. (3.5), where subscript "o" refers to the colour reading of fresh sweet corn kernel. Fresh sweet corn kernel was used as the reference and a larger ΔE denotes greater colour change from the reference material.

$$\Delta E = \sqrt{(L_o^* - L^*)^2 + (a_o^* - a^*)^2 + (b_o^* - b^*)^2} \quad \ldots(1.1)$$

Where, L* is degree of lightness to darkness, L_o* is initial value of L*, a* is degree of redness to greenness, a_o* is initial value of a*, b* is degree of yellowness to blueness and b_o* is initial value of b*.

Chroma was expressed as $(a^{*2} + b^{*2})^{1/2}$ for providing more information regarding spatial colour distribution (Ihl and Bifani., 1998).

$$\text{Chroma}= \sqrt{a^{*2}+ b^{*2}} \quad \dots(1.2)$$

Browning index (BI) is a measure of purity of brown colour and provide information regarding browning (Lopez-Malo *et al.*, 1998) [15].

$$\text{Browning Index}=\frac{[100(x\text{-}0.31)]}{0.17} \quad \dots(1.3)$$

Where,

$$x=\frac{(a^{*}+1.75L^{*})}{(5.645L^{*}+a^{*}-3.012b^{*})} \dots(1.4)$$

3. Results and discussion

3.1 The effect of fluidized bed drying and grinding techniques on the colour properties of sweet orange peel powder

Table 2 shows response surface graph of colour properties. Effect of drying temperature, drying time and grinding temperature on colour properties found significant effect (Fig, 1(A-R)).

3.1.1 Effect of fluidized bed drying on colour L*, Colour a* and colour b* of sweet orange peel powder

Colour is an important part of food quality, because the color of food is consumers first appraise when making purchasing decisions. The results of color changes in fresh samples for fluidized bed drying, and grinding conditions were given in Table.2. The treatment wise values of colour L* of fluidized dried sweet orange peel powder are tabulated in the Table 2. It can be observed that the maximum colour L* was obtained 66.17 in the treatment 40 °C drying temperature, 60 min drying time and -15 °C grinding temperature, while the minimum colour L* after fluidized bed drying of sweet orange peel was obtained 51.07 in the treatment at 60 °C drying temperature, 180 min drying time and 25 °C grinding temperature. Fluidized bed dried sweet orange peel powder small value of coefficient of variation (1.89) for colour L* that the experimental results were precise and reliable (Table 3). The maximum value of colour b* after fluidized bed drying of sweet orange peel was obtained 76.27 for the treatment at 40 °C drying temperature, 60 min drying time and -15 °C grinding temperature, while the minimum value of colour b* after fluidized bed drying of sweet orange peel was obtained 45.68 in the treatment at 60 °C drying temperature, 180 min drying time, and 25 °C grinding temperature (Table 2). When compared to the fresh sample colour b* (77.56) values fell considerably ($P<0.001$) with drying temperature, drying time, and grinding temperature. The linear effect of drying temperature, drying time and grinding temperature negatively significant at $p<0.001$ on colour b* of sweet orange peel powder in fluidized bed drying. Fluidized bed dried sweet orange peel powder small value of coefficient of variation (1.77) for colour b* that the experimental results were precise and reliable (Table 3). It can be observed that the maximum colour a* was obtained 33.64 in the treatment 60 °C drying temperature, 180 min. drying time and 25 °C grinding temperature, while the minimum colour a* after fluidized bed drying of sweet orange peel was obtained 21.32 in the treatment at 40 °C drying temperature, 60 min. drying time and -15 °C grinding temperature. Compared to the fresh sample, a* values (19.77) significantly increased ($P<0.001$) with drying temperature, drying time and grinding temperature treated sample (Table 2). the linear effect of drying temperature, drying time and grinding temperature positively significant at $p<0.001$ on colour a* of sweet orange peel powder in fluidized bed drying. Small value of coefficient of variation (1.38) for colour a* that the experimental results were precise and reliable (Table 3).

This was in line with the result of researchers (Ghanem *et al.*, 2012 and Geraci *et al.*, 2017) [3, 4]. whereas higher temperatures levels decreased sample lightness or yellowness during drying. This could be associate with the damage of carotenoids and flavonoids pigments of bitter orange peel which are responsible for the yellow and orange color of the biomaterial. Farahmandfar *et al.*, (2019) [2] found similar result colour L* (50.24 to 66.67) and colour b* (69.53 to 75.14) decreased with increase in temperature and different drying method. All drying treatment caused reduction in the value of a* (greenness/redness), compared to those of fresh bitter orange peel, which indicated a lower redness and more carotenoid loss in dried samples (Ghanem *et al.*, 2012) [3]. According to Reza *et al.*, (2019) [14] colour a* (9.63 to 32.58) increased with increase in temperature and different drying method.

3.2 Effect of fluidized bed drying on chroma, browning index and total colour difference of sweet orange peel powder

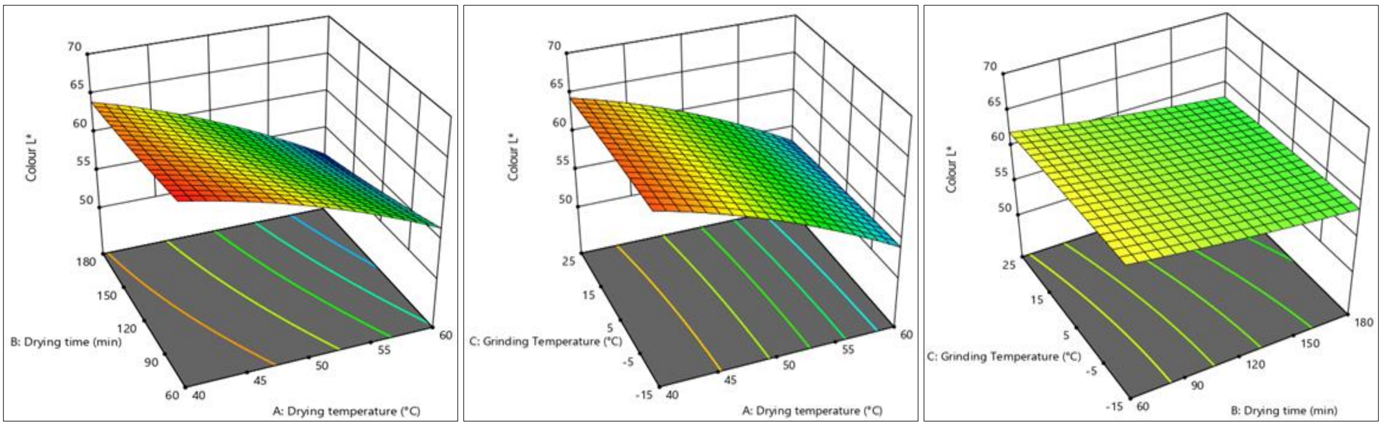
The chroma of dried sweet orange peel powder varied from 56.73 to 79.19 (Table 2). Fluidized bed dried sweet orange peel powder small value of coefficient of variation (1.89) explained that the experimental results were precise and reliable (Table 3). Chroma decreases as the drying temperature, drying rime and grinding temperature increases according to Table 2. The color parameter is BI which displays the purity of brown color in enzymatic and non-enzymatic browning processes (Saricoban *et al.*, 2010). The BI of dried sweet orange peel powder was found varied from 210.18 to 306.11 (Table 2). The total color difference (ΔE) is another color index which shows the degree of overall color change in dried samples with respect to the color of fresh sweet orange peel. Dried products with excellent quality should have a low ΔE value. he total colour difference of dried sweet orange peel powder was found varied from 3.06 to 38.88. In fluidized bed dried sweet orange peel powder small value of coefficient of variation (7.02) for BI explained that the experimental results were precise and reliable (Table 3). According to Reza *et al.*, (2019) total colour difference (19.42 to 31.21) noted in temperature and different drying methods.

Table 2: Experimental value of milling loss and colour properties of sweet orange peel powder dried by fluidized bed dryer

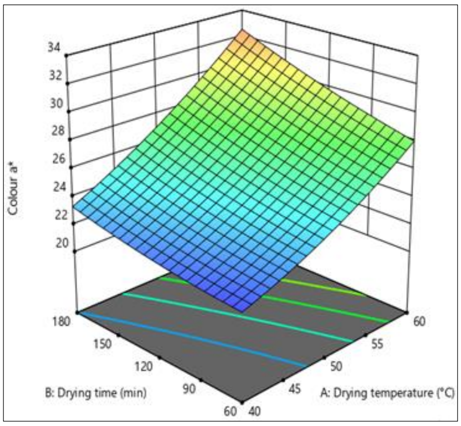
Sr. No.	Std. run	Drying Temperature (°C)	Drying Time (min.)	Grinding Temperature (°C)	colour L*	Colour a*	Colour b*	Croma	BI	ΔE
1	12	40	180	-15	64.23	22.83	72.77	76.27	296.21	7.09
2	19	60	120	5	53.64	30.19	51.92	60.06	230.87	31.40
3	9	50	120	5	60.37	25.21	64.17	68.94	263.31	16.57
4	1	50	180	5	58.32	27.81	58.27	64.57	238.51	23.23
5	16	60	60	-15	56.43	27.92	55.21	61.87	231.21	26.66
6	15	50	120	25	58.72	26.73	61.34	66.91	256.80	20.16
7	2	40	120	5	64.82	22.41	73.16	76.52	293.41	6.30
8	7	50	120	5	60.52	25.25	64.27	69.05	262.84	16.43
9	13	60	60	25	56.31	28.47	54.37	61.37	226.86	27.59
10	11	50	60	5	62.73	24.13	67.78	71.95	270.12	12.15
11	17	50	120	5	60.78	25.32	64.38	69.18	261.53	16.24
12	18	50	120	5	60.37	25.27	64.21	69.00	263.67	16.56
13	10	50	120	5	60.58	25.27	64.32	69.11	262.72	16.36
14	6	40	60	25	66.13	21.89	75.83	78.93	302.99	3.60
15	8	60	180	25	51.07	33.64	45.68	56.73	210.18	38.88
16	3	60	180	-15	51.68	31.47	48.32	57.66	221.28	35.69
17	4	40	60	-15	66.17	21.32	76.27	79.19	306.11	3.06
18	5	40	180	25	63.78	23.77	69.62	73.57	275.04	10.05
19	14	50	120	-15	61.58	24.89	66.84	71.32	273.48	13.73

Table 3: Analysis of variance (ANOVA) and regression coefficients for response surface quadratic model of different colour properties of sweet orange peel powder by using fluidized bed dryer

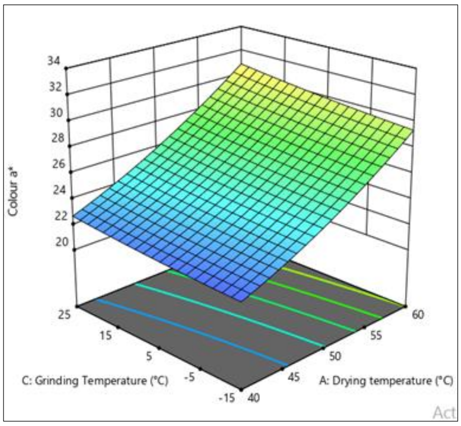
Source	Colour L*	Colour a*	Colour b*	Croma	BI	ΔE
Intercept	60.42***	25.45***	64.08***	68.95***	262.36***	16.69***
X1	-5.60***	3.95***	-11.22***	-8.68***	-35.34***	13.01***
X2	-1.87***	1.58***	-3.48***	-2.45***	-9.61***	4.19***
X3	-0.408*	0.607***	-1.26**	-0.8800*	-5.64**	1.40**
X1X2	-0.71*	0.666***	-0.733*	-0.0712	1.41*	1.23*
X1X3	-0.030	0.151	0.013	0.1913	1.11	0.077
X2X3	-0.112	0.248*	-0.563	-0.3587	-3.10*	0.585
$X1^2$	-1.06*	0.613*	-1.31	-0.5263	0.353*	1.85*
$X2^2$	0.2304	0.283	-0.820	-0.5563	-7.47	0.685
$X3^2$	-0.1446	0.123	0.244	0.2987	3.35	-0.059
R2	0.9913	0.9940	0.9922	0.9887	0.9875	0.9926
Adj-R^2	0.9825	0.9880	0.9843	0.9774	0.9750	0.9852
Pred-R^2	0.9351	0.9478	0.9388	0.9028	0.8863	0.9441
Adeq Precision	36.6006	47.109	39.4341	32.3237	31.4170	40.6097
F-value	113.44	165.99	126.55	87.42	78.97	134.26
Lack of fit	NS	NS	NS	NS	NS	NS
C.V. %	1.89	1.38	1.77	1.89	1.70	7.02



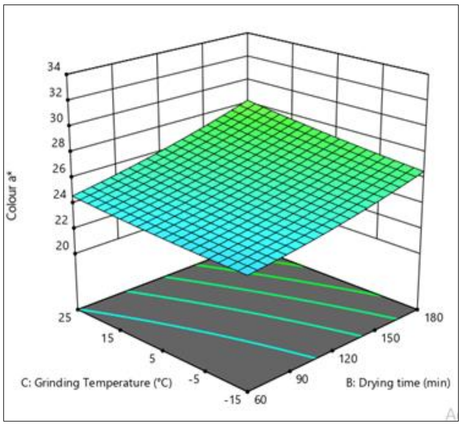
A B C



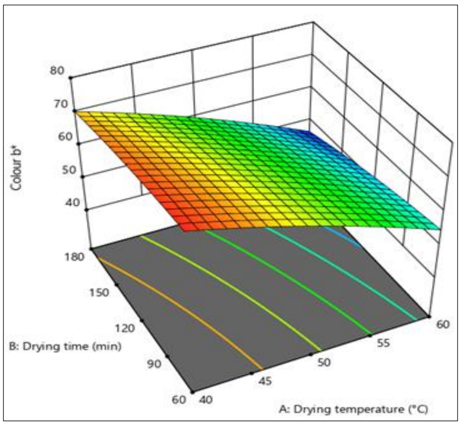
D



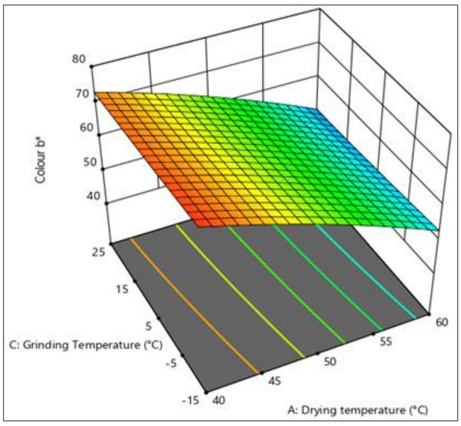
E



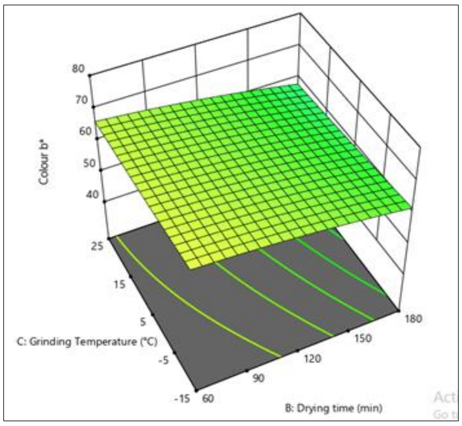
F



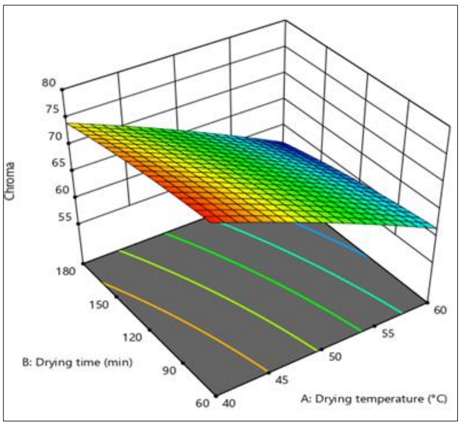
G



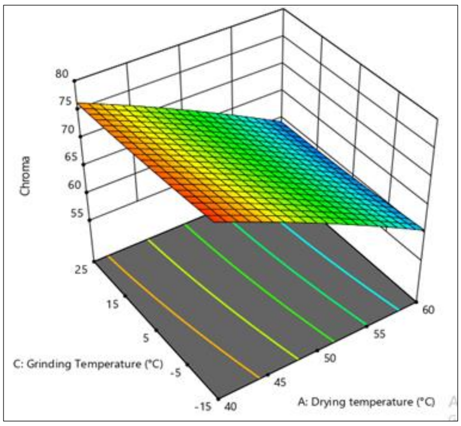
H



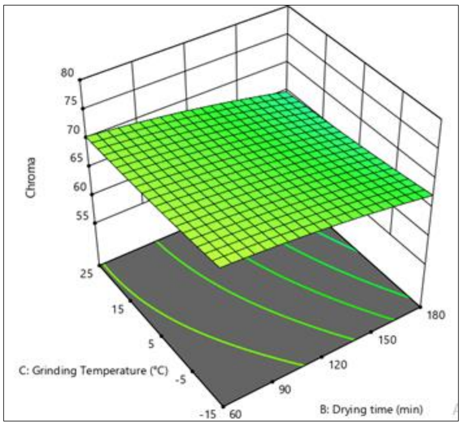
I



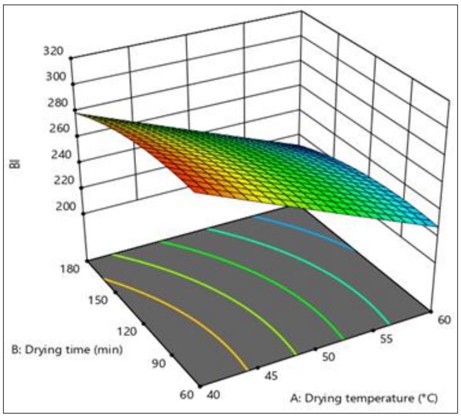
J



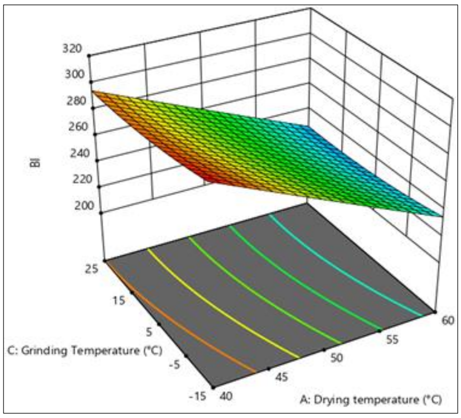
K



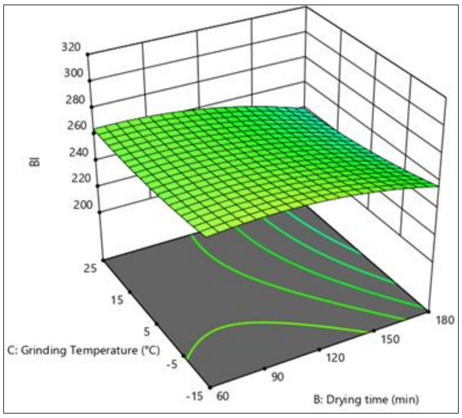
L



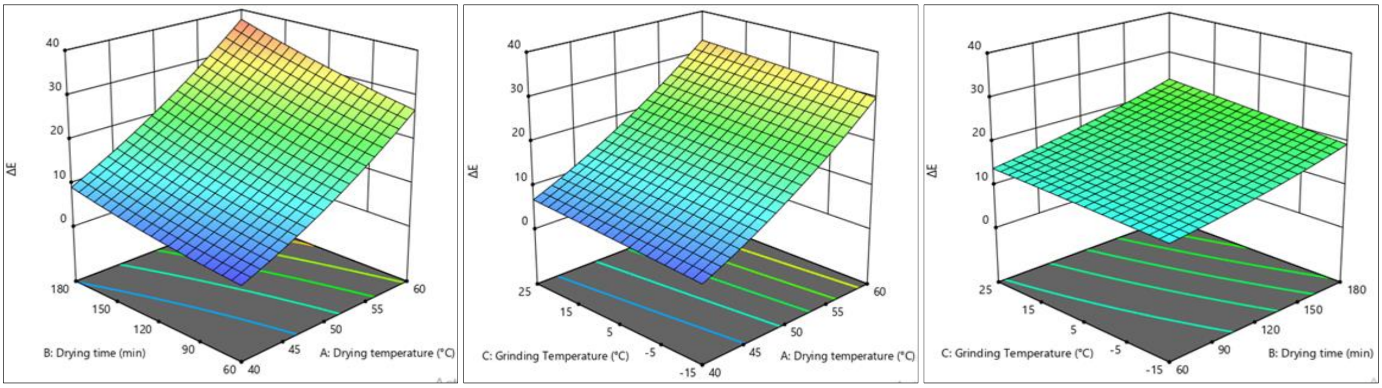
M



N



O



P Q R

Fig 1: Response surface for color analysis of fluidized bed dried sweet orange peel powder

4. Conclusion

The present investigation is the first to examine the effects of various drying temperatures, drying periods, and grinding temperatures on the colour features of sweet orange peel under varied situations. In summary, low drying temperature and low grinding temperature samples showed the most colour brightness and yellowness, as well as the least amount of change in ΔE. Moreover, Sweet orange peel powder obtained by 50 °C drying temperature, 180 min. drying time and 5 °C grinding temperature with LN_2 cooling had significantly higher colour properties compared to all other treatments. Color properties are found to be desirable in fluidized bed drying and cryogenic grinding and these properties of sweet orange peel powder are important in storage packaging and handling/ transportation. Therefore, our outcomes could offer a useful data in favor of developing a process for drying and low temperature grinding combination of sweet orange peel and cryogenic grinding could be suggested as a potential approach for producing an excellent nutritional content with supreme color quality compare to normal grinding.

5. References

1. El Adawy TA, El Bedawy AA, Rahma EH, Gafar AM. Properties of some citrus seeds. Part 3. Evaluation as a new source of protein and oil. Food Nahrung. 1999;43(6):385-391.
2. Farahmandfar R, Tirgarian B, Dehghan B, Nemati A. Comparison of different drying methods on bitter orange (*Citrus aurantium* L.) peel waste: Changes in physical (density and color) and essential oil (yield, composition, antioxidant and antibacterial) properties of powders. Journal of Food Measurement and Characterization. 2020;14(2):862-875.
3. Ghanem N, Mihoubi D, Kechaou N, Mihoubi NB. Microwave dehydration of three citrus peel cultivars: Effect on water and oil retention capacities, color, shrinkage and total phenols content. Industrial Crops and Products. 2012;40:167-177.
4. Geraci A, Di Stefano V, Di Martino E, Schillaci D, Schicchi R. Essential oil components of orange peels and antimicrobial activity. Natural product research. 2017;31(6):653-659.
5. Hashmi S, Ghate P, Machewad G, Pawar S. Studies on extraction essential oil and pectin from sweet orange. Dept. Food and Indst. Micro bio, college of Food Technol. Marathwada Krishi Vidyapeeth, Parhani, Maharashtra, India; c2012.
6. Millind P, Dev C. Orange: Range of benefits: A review. International Research Journal of Pharmacy. 2012;3(7):59-63.
7. Mohnen D. Pectin structure and biosynthesis. Current opinion in plant biology. 2008;11(3):266-277.
8. Saricoban C, Yilmaz MT. Modelling the effects of processing factors on the changes in colour parameters of cooked meatballs using response surface methodology. World Applied Sciences Journal. 2010;9(1):14-22.
9. Shyura LF, Tsung J, Chen J, Chiu CY, Lo CP. Antioxidant properties of extracts from medicinal plants popularly used in Taiwan. International Journal of Applied Science and Engineering. 2005;3(3):195-202.
10. Silalahi J. Anticancer and health protective properties of Citrus fruit components. Asia Pacifica Journal of Clinical Nutrition. 2002;11:79-84.
11. Silke S, Ankit B. Biosorption of Pb2+ by original and protonated citrus peels: equilibrium, kinetics, and mechanism. Chemical Engineering Journal. 2009;146(2):211-219.
12. Milind P, Dev C. Orange: Range of benefits. International research journal of pharmacy. 2012 Jun;3(7):59-63.
13. Dierks T, Frölich L, Ihl R, Maurer K. Event-related potentials and psychopharmacology. Pharmacopsychiatry. 1994 Mar;27(02):72-4.
14. Elbohy H, Bahrami B, Mabrouk S, Reza KM, Gurung A, Pathak R, *et al*. Tuning hole transport layer using urea for high-performance perovskite solar cells. Advanced Functional Materials. 2019 Nov;29(47):1806740.
15. Palou E, López-Malo A, Barbosa-Cánovas GV, Welti-Chanes J, Swanson BG. Polyphenoloxidase activity and color of blanched and high hydrostatic pressure treated banana puree. Journal of food science. 1999 Jan;64(1):42-45.