

Modeling of Sensory Quality (Texture) of the Sliced Chicken as a Function of Period of Storage and Gamma-Irradiation Dose Given

Ravi Shankar

Department of Food Process Engineering, Vaugh School of Agriculture Engineering and Technology,
Sam HigginBottom Institute of Agriculture, Technology and Sciences-Deemed University,
P.O Naini, Allahabad, U.P-211007, India

Copyright © 2014 ISSR Journals. This is an open access article distributed under the **Creative Commons Attribution License**, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

ABSTRACT: This paper deals with the developing the most suggested model with $R^2 = 0.9488$ for Sensory (Texture) Quality as a function of the irradiation dose and the storage period for a sliced chicken meat.

KEYWORDS: Irradiation, Radiation, Modeling, Cobalt-60, Radiolysis, Design Expert Software 8.0.

1 INTRODUCTION

Poultry carcasses are commonly contaminated with en-teric pathogens such as Salmonella, Campylobacter and *Listeria monocytogenes* (Jacobsreitsma et al., 1994; Murphy et al., 2004); the possibility of cross contamination of poultry carcasses post slaughter is high. Decontamination of poultry carcasses is therefore desirable. Various decontamination technologies have been proposed including the use of various chemical agents such as alkali (Rodriguez et al., 1996), physical methods such as steam treatment (James et al., 2007) and biological control with bacteriophages (Carvalho et al., 2010), but only treat-ment with water supplemented with chlorine or a chlorine-ting agent is used commercially. The effects of such decontaminating treatments are limited (Oyarzabal, 2005; Russell and Axtell, 2005).

The term "radiation chemistry" refers to the chemical reactions that occur as a result of the absorption of ionizing radiation. In the context of food irradiation, the reactants are the chemical constituents of the food and initial radiolysis products that may undergo further chemical reactions. The chemistry involved in the irradiation of foods has been the subject of numerous studies over the years and scientists have compiled a large body of data regarding the effects of ionizing radiation on different foods under various conditions of irradiation. The basic principles are well understood and provide the basis for extrapolation and generalization from data obtained in specific foods irradiated under specific conditions to draw conclusions regarding foods of a similar type irradiated under different, yet related, conditions. The types and amounts of products generated by radiation induced chemical reactions ["radiolysis products"] depend on both the chemical constituents of the food and on the specific conditions of irradiation.

The principles of radiation chemistry also govern the extent of change, if any, in both the nutrient levels and the microbial loads of irradiated foods.

Factors Affecting the Radiation Chemistry of Foods- Apart from the chemical composition of the food itself, the specific conditions of irradiation that are most important in considering the radiation chemistry of a given food include the radiation dose, the physical state of the food (e.g., solid or frozen versus liquid or non-frozen state, dried versus hydrated state), and the ambient atmosphere (e.g., air, reduced oxygen, and vacuum). The temperature at which irradiation is conducted can also be a factor, with more radiation-induced changes occurring with increasing temperature. Temperature is less important, however, than the physical state of the food. The amounts of radiolysis products generated in a particular food are directly proportional to the radiation dose. Therefore, one can extrapolate from data obtained at high radiation doses to draw conclusions regarding the effects at lower doses.

The radiation chemistry of food is strongly influenced by the physical state of the food. If all other conditions, including dose and ambient atmosphere, are the same, the extent of chemical change that occurs in a particular food in the frozen state is less than the change that occurs in the non-frozen state. This is because of the reduced mobility, in the frozen state, of the initial radiolysis products, which will tend to recombine rather than diffuse and react with other food components. Likewise, and for similar reasons, if all other conditions are the same, the extent of chemical change that occurs in the dehydrated state is less than the change that occurs in the fully hydrated state.

The formation of radiolysis products in a given food also is affected by the ambient atmosphere. Irradiation in an atmosphere of high oxygen content generally produces both a greater variety, and greater amounts, of radiolysis products in the food than would be produced in an atmosphere of lower oxygen content. This is because irradiation initiates certain oxidation reactions that occur with greater frequency in foods with high fat content.

With few exceptions, the radiolysis products generated in a particular food are the same or very similar to the products formed in other types of food processing or under common storage conditions. These radiolysis products are also typically formed in very small amounts. Radiation-induced chemical changes, if sufficiently large, however, may cause changes in the organoleptic properties of the food. Because food processors want to avoid undesirable effects on taste, odor, color, or texture, there is an incentive to minimize the extent of these chemical changes in food. Thus, the doses used to achieve a given technical effect (e.g., inhibition of sprouting, reduction in microorganisms) must be selected carefully to both achieve the intended effect and minimize undesirable chemical changes.

Typically, the dose or dose range selected will be the lowest dose practical in achieving the desired effect. Irradiation also is often conducted under reduced oxygen levels or on food held at low temperature or in the frozen state.

In general, during inactivation of microorganisms on surfaces, the rate of inactivation is inversely proportional to the initial cell concentration (Shintani, 2000). Food irradiation is being considered an important tool, in ensuring safety and extending shelf-life of fresh meat and poultry (Yoon, 2003). Thus irradiation can eliminate food-borne pathogenic microorganisms in meat. Furthermore, the use of gamma irradiation as a safety technological treatment in food preservation has now become legally accepted in many countries of the world (Abdel-Daium, 2007).

Mathematical modeling is an effective way of representing a particular process. It can help us to understand and explore the relationship between the process parameters. Mathematical modeling can help to understand and quantitative behavior of a system. Mathematical models are useful representation of the complete system which is based on visualizations. Mathematical modeling is an important method of translating problems from real life systems to conformable and manageable mathematical expressions whose analytical consideration determines an insight and orientation for solving a problem and provides us with a technique for better development of the system.

The objective of the study is modeling of the Textural Quality of the product as a function of the irradiation dose and the storage period of irradiated sliced chicken meat.

2 MATERIALS AND METHODS

²⁶Sliced chicken were purchased from local market (Benha, Qaliobia governorate, Egypt). All samples were transported to the laboratory food irradiation unit, Nuclear Research Center in ice-box (0°C) and surveyed for microbiological counts spore forming bacteria. Then, sliced chicken samples were packed in tightly sealed polyethylene pouches and divided into seven groups and stored in freezing till irradiation treatments.

2.1 GAMMA IRRADIATION TREATMENTS²⁶

Four bags from each of sliced chicken were gamma irradiated at 0, 2, 4, and 6 kGy doses using cobalt-60 gamma chamber (1.367 kGy/h) in Cyclotron Project, Nuclear Research Center Atomic Energy Authority, Inshas, Cairo, Egypt. After irradiation, all samples were stored at 4±1°C.

2.2 SENSORY (TEXTURE) ANALYSIS²⁶

2.3 STATISTICAL ANALYSIS²⁶

The statistical evaluation of the mean data was compared using one-way analysis of variance (ANOVA) according to Zar (1984). The chosen level of significance was $P \leq 0.05$.

The experimental data²⁶ obtain using the previous procedures were analyzed by the response surface regression procedure using the following higher-order polynomial equations:

like, $y = \beta_0 + \sum \beta_i x_i + \sum \beta_{ii} x_i^2 + \sum \beta_j x_j + \sum \beta_{jj} x_j^2 + \sum \beta_{ij} x_i x_j$, where y is the response, x_i and x_j are the uncoded independent variables (factors), and β_0, β_i & β_j, β_{ii} & β_{jj} and β_{ij} are intercept, linear, quadratic, and interaction constant coefficients, respectively. Design Expert software package 8.0 was used for regression analysis, analysis of variance (ANOVA) and developing of models of different forms by transformation (linear and of higher order) based on above mentioned principles of forming a functions. Confirmatory experiments were carried out to validate the equations using the combinations of independent variables which were not part of the original experimental design but were within the experimental region. Various models were compared for the best fit summary and there R^2 values were compared to choose the best appropriated model for particular data design and selected runs. In this the product Texture is the response and the dependent two factors were the Storage time and the gamma-irradiation Dose given to the sliced chicken.

3 RESULT AND DISCUSSION

The result of statistical Analysis are shown below:

Table 1. shows the fit summary the models

| Summary (detailed tables shown below) | | | | | |
|---------------------------------------|--------------------|-------------|---------------|---------------|------------------|
| | Sequential | Lack of Fit | Adjusted | Predicted | |
| Source | p-value | p-value | R-Squared | R-Squared | |
| Linear | < 0.0001 | | 0.6840 | 0.5800 | |
| <u>2FI</u> | <u>< 0.0001</u> | | <u>0.9392</u> | <u>0.9102</u> | <u>Suggested</u> |
| Quadratic | 0.6682 | | 0.9344 | 0.8770 | |
| Cubic | 0.4155 | | 0.9359 | 0.7259 | |
| Quartic | 0.2782 | | 0.9491 | 0.0865 | Aliased |

Table 2. Shows the model sum of square

| Sequential Model Sum of Squares [Type I] | | | | | | |
|--|----------------|----------|--------------|--------------|--------------------|------------------|
| Source | Sum of Squares | df | Mean Square | F Value | p-value Prob > F | |
| Mean vs Total | 838.38 | 1 | 838.38 | | | |
| Linear vs Mear | 55.28 | 2 | 27.64 | 21.57 | < 0.0001 | |
| <u>2FI vs Linear</u> | <u>17.84</u> | <u>1</u> | <u>17.84</u> | <u>72.30</u> | <u>< 0.0001</u> | <u>Suggested</u> |
| Quadratic vs 2 | 0.22 | 2 | 0.11 | 0.41 | 0.6682 | |
| Cubic vs Quad | 1.13 | 4 | 0.28 | 1.08 | 0.4155 | |
| Quartic vs Cub | 1.36 | 4 | 0.34 | 1.65 | 0.2782 | Aliased |
| Residual | 1.24 | 6 | 0.21 | | | |
| Total | 915.45 | 20 | 45.77 | | | |

Table 3. Model summary Statistics

| Model Summary Statistics | | | | | | |
|--------------------------|-------------|---------------|--------------------|---------------------|-------------|------------------|
| Source | Std. Dev. | R-Squared | Adjusted R-Squared | Predicted R-Squared | PRESS | |
| Linear | 1.13 | 0.7173 | 0.6840 | 0.5800 | 32.37 | |
| 2FI | 0.50 | 0.9488 | 0.9392 | 0.9102 | 6.92 | Suggested |
| Quadratic | 0.52 | 0.9516 | 0.9344 | 0.8770 | 9.48 | |
| Cubic | 0.51 | 0.9663 | 0.9359 | 0.7259 | 21.13 | |
| Quartic | 0.45 | 0.9839 | 0.9491 | 0.0865 | 70.40 | Aliased |

"Model Summary Statistics": Focus on the model maximizing the "Adjusted R-Squared" and the "Predicted R-Squared".

Table 4. Shows the ANNOVA tables

| Analysis of variance table [Partial sum of squares - Type III] | | | | | | |
|--|----------------|----|-------------|---------|------------------|-------------|
| Source | Sum of Squares | df | Mean Square | F Value | p-value Prob > F | |
| Model | 73.12 | 3 | 24.37 | 98.78 | < 0.0001 | significant |
| A-storage pe. | 61.84 | 1 | 61.84 | 250.65 | < 0.0001 | |
| B-GID | 29.30 | 1 | 29.30 | 118.76 | < 0.0001 | |
| AB | 17.84 | 1 | 17.84 | 72.30 | < 0.0001 | |
| Residual | 3.95 | 16 | 0.25 | | | |
| Cor Total | 77.07 | 19 | | | | |

The Model F-value of 98.78 implies the model is significant. There is only a 0.01% chance that an F-value this large could occur due to noise.

Table 5. ANNOVA Summary

| | | | |
|-----------|------|---------------|--------|
| Std. Dev. | 0.50 | R-Squared | 0.9488 |
| Mean | 6.47 | Adj R-Squared | 0.9392 |
| C.V. % | 7.67 | Pred R-Square | 0.9102 |
| PRESS | 6.92 | Adeq Precisor | 27.528 |

The "Pred R-Squared" of 0.9102 is in reasonable agreement with the "Adj R-Squared" of 0.9392; i.e. the difference is less than 0.2.

"Adeq Precision" measures the signal to noise ratio. A ratio greater than 4 is desirable. Your ratio of 27.528 indicates an adequate signal. This model can be used to navigate the design space.

The developed equation in terms of coded factor:

Final Equation in Terms of Coded Factors:

$$\begin{aligned}\text{Texture} = & \\ & +3.35 \\ & -5.84 * A \\ & +3.14 * B \\ & +3.37 * AB\end{aligned}$$

The equation in terms of coded factors can be used to make predictions about the response for given levels of each factor. By default, the high levels of the factors are coded as +1 and the low levels of the factors are coded as -1. The coded equation is useful for identifying the relative impact of the factors by comparing the factor coefficients.

The developed Fit Suggested required Model:

Final Equation in Terms of Actual Factors:

$$\begin{aligned}\text{Texture} = & \\ & +9.41281 \\ & -0.65737 * \text{storage period} \\ & -0.075196 * \text{GID} \\ & +0.080152 * \text{storage period} * \text{GID}\end{aligned}$$

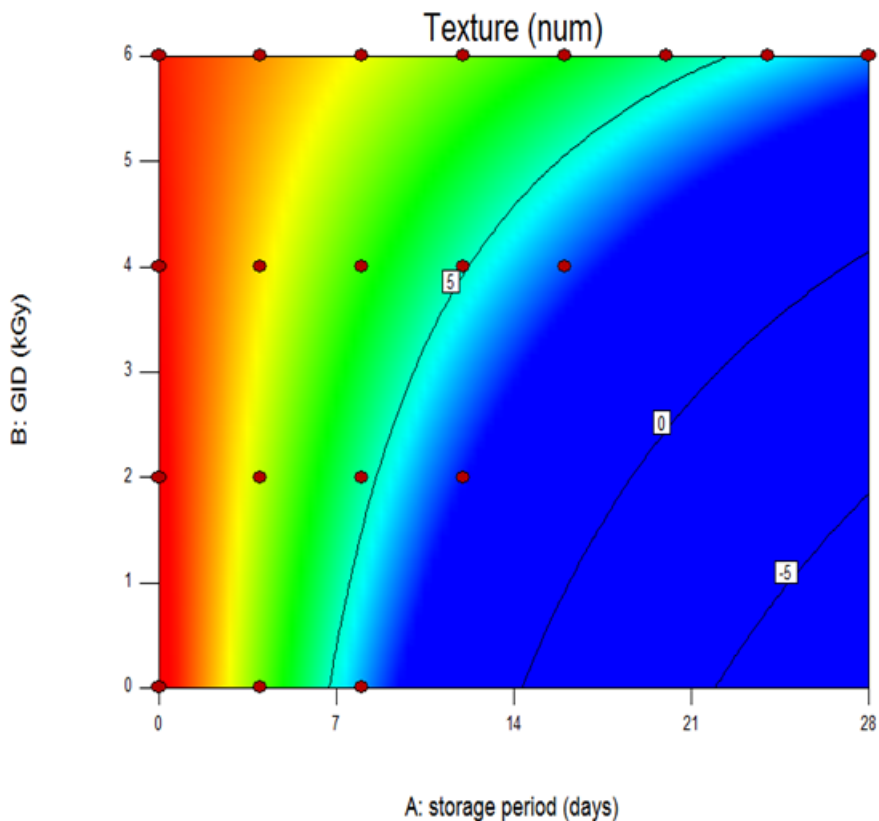


Fig 1. Shows the Contour Graph for the developed Model.

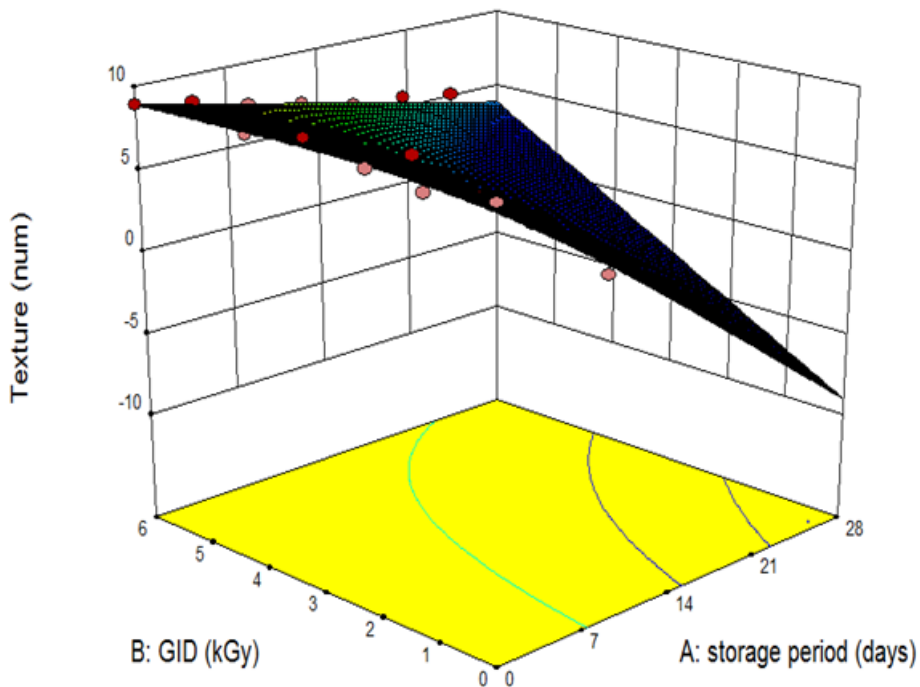


Fig 2. Shows the 3-D Graph Plotted between Texture, GID and SP. For the developed model.

4 CONCLUSION

Thus we get a most fitted model for Texture as a function of the gamma Irradiation dose (GID) and storage period (SP) as the two variants, with $R^2 = 0.9488$, F value 98.78 and P value <0.0001 , the suggested model is more significant for the given design data set.

ACKNOWLEDGEMENT

We are appreciative of the SHIATS University for its continuous support in the development of important technologies for the future use. The effort of higher authorities to promote the technologies has been very valuable in the promotion of new technologies. A special thanks goes to the dean and head of department for believing in our dream to develop new technologies. Many people have contributed either directly or indirectly to make this work a reality.

REFERENCES

- [1] APHA (1992). Compendium of Methods for the Microbiological Examination of Foods,(2nd ed.), American Public Health Association, Washington DC.
- [2] Becker K, Koutsospyros A, Yin SM, Christodoulatos C, Abramzon N, Joaquin JC, No GBM (2005). Environmental and biological applications of microplasmas Plasma Phys. Control. Fusion 47, B513-B523.
- [3] Carvalho CM, Gannon BW, Halfhide DE, Santos SB, Hayes CM, Roe JM, Azeredo J (2010). The in vivo efficacy of two administration routes of a phage cocktail to reduce numbers of *Campylobacter coli* and *Campylobacter jejuni* in chickens. BMC Microbiol. 10:232.
- [4] Deng XT, Shi JJ, Shama G, Kong MG (2005). Effects of microbial loading and sporulation temperature on atmospheric plasma inactivation of *Bacillus subtilis* spores. Appl. Phys. Lett. 87:153901.
- [5] Ehlbeck J, Brandenburg R, von Woedtke T, Krohmann U, Stieber M, Weltmann KD (2008). PLASMOSE - antimicrobial effects of modular atmospheric plasma sources. *GMS Krankenhaushygiene Interdisziplinär* 3(1):1-12
- [6] Ehlbeck J, Schnabel U, Polak M, Winter J, von Woedtke T, Brandenburg R, von dem Hagen T, Weltmann K-D (2011). Low temperature atmospheric pressure plasma sources for microbial decontamination. J. Phys. D: Appl. Phys. 44:18.
- [7] FDA, Food and Drug Administration (2002). Bacteriological Analytical Manual. 9th Ed., AOAC Int., Arlington, VA, USA.
- [8] Fernandez A, Shearer N, Wilson DR, Thompson A (2012). Effect of microbial loading on the efficiency of cold atmospheric gas plasma inactivation of *Salmonella enterica* serovar Typhimurium International. J. Food Microbiol. 152:175-180.
- [9] Foest R, Kindel E, Ohl A, Stieber M, Weltmann KD (2005). Non-thermal atmospheric pressure discharges for surface modification. Plasma Phys. Control. Fusion 47:B525-B536.
- [10] Jacobsreitsma WF, Bolder NM, Mulder RWA (1994). Cecal Carriage of *Campylobacter* and *Salmonella* in Dutch broiler Flocks at slaughter - A one-Year study. Poultry Sci. 73:1260-1266.
- [11] James C, James SJ, Hannay N, Purnell G, Barbedo-Pinto C, Yaman H, Araujo M, Gonzalez ML, Calvo J, Howell M, Corry JEL (2007). Decontamination of poultry carcasses using steam or hot water in combination with rapid cooling, chilling or freezing of carcass surfaces. Int. J. Food Microbiol. 114:195-203.
- [12] Kayes MM, Critzer FJ, Kelly-Wintenberg K, Roth JR, Montie TC, Golden DA (2007). Inactivation of foodborne pathogens using a one atmosphere uniform glow discharge plasma. Foodborne Pathog. Dis. 4(1):50-59.
- [13] Massines F, Sarra-Bournet C, Fanelli F, Naude N, Gherardi N (2012). Atmospheric Pressure Low Temperature Direct Plasma Technology: Status and Challenges for Thin Film Deposition. Plasma Process. Polym. 9:1041-1073.
- [14] Montie TC, Kelly-Wintenberg K, Roth JR (2000). An overview of research using the one atmosphere uniform glow discharge plasma (OAugDP) for sterilization of surfaces and materials. IEEE Trans. Plasma Sci. 28:41-50.
- [15] Moreau S (2000). Using the flowing afterglow of a plasma to inactivate *Bacillus subtilis* spores: Influence of the operating conditions. J. Appl. Phys. 88(2):1166-1174.
- [16] Muranyi P, Wunderlich J, Heise M (2007). Sterilization efficiency of a cascade dielectric barrier discharge. J. Appl. Microbiol. 103:1535-1544.
- [17] Murphy RY, Osaili T, Duncan LK, Marcy JA (2004). Thermal inactivation of *Salmonella* and *Listeria monocytogenes* in ground chicken thigh/leg meat and skin. Poultry Sci. 83:1218-1225
- [18] Rodriguez De Ledesma AM, Riemann HP, Farver TB (1996). Short-time treatment with alkali and/or hot water to remove common pathogenic and spoilage bacteria from chicken wing skin. J. Food Prot. 59:746-750.
- [19] Russell SM, Axtell SP (2005). Monochloramine versus sodium hypochlorite as antimicrobial agents for reducing populations of bacteria on broiler chicken carcasses. J. Food Prot. 68:758-763.

- [20] Shintani H (2000). The reason for the dependency of D value on the initial concentration of microorganisms. *J. Antibacterial Antifungal Agents* 28:680.
- [21] Vleugels M, Shama G, Deng XT, Greenacre E, Brocklehurst T, Kong MG (2005). Atmospheric plasma inactivation of biofilm-forming bacteria for food safety control. *IEEE Trans. Plasma Sci.* 33:824-828.
- [22] Yoon KS (2003). Effect of gamma irradiation on the texture and microstructure of chicken breast meat. *Meat Sci.* 63:273.
- [23] Yu H, Perni S, Shi JJ, Wang DZ, Kong MG, Shama G (2006). Effects of cell surface loading and phase of growth in cold atmospheric gas plasma inactivation of *Escherichia coli* K12. *J. Appl. Microbiol.* 101:1323-1330.
- [24] Zar JH (1984). *Biostatistical analysis*. Prentice Hall, Englewood, N.J. pp. 718.
- [25] Abdel-Daium MH (2007). Manufacturing of low-fat Chicken sausage and keeping its quality by gamma irradiation. *Arab J. Nucl. Sci. Appl.* 40: 296-304.
- [26] Ahmed A. Aly and G.M.El-Aragi (2013). Comparison between gamma irradiation and plasma technology to improve the safety of cold sliced chicken. *10.5897/AJFS, Vol.7(12),pp.46147*
- [27] Allen, D.M., 1971, "Mean Square Error of Prediction as a Criterion for Selecting Variables," *Technometrics*, 13, 469-475.
- [28] Allen, D.M., 1974, "The Relationship Between Variable Selection and Data Augmentation and a Method for Prediction," *Technometrics*, 16, 125-127.
- [29] Box, G. E. P. and N.R. Draper, 1987. "Empirical Model-Building and Response Surfaces," *Jon Wiley & Sons, New York*.
- [30] Khuri, A.I. and J.A. Cornell, 1996. "Response Surfaces," 2nd edition, *Marcel Dekker, New York*.
- [31] Mandel, J., *The Statistical Analysis of Experimental Data*, *Dover Publications, New York*, 1964, pp. 81-84.
- [32] Triola, M. F., *Elementary Statistics*, *Addison-Wesley Publishing Co., Reading MA*, 1992, p. 84.

AUTHOR'S BIOGRAPHY

RAVI SHANKAR- AMIMI, AMIAEI, AMIE, Pursuing M.Tech (4th sem) in Food Technology (Food Process Engineering), Department of Food Process Engineering, Vaugh School of Agriculture Engineering and Technology, SHIATS-Deemed University, P.O-Naini, Allahabad, U.P-211007, India. B.E in Food Technology, SLIET, Sangrur, (P.T.U) Punjab, India.

