ANALYSIS

17(48), 2020

ISSN 2319–7757 EISSN 2319–7765

Indian Journal of Engineering

Optimization of Wheat Flour Storage Conditions using Central Composite Rotatable Design (CCRD)

Nwadinobi Chibundo Princewill[1✉], Ezeaku Innocent Ikeokwu[1], Nwasuka Nnamdi Cyprain[1], Mbanefo Adaeze[2]

[1]Department of Mechanical Engineering, Abia State University, Uturu, Abia State, Nigeria
[2]Department of Food Science and Technology, Abia State University, Uturu, Abia State, Nigeria

✉**Corresponding Author:**
Department of Mechanical Engineering,
Abia State University, Uturu, Abia State,
Nigeria
Email: chibundop@gmail.com,
+2348063935655

Article History
Received: 28 August 2020
Accepted: 07 October 2020
Published: October 2020

Citation
Nwadinobi Chibundo Princewill, Ezeaku Innocent Ikeokwu, NwasukaNnamdi Cyprain, Mbanefo Adaeze. Optimization of Wheat Flour Storage Conditions using Central Composite Rotatable Design (CCRD). *Indian Journal of Engineering*, 2020, 17(48), 493-502

ABSTRACT
The present study focused on the effect of storage temperature and packaging material on the optimization of functional properties of wheat flour. The study was designed by using the Response Surface Methodology (RSM), with a central composite rotatable design (CCRD). The wheat flour was packaged in three different materials (plastic, brown envelope and nylon), and stored at 10 - 40

ºC for 7 days. The wheat flour samples were evaluated for functional properties. The result of the optimial sample had water absorption capacity of 1.30g/ml, oil absorption capacity of 1.00 bulk density of 0.714g/ml, swelling index; 1.20, 10% least gelation and 40% emulsion capacity; 24.05% and dispersibility of 29%. In addition, it was also observed that the packaging of wheat flour in plastic containers and storing at the temperature of 40ºC will give flour with desirable functional properties. From the statistical analysis obtained, the developed models, as well as the model terms, were significant (at $P \leq 0.05$).

Keywords: Flour, storage time, packaging material, optimization, functional properties

1. INTRODUCTION

Cereal crops are grasses that belong to the family *Poaceae* of monocot plants and has been the remarkable source of calories for mankind (Feuillent *et al*., 2007). They have been used for human consumption and account for majority of the world food supply. Wheat (*Triticumaestivum L.*) is a member of this family and is one of the most important staple food as well as feed crops in many parts of the world. Currently, wheat is cultivated world over and responsible for the daily protein, energy and also constitutes an important source of dietary nutrients (Vasil 2007; Shewry, 2009). Besides, wheat-derived ingredients also source as valuable raw materials for diverse food-based industries (Sanjay *et al,* 2015). Today wheat is grown in the Mediterranean and subtropical parts of both hemispheres from 69°N in Scandinavia and Russia to 45°S in Argentina, including elevated regions in the tropics (Shewry, 2009; Sanjay et al, 2015).

Because of their importance to human nutrition, wheat has been the major target of all crop improvement programmes. Wheat grain on maturity improves and stores the proteins, starch, lipids and sugars in the endosperms for the next generation. Humans are benefited from these stored foods for their nutrient needs (Uthayakumaran and Wrigley, 2010). Wheat varieties are used for a wide range of applications, such as bread, cakes, pastries, biscuits, puddings and noodles, pasta production and so on. Wheat is reported to be a rich source of dietary fibre and dietary fibre has been established to possess immense health benefits. Thus there is much need its post-harvest processing and handling.

Consequent on this, optimizing the utilization of wheat storage facilities has been recommended by studies to minimize post-harvest losses (Tefera *et al*, 2011). Post-Harvest Losses (PHL) can be defined as the degradation in both quantity and quality of a food product from harvest to consumption (Kader and Rolle, 2004). In developing counties, the largest amount of PHL usually occurs around harvesting, consolidation and storage (Hodges *et al*, 2011). These losses are often caused by improper packing, poorly equipped transportation medium and inadequate storage facilities (Baqui 2005; Basavaraya *et al*, 2007; Ofor and Ibeawuchi 2010).

Several existing research studies focused on optimizing the number, size and location of grain and flour storage facilities. Despite the significant contributions of these optimization models, they are limited due to their inability of considering the impact of storage conditions on stored products. Therefore, a successful optimization of storage conditions to sustain the functional properties of wheat flour makes for increased utilization of the wheat flour especially in the production of value-added functional foods with high health benefit potentials. In achieving this result, Response surface methodology with a central composite rotatable design (CCRD) was utilized. It is an effective statistical technique for the investigation of complex processes. The main idea of this method is to determine the influence of independent variables on the response, get a model of the relationship between independent variables and the response and get the process conditions that produce the best response (Dedy *et al*, 2017). In this work, storage conditions of wheat flour was studied. RSM comprising a three-level-two-factor central composite rotatable design was used to evaluate the interactive effects on some functional properties and to obtain the optimum conditions.

2. MATERIALS AND METHODS

Wheat flour and the packaging materials (brown envelope, plastic container, and nylon) were purchased from Ubani modern market Umuahia, Abia State. 500grams of the flour sample was used for each of the experiments. The wheat flour was packed in the different packaging materials (brown envelope, plastic container, and nylon) and stored at the different storage temperature (10^0C, 27^0C and 40^0C) for a period of 7 days. After which the functional properties of the flour was evaluated.

Response Surface Modelling (RSM) comprising of central composite design was used in this study with two factors (storage temperature (A) and packaging material (B)) at three levels to evaluate the statistical significance of the effect of the storage conditions process variables on the response of functional properties of flour. The variables and their ranges selected for the experimental design are as shown in Table 1.

Table 1: Limits of the Storage Conditions process parameters

S/N	Factor Description	Factor Symbols		Factor Values		
		Coded	Actual	High (+)	Mid-point (0)	Low (-)
1	Storage temperature (^{0}C)	X_1	A	40	27	10
2	Packaging material	X_2	B	Paper	Nylon	Plastic

The two independent (process) variables used are storage temperature (A) and packaging material (B).Six parameters such as water absorption capacity, oil absorption capacity, bulk density, swelling index, emulsion capacity and dispersibility were considered as response variables. Experimental matrix design for the study is shown in Table 2 with eleven numbers of experiments.

Table 2: Coded and actual variables of the experimental design

Runs	Coded levels		Actual values	
	X_1	X_2	Storage Temperatre (^{0}C)	Packaging Material
1	0.00	0.00	27	Nylon
2	-1.00	0.00	40	Nylon
3	0.00	1.00	27	Plastic
4	1.00	-1.00	10	Paper
5	0.00	-1.00	27	Paper
6	-1.00	-1.00	40	Paper
7	1.00	0.00	10	Nylon
8	-1.00	1.00	40	Paper
9	0.00	0.00	27	Nylon
10	1.00	1.00	10	Plastic
11	0.00	0.00	27	nylon

For each variable a full factorial CCD for the two variables consisting four factorial points, four axial points and three replicates at the center points were employed indicating that a total of 11 experiments as calculated from equation 1 (Ahmad *et al*., 2009).

$$N = 2^n + 2n + nc (1)$$

Where N is the total number of experiments required and n (equal to two) is number of independent variables.nc is the number of center points required.

The experimental condition with the function of desirability are applied using Design Expert Software version 8.0.3.1 (Stat- Ease Inc., Minneapolis, USA). Quadratic models were developed using the design expert software based on central composite design (CCD) and the experiments conducted. The second order polynomial is of the form in equation 2 (Bradley, 2007; NIST/ SEMATECH 2012).

$$Y = \beta_0 + \sum_{j=1}^{k} \beta_j x_j + \sum \beta_{jj} x^2{}_j + \sum_{j<} \sum_{j=2}^{k} \beta_{ij} x_i x_j \qquad (2)$$

Adequacy of the quadratic models was analysed using the model adequacy check, significant test and lack of fit test. Contour plots are developed as a function of independent variables with response parameter to analyze the interactive effect of storage temperature (A) and packaging material (B) in order to locate the optimum response.

Functional Properties Determination

Thereafter, the evaluation of water absorption capacity, oil absorption capacity, bulk density, swelling index, emulsion capacity and dispersibility, of the wheat flour were undertaken;

Water absorption capacity was determined as reported by Onwuka (2005). In this experiment, 1g of each sample was weighed and put into a weighed test tube. Distilled water (10ml) was added and the mixture stirred. The mixture was allowed to stand for 30 minutes at room temperature. Centrifugation was done at 3500rpm for 30 minutes. The supernatant was decanted and the residue in the test tube was inverted over an absorbance paper. This was allowed to dry completely before weighing was done. Thus, the water absorption capacity (WAC) was computed from the relation in Equation (3).

$$WAC = \frac{W_2 - W_1}{W} \quad (3)$$

Where W = weight of sample, W_1= weight of tube empty, W_2 = weight of tube + water absorbed.

The Oil absorption capacity of the flour was determined as described by Ruperez and Saura-Calixto (2001). Here, a refined vegetable oil (Turkey brand) was used and the time allowed for absorption was one (1) hours at room temperature. Again the oil absorption capacity (OAC) was determined by difference as the weight of oil absorbed and held by 1g of the sample. The computation is as presented in Equation (4).

$$O.A.C = \frac{W_2 - W_1}{W} \quad (4)$$

Where, W= weight of empty tube, W_1 = weight of empty tube, W_2 = weight of tube + oil absorbed.

Bulk density was determined by the method described by Onwuka (2005).Here, the flour sample of 10ml was inserted in a dried measuring cylinder. The bottom of the cylinder was tapped several time on the laboratory table until there was no further determination of the sample below the level marked 10ml, thus the samples Bulk densitieswere computed from the following relation in Equation (5),

$$\text{Bulk density} = \frac{weight\ of\ samples}{volume\ of\ samples\ (cm^3)} \quad (5)$$

Where, Weight of sample = weight of cylinder – weight of empty samples and sample cylinder.

In determining the emulsion capacity, one gram of the sample was mixed with 30ml of distilled water blended for 30 seconds in a blender. 30ml of refined vegetable oil (Turkey) was added while mixture was still blending at the rate of 10ml/min. After 3 minute of blending, the blended mixture was transfer quickly but carefully to 100ml graduated centrifuge tube. They cylinder was left to stand in a water bath at 80^{0}C for 15 minutes. After centrifugation, the volume of oil separated from the sample was measured. The emulsion capacity (EC) was expressed as the amount of oil emulsified and held per gram of the sample. It was calculated as given in Equation (6),

$$Emulsion\ Capacity = \frac{Height\ of\ Emulsified\ layer}{Height\ of\ whole\ solution\ in\ the\ centrifuge\ tube} \quad (6)$$

Dispersibility determination was done according to the method described by Onwuka (2005). 10g of flour sample was put in a 200ml measuring cylinder containing 100ml of water. The entire mixture was shaken vigorously and allowed to stand for 3 hours. The height of the sediment was measured and recorded. Dispersibility (DISP) of the flour was calculated from Equation (7),

$$Dispersibility = 100 - Sediment\ height \quad (7)$$

3. RESULTS AND DISCUSSION

The result of the functional properties of the flour samples is presented in Table 3.

Table 3. Design Table of the functional properties of wheat flour

Runs	Storage Temperatre (^{0}C)	Packaging Material	WAC (g/ml)	OAC (g/ml)	BD (g/ml)	SI	EC (%)	DISP (%)
1	27	Nylon	1.20	1.60	0.721	1.22	23.72	24

2	40	Nylon	2.00	1.20	0.771	1.20	24.45	28
3	27	Plastic	2.00	1.20	0.769	1.20	23.10	26
4	10	Paper	1.30	1.00	0.728	1.40	23.15	27
5	27	Paper	1.40	1.20	0.769	1.18	24.25	28
6	40	Paper	1.00	1.00	0.769	1.38	25.15	28
7	10	Nylon	1.40	1.80	0.769	1.33	22.40	26
8	40	Paper	1.30	1.00	0.714	1.20	24.05	29
9	27	Nylon	1.20	1.60	0.721	1.22	23.72	24
10	10	Plastic	1.00	0.90	0.769	1.31	21.90	28
11	27	nylon	1.20	1.60	0.721	1.22	23.72	24

The results obtained show that the water absorption capacity of the flour samples ranged from 1.00 – 2.00g/ml. The result shows that both storage temperature and storage container affected the WAC of the flour. Adebowale *et al.* (2017) reported similar variation in the WAC of water yam flour stored with different material and varying conditions. The ANOVA result showed that the model and model terms were all significant ($p \leq 0.05$). The final equation is shown in Eq. (8).

$$WAC = 1.53-0.100A+0.27B-0.32A^2+0.18B^2-0.15AB \quad (8)$$

The 3D plot showing the effect of temperature and storage on the WAC is shown in Figure 1.

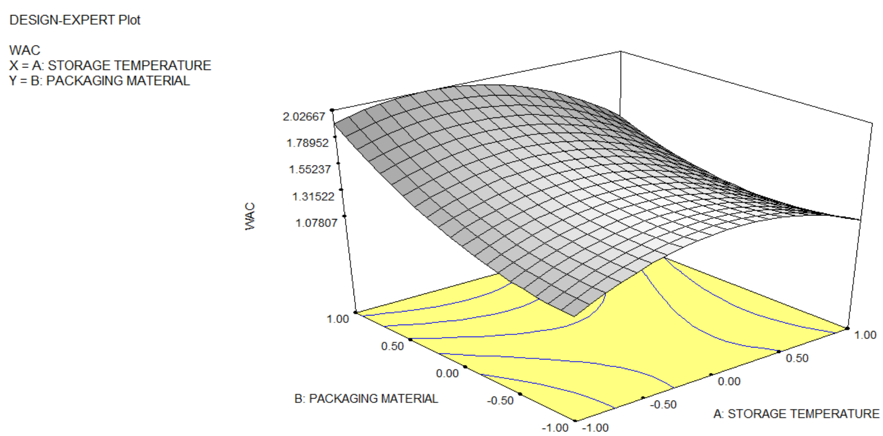

Figure 1: 3D plot showing the effect of temperature and storage on the WAC

Also from table 1, the oil absorption capacity of the samples ranged from 1.00 – 1.80g/ml. Storage condition of run 7 had the highest value followed by run 11 and 1 respectively, run 10 had the least. The result shows that both storage temperature and storage container affected the OAC of the flour. Adebowale *et al.* (2017) reported similar variation in the OAC of water yam flour stored with different material and varying conditions. The ANOVA result showed that the model and model terms were significant ($p \leq 0.05$) except AB. The final equation is shown in Eq. (9)

$$OAC = +1.63+0.083A-0.017B-0.17A^2-0.47B^2-0.025AB \quad (9)$$

The 3D plot showing the effect of temperature and storage on the OAC is shown in Figure 2.

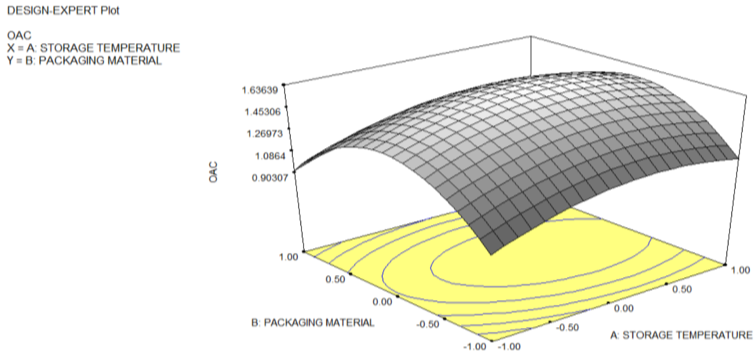

Figure 2: 3D plot showing the effect of temperature and storage on the OAC

The bulk density of the flour samples ranged from 0.714 – 0.771g/ml. Same value (0.769g/ml) was obtained for the storage condition of runs 3, 5, 6, 7, and 10. The result shows that both storage temperature and storage container affected the bulk density of the flour. Adebowale *et al*. (2017) reported similar variation in the bulk density of water yam flour stored with different material and varying conditions. The analysis of variance (ANOVA) indicated that the model and model terms were all significant ($p \le 0.05$). The final equation expressing the relationship of the term coefficients with the bulk density is shown in Eq. (10).

$$\text{Bulk density} = 0.75+2.00A-2.333AB \qquad (10)$$

The 3D plot showing the effect of temperature and storage on the Bulk density is shown in Figure 3.

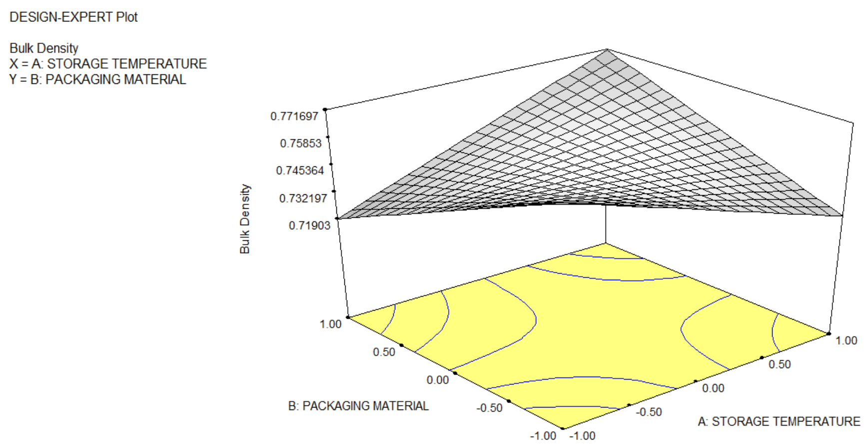

Figure 3: 3D plot showing the effect of temperature and storage on the Bulk density

The swelling index of the samples were in the range of 1.18 – 1.60. The highest value was obtained in run 2 while the least was obtained in run 5. The result also shows that both storage temperature and storage container affected the swelling index of the flour. Adebowale *et al.* (2017) reported gave similar observation in the bulk density of water yam flour stored with different material and varying conditions. The differences in swelling index of the samples could be attributed to variation in starch content and presence of other components such as lipids and proteins (Priyawiwatkul *et al*., 1997). The ANOVA showed that the model and model terms were significant ($p \le 0.05$). The final equations for Swelling index (SI) is shown in Eq. (11).

$$\text{Swelling index} = +124-0.023A-0.042B+0.19A^2-0.089B^2+0.023AB \qquad (11)$$

The 3D plot showing the effect of temperature and storage on the Swelling Index is shown in Figure 4.

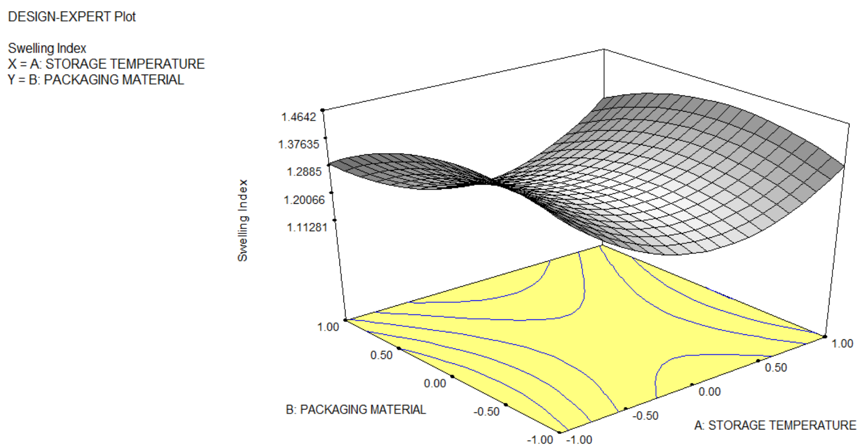

Figure 4: 3D plot showing the effect of temperature and storage on the Swelling Index

In addition, the emulsion capacity of the flour ranged between 21.90 – 25.15%. Storage condition of run 6 gave the highest emulsion capacity, followed by the condition of run 2. 5 and 8 respectively, while the condition of run 10 gave the least. The result however, shows that both storage temperature and storage container affected the emulsion capacity of the flour. The analysis of variance (ANOVA) indicated that the model and model terms were all significant ($p \leq 0.05$). The final equation expressing the relationship of the term coefficients is shown in Eq. (12).

$$\text{Emulsion capacity} = 23.68 - 1.03A - 0.58B - 0.20A^2 + 0.051B^2 - 0.037AB \quad (12)$$

The 3D plot showing the effect of temperature and storage on the Emulsion capacity is shown in Figure 5.

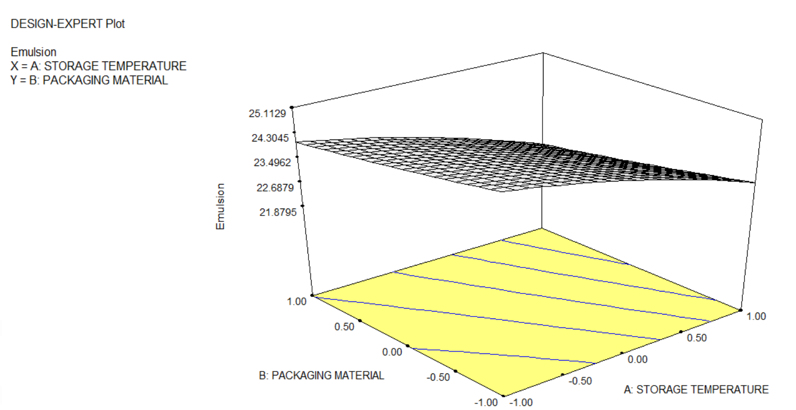

Figure 5: 3D plot showing the effect of temperature and storage on the Emulsion capacity

Furthermore, the dispersibiltiy of the flour ranged from 24 – 29%. The highest value was obtained for run 8 (29%) followed by run 5. 6 and 10 with the same value (28%), while run 1, 9 and 11 with the same value (24%) also had the least. The dispersibility is widely used in flour and powder studies to estimate their reconstitute ability in water. The higher the dispersibility, the better the reconstitution property (Oluwole *et al.*, 2016). The analysis of variance (ANOVA) indicated that the model and model terms were all significant ($p \leq 0.05$). The final equation expressing the relationship of the term coefficients with the bulk density is shown in Eq. (13).

$$\text{Dispersibility} = 24.11 - 0.17A + 0.000B + 1.24A^2 + 2.74B^2 \quad (13)$$

The 3D plot showing the effect of temperature and storage on the Dispersibility is shown in Figure 6.

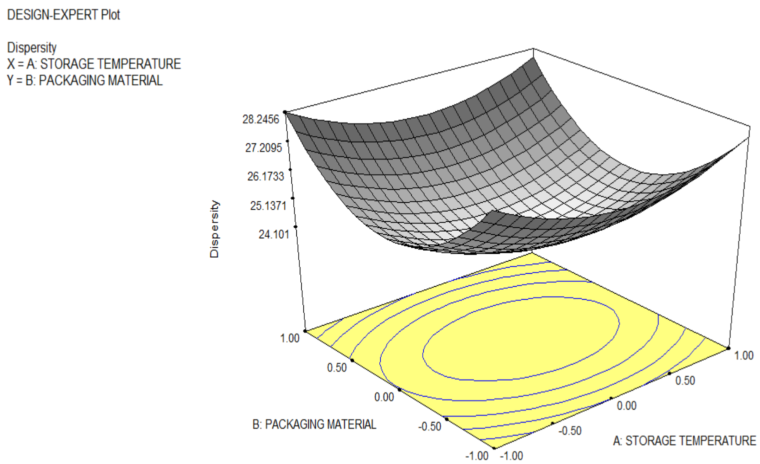

Figure 6: 3D plot showing the effect of temperature and storage on the Dispersibility

The main, quadratic and interaction effects of concentration of wheat flour storage conditions on its functional properties as determined by analysis of variance (ANOVA) are given in Table 4. The significance and adequacy of the model was measured in terms of F-value and p-value at 5% significance level (p≤0.05). The measurement of F-value and p-values indicated that the storage temperature and container had positive significant linear effect on oil absorption capacity, emulsion capacity and dispersibility, but a negative significant linear effect on water absorption capacity, bulk density and swelling index of the flour samples. The quadratic and interaction effects were found to be non-significant in each case. The correlation coefficient (R^2) values for WAC, bulk density and swelling index of the blends indicated that more than 54% of the variability in functional properties could be explained by the suggested model. However, the variability in OAC, emulsion capacity and dispersibility was explained more than 73.7% by the model. The values of adjusted R^2 for these responses also advocate the significance of the model. The relatively low values of Coefficient of variation (CV) such as 48.52, 13.58, 3.24, 7.97, 0.28 and 3.60% for WAC, OAC, bulk density, swelling index, emulsion capacity and dispersibility respectively showed a better precision and reliability of the experiments performed.

The result obtained from the response surface model shows that run 8 gave the optimum yield for all the parameters evaluated.

Table 4a: ANOVA result for the effect of storage conditions on some functional properties of wheat flour.

Source	WAC			OAC			Bulk density		
	Rc	F-value	P-value	Rc	F-value	P-value	Rc	F-value	P-value
Model	0.86	0.34	0.8668	0.82	5.44	0.0432	2361E	1.34	0.3364
A	0.060	0.12	0.0427	0.042	1.37	0.2938	2.400E	0.041	0.4456
B	0.43	0.86	0.0372	1.667E	0.055	0.8239	3.267	0.056	0.0203
A^2	0.25	0.51	0.5082	0.070	2.30	0.1900	-	-	-
B^2	0.086	0.17	0.6951	0.55	18.1	0.0080	-	-	-
AB	0.090	0.18	06885	24.00E	0.082	0.7855	2.30	3.92	0.0881
	CV = 48.53, R^2 = 0.5559, Adjusted R^2 = 0.4882			CV = 13.58, R^2 =0.8448, Adjusted R^2 = 0.6896			CV = 3.24, R^2 = 0.634, Adjusted R^2 = 0.9025,		

Table 4b: ANOVA result for the effect of storage conditions on some functional properties of wheat flour.

	Swelling index			Emulsion capacity			Dispersibility		
Source	Rc	F-value	P-value	Rc	F-value	P-value	Rc	F-value	P-value
Model	0.11	2.01	0.2307	8.55	398.76	<0.0001	29.69	6.61	0.0293

A	3.26E	0.31	0.0441	6.41	1493.24	<0.0001	0.17	0.19	0.0246
B	0.010	0.98	0.3687	2.04	475.86	<0.0001	0.000	0.000	1.0000
A^2	0.087	8.19	0.0354	0.10	23.37	0.0047	3.88	4.31	00.0924
B^2	0.020	1.89	0.2279	6.603 E	1.54	0.2698	18.98	21.13	0.0059
AB	2.025E	0.19	0.6814	5.625 E	1.31	0.3040	0.000	0.000	1.0000
	CV = 7.97, R^2 0.6680, Adjusted R^2 = 0.3359			CV = 0.28, R^2 = 00.9975, Adjusted R^2 = 0.9950			CV = 3.61, R^2 = 0.86866, Adjusted R^2 = 0.7372		

4. CONCLUSION

Using response surface the optimum set of operating variables was obtained, in order to achieve the desired levels for functional properties for stored wheat flour. It can be inferred that the considered variables (storage temperature and packaging material) individually had positive effect on functional properties of wheat flour. High values of R^2 suggest that the applicability and adequacy of the suggested model was very good. From the result obtained in this study, packaging of wheat flour in plastic containers and storing at the temperature of 40^0C will give flour with desirable functional properties. The data obtained in this research, may provide valuable guide for the researchers, industrialists and manufacturers to achieve their desired goals in wheat flour processing.

Conflict of interest

On behalf of all authors, the corresponding author states that there is no conflict of interest.

Funding

This study has not received any external funding.

Peer-review

External peer-review was done through double-blind method.

Data and materials availability

All data associated with this study are present in the paper.

REFERENCE

1. Adebowale K.O., Olu-Owolabi B.I., Olawumi E.K. and Lawal O.S. (2005). Functional properties of native, physically and chemically modified breadfruit (Artocarpusartillis) starch. *Ind. Crops Prod*. 21, 343–351.
2. Baqui, M. (2005)"post-harvest processing, handling, and preservation of Agricultural products: its present status and further challenges in Bangladesh."FMPHT Division Bangladesh Rice Research Institute (BRRI).page 10.
3. Bassvaraja, H., Mahajanashetti, S.B. and Udagatti, N.C. (2007)."Economics Analysis of postharvest losses in food Grains in India: A case study of Karnataka." Agricultural Economics research review, 20th January-June 2007, page 117-126.
4. Bradley, N. 2007,"The Response Surface Methodology". Thesis Submitted to the Faculty of the Indian University of South Bend in Partial Fulfillment of Requirements for the Degree of Master of Science in Applied Mathematics & Computer Science. (Accessed from http://wwwtest.iusb.edu/math-compsci_prior...NBradley_thesis.pdf on 19/08/2014).
5. DedySuhendra, Erin Ryantin Gunawan, Arista DewiNurita, DesyKomalasari and Teguh Ardianto (2017) Optimization of the Enzymatic Synthesis of Biodiesel from *Terminaliacattapa* L. Kernel Oil Using Response Surface Methodology; *Journal of Oleo Science; pp 1-7, doi : 10.5650/jos.ess16167*
6. Feuillet, C *et al.*, 2007. Cereal breeding takes a walk on the wild side. *Trends Genet*. 24(1):24-32.
7. Hodges, R.J., Buzby, J.C, and Bennett, B. (2011).postharvest losses and waste in developed and less developed countries: opportunities to improve resource use. '*Journal of Agricultural science*, 149,37-45.
8. Kader, A.A. (2004)" Increasing food availability by reducing postharvest losses of fresh produce." Proceedings of the 5th international post –harvest symposium. Ed. F. Mencarel, and P.Tonutti; Verona: International Society for Horticultural Science (ISHS).

9. Kader, A.A. and R.S. Rolle. 2004. "The Role of Post-harvest Management in Assuring the Quality and Safety Horticultural Crops". Food and Agriculture Organization. Agricultural Services Bulletin 152, 52 p.
10. NIST/SEMATECH. 2012, Engineering Statistics Handbook. (Accessed from www.nist.gov/div898/handbook. 28/12/2013).
11. Ofor, M.O. and Ibeawuchi, I.I. (2010). "Sun-drying, A low cost technology for reducing post harvest losses." Academic Arena.
12. Onimawo, I.A. and Akubor, P.I. (2012). Food Chemistry (Integrated Approach with Biochemical background).2nd ed. Joytal printing press, Agbowo, Ibadan, Nigeria.
13. Onwuka G. I., (2005) Physical and chemical analysis of fats. Food analysis and instrumentation theory and practice 1 *ed.*
14. Peng, J. *et al.*, 2011. Wild emmer wheat, *Triticumdicoccoides*, occupies a pivotal position in wheat domestication. *Australian Journal of Crop Science*. 5:1127-1143.
15. Sanjay Singh Parmar; Shushant Kumar Kaushik; Neelesh Agarwal; Shiva Paliwal and Dheeraj Kumar Dhingra (2015) Genetic Transformation of Wheat: An Update on Recent Progresses; *Trends in Biosciences Vol. 8, No. 20, pp 5443-5457.*
16. Shewry, P. 2009. Wheat. *J Experiment Bot*. 60:1537-1553.
17. Tefera. T., Kanampiu. F, Groote. H, Helin. J., Mugo. S., Kimenju. S., Beyene. Y., Boddupali P., Shiferaw, B., and Banziger, M. (2011) "The metal silo; An effective grain storage technology for reducing post –harvest insect and pathogen losses in maize while improving smallholder farmers' food security in developing countries. "crop protection, Elsevier, 30.pp 140-245.
18. Uthayakumaran S, Wrigley CW. Wheat: characteristics and quality requirements. In: Wrigley CW, Batey IL, editors. Cereal grains assessing and managing quality. New Delhi: Woodhead publishing limited; 2010. pp. 59–111.
19. Vasil I. K. (2007) Molecular genetic improvement of cereals: transgenic wheat (Triticumaestivum L.); Plant Cell Rep.; Vol. 26, No. 8, pp 1133-1154. Doi: 10.1007/s00299-007-0338-3